A Comparative Study of Carbon Pricing Policies in China and the Scandinavian Countries: Lessons for Effective Climate Change Mitigation with a Focus on Sweden

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Abstract. Under the Paris Agreement's goal of limiting global warming to 1.5 degrees by 2100, nations are taking steps to reduce carbon emissions. Carbon pricing is a popular policy instrument to mitigate carbon emissions. This paper presents a comparative analysis of carbon pricing policies in China and Scandinavian countries (Norway, Denmark, and Sweden), focusing on their impacts on the transportation, industrial, and building sectors. The study highlights that both regions have successfully implemented carbon pricing policies, combining carbon taxes with emissions trading systems, resulting in significant emissions reductions and decoupling of economic growth from greenhouse gas emissions. In the transportation sector, carbon pricing policies have driven the adoption of electric vehicles and cleaner fuels. In the industrial sector, these policies have led to investments in energy efficiency, fuel switching, and low-carbon technologies. In the building sector, carbon pricing has encouraged energy efficiency improvements and the adoption of low-carbon heating technologies. The paper underscores the importance of integrating carbon pricing policies with other energy and environmental policies, fostering public engagement, and designing robust monitoring, reporting, and verification systems to ensure their effectiveness in promoting low-carbon development.

1 Introduction

Climate change poses a significant threat to global ecosystems, economies, and societies. To mitigate the adverse impacts of climate change, it is crucial to reduce greenhouse gas (GHG) emissions, primarily through the adoption of low-carbon technologies and practices. With the objective that limiting global warming to 1.5 ° C by 2100 in the Paris Agreement, countries around the world are taking action to reduce carbon emissions [1]. The European Union (EU) has set a climate goal of reducing carbon emissions by 55% by 2030 [2]. Meanwhile, the Chinese government also has the ambition to reach the goal of net zero in 2060. Some scholars are searching the feasible measures to reach the ambitious goal. The implementation of carbon pricing is regarded as one of the fundamental policy instruments to control CO_2 emissions. Experts propose carbon pricing as the most cost-efficient method for decreasing GHG emissions [3].

Carbon pricing policies, such as carbon taxes and emissions trading systems (ETSs), have emerged as effective instruments for reducing GHG emissions by internalizing the social costs of carbon emissions and incentivizing low-carbon investments [4]. This research employs a qualitative comparative analysis method based on data from academic articles, government reports, and policy documents. This paper aims to compare carbon pricing policies in China and the Scandinavian countries (Norway, Denmark, and Sweden), with a particular focus on Sweden, to examine their effectiveness in driving low-carbon development and draw lessons for other countries seeking to implement similar policies.

2 Carbon pricing policies in China and the Scandinavian countries

2.1 China

China, as the world's largest GHG emitter, has been actively implementing carbon pricing policies to address climate change and promote low-carbon development. In 2011, China initiated regional pilot ETS programs in seven provinces and cities [5]. Building on the experience from the pilot programs, China launched its national ETS in 2021, covering major industrial sectors, including power, cement, and steel [6]. The Chinese ETS employs a cap-and-trade system, setting an overall emissions cap and distributing allowances to regulated entities [6].

China initiated its national ETS in 2017, with the power sector being the first to be covered [5]. The ETS aims to create a market-based mechanism that encourages companies to reduce emissions by putting a price on carbon. Participants in the ETS are required to obtain allowances for their emissions, which can be traded in the market [6]. Before the launch of the national ETS, China had implemented seven regional

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https://doi.org/10.1051/e3sconf/202342404005

pilot ETS programs in cities and provinces, including Beijing, Shanghai, Guangdong, and Shenzhen, among others [7]. These pilot programs have provided valuable insights and experiences for the development of the national ETS, such as the design of allocation methods, monitoring, reporting, and verification (MRV) systems, and market operation rules [8].

The regional pilot ETS programs have a broader sectoral coverage compared to the national ETS, including industrial sectors such as cement, steel, and chemicals, as well as the building and transportation sectors in some cases [7]. The national ETS covers around 2,200 companies, accounting for approximately 40% of China's total GHG emissions [9]. The system focuses primarily on carbon dioxide (CO_2) emissions, but there are plans to expand the scope to include other GHGs in the future [6].

China's carbon pricing policies are expected to evolve further in the coming years. The national ETS is likely to expand its coverage to include more sectors and a larger share of the country's GHG emissions [6]. There is also potential for China to implement a carbon tax or a hybrid carbon pricing policy that combines elements of both an ETS and a carbon tax [5]. Despite the progress made in implementing carbon pricing policies in China, several challenges remain, such as the need for more accurate emissions data, the development of a robust MRV system, and ensuring policy compliance [8]. Addressing these challenges will be crucial for the effectiveness and credibility of China's carbon pricing policies in driving emissions reductions and low-carbon development.

2.2 Scandinavian countries

Scandinavian countries have been pioneers in implementing carbon pricing policies, with all three countries adopting carbon taxes in the early 1990s [10]. Additionally, they participate in the European Union Emissions Trading System (EU ETS), which covers large emitters in the power, industry, and aviation sectors [11]. Sweden, as a leading example in the Nordic region, introduced its carbon tax in 1991, targeting the energy and transport sectors [10]. The tax rate has increased over time, reaching approximately €120 per ton of CO_2 in 2020, making it one of the highest carbon tax rates in the world [9]. Sweden also participates in the EU ETS, covering large emitters in the power, industry, and aviation sectors.

Denmark, Sweden, and Norway introduced carbon taxes in the early 1990s as one of the first countries globally to do so [12]. The carbon taxes cover various sectors, such as energy, industry, and transportation, and provide incentives for businesses and households to reduce their GHG emissions and adopt low-carbon technologies. Sweden's carbon tax is often regarded as one of the most successful examples of carbon pricing policies, with a high tax rate and broad sectoral coverage [13]. The carbon tax has contributed to a significant reduction in GHG emissions while maintaining economic growth [14]. In Denmark, the carbon tax has been combined with other energy and environmental policies, such as renewable energy support schemes and energy efficiency standards, to create a comprehensive policy framework for low-carbon development [15].

Scandinavian countries also participate in the EU ETS, a cap-and-trade system covering more than 11,000 installations across the European Union [16]. The EU ETS covers large industrial emitters and the power sector, accounting for about 45% of the EU's GHG emissions [17]. The EU ETS allows for the trading of emissions allowances between companies and countries, providing flexibility for businesses to find cost-effective solutions to reduce emissions [11]. The cap on emissions declines over time, ensuring a continuous reduction in GHG emissions.

Scandinavian countries continue to lead the way in carbon pricing policies, with ambitious climate targets and ongoing efforts to improve the design and effectiveness of their carbon taxes and participation in the EU ETS. The potential for further integration of carbon pricing policies with other energy and environmental policies, such as renewable energy support schemes, energy efficiency standards, and regulations, remains an important area for future development [18].

Challenges for carbon pricing policies in Scandinavian countries include addressing concerns about competitiveness and distributional impacts, ensuring policy coherence and integration, and promoting public acceptance and engagement [12].

2.3 Comparison and discussion

China's ETS faces challenges in data accuracy, monitoring, and compliance, which hinder policy effectiveness [6]. In contrast, Sweden has developed robust monitoring, reporting, and verification (MRV) systems to ensure policy compliance and facilitate continuous improvement [19]. Additionally, Sweden's carbon tax is well-integrated with other energy and environmental policies, creating a coherent policy framework that promotes low-carbon development [12]. China's ETS is relatively new, and its impact on emissions reduction is yet to be fully assessed. However, preliminary data shows a decline in carbon intensity in key sectors [20]. The Scandinavian countries have achieved significant emissions reductions, partly due to their carbon pricing policies, with an average reduction of 26% between 1990 and 2019 [21]. Sweden, in particular, has successfully decoupled economic growth from GHG emissions, reducing its emissions by approximately 27% between 1990 and 2019, while its GDP grew by around 78% during the same period [22].

The findings suggest that the Scandinavian countries' long-standing commitment, policy coordination, and public engagement have contributed to the success of their carbon pricing policies. Sweden's experience demonstrates the importance of a high carbon tax rate, a coherent policy framework, and strong MRV systems. China could learn from these experiences and improve its ETS design, MRV systems, and stakeholder engagement to enhance policy effectiveness.

Furthermore, international cooperation and knowledge sharing can help both regions to address common challenges and foster low-carbon development. Sweden's carbon tax has been successful in part due to its broad coverage and high rate. The tax covers most GHG emission sources, including transport, industry, and heating, making it a comprehensive policy tool for driving emissions reductions [23]. Additionally, the high carbon tax rate has provided strong incentives for businesses and households to switch to low-carbon technologies and practices, leading to significant emissions reductions over time [12].

Another critical factor in Sweden's success is the integration of carbon pricing policies with other energy and environmental policies. This coherent policy framework, which includes renewable energy subsidies, energy efficiency standards, and research and development support for low-carbon technologies, has facilitated a smooth transition to a low-carbon economy [12]. This integration has also helped address concerns about the regressive distributional impacts of carbon pricing, as complementary policies have been designed to mitigate potential adverse effects on low-income households [23].

3 Sector-specific impacts of carbon pricing policies

3.1 Transportation sector

In Scandinavian countries, carbon pricing policies have driven the adoption of cleaner fuels, electric vehicles (EVs), and improvements in public transportation systems. In Sweden, the high carbon tax has encouraged a shift from fossil fuels to biofuels and the adoption of EVs [24]. The increased uptake of EVs has not only contributed to reduced emissions from the transportation sector but also spurred the development of supportive infrastructure, such as charging stations [13]. Moreover, these policies have stimulated investments in public transportation systems, promoting greater use of trains and buses, which are more energy-efficient and environmentally friendly compared to private vehicles [25].

In China, the national ETS does not currently cover the transportation sector. However, regional pilot ETS programs, such as the one in Shenzhen, have included transportation, encouraging investments in EVs and public transportation [26]. The city's public transportation fleet has significantly grown as a result of the Shenzhen ETS, and it now runs almost exclusively on electricity [27]. Furthermore, China has implemented other complementary policies, such as subsidies and tax exemptions, to promote the adoption of EVs and the development of charging infrastructure [28].

The experiences of Scandinavian countries and China demonstrate the potential of carbon pricing policies to drive the adoption of low-carbon technologies and practices in the transportation sector. By integrating carbon pricing with other supportive policies, these countries have created a policy environment conducive to the transition towards cleaner and more sustainable transportation systems.

3.2 Industrial sector

In Scandinavian countries, carbon pricing policies have led to investments in energy efficiency, fuel switching, and low-carbon technologies in the industrial sector [10]. For example, in Sweden, the high carbon tax has stimulated investments in bioenergy and waste heat recovery in the pulp and paper industry, resulting in significant emission reductions and cost savings [18]. Additionally, the carbon tax has prompted Swedish industries to adopt innovative technologies, such as carbon capture and storage (CCS), to further reduce their carbon emissions [12]. In Denmark, the carbon tax and participation in the EU ETS have incentivized industrial companies to invest in energy-efficient technologies and renewable energy, contributing to the country's ambitious climate goals [15]. Similar trends are observed in Norway and Finland, where carbon pricing has played a crucial role in driving industrial decarbonization [29].

In China, the national ETS covers major industrial sectors, including power, cement, and steel. Although the system is still in its early stages, it has the potential to drive investments in energy efficiency and low-carbon technologies across these sectors [6]. Early evidence from the pilot ETS programs in China shows that they have led to improved energy efficiency, emissions reductions, and increased awareness of carbon management among participating enterprises [5].

In conclusion, carbon pricing policies in Scandinavian countries and China have been effective in driving investments in energy efficiency, fuel switching, and low-carbon technologies in the industrial sector. By providing a clear price signal for carbon emissions, these policies have stimulated innovation and accelerated the transition to a low-carbon economy.

3.3 Building sector

In Scandinavian countries, carbon pricing policies have encouraged energy efficiency improvements and the adoption of low-carbon heating technologies in the building sector. For example, in Sweden, the carbon tax has facilitated the transition from fossil fuel heating to bioenergy and heat pumps, reducing emissions and energy consumption in residential and commercial buildings [30]. This shift has also contributed to the increased deployment of district heating systems, which utilize waste heat from industries and combined heat and power plants, thereby improving overall energy efficiency [31]. The national ETS in China does not apply to the building sector. However, some regional pilot ETS programs, such as the one in Beijing, have included large commercial and public buildings, encouraging energy efficiency improvements and the adoption of low-carbon technologies [32]. This has led to the implementation of energy-saving measures such as insulation upgrades, efficient lighting, and the use of advanced heating, ventilation, and air conditioning (HVAC) systems [33].

In addition to the regional ETS programs, China has also introduced building energy efficiency standards and green building certification schemes to promote low-carbon development in the sector [34]. These complementary policies, alongside carbon pricing, have the potential to drive substantial improvements in the energy performance of China's building stock and contribute to the country's climate mitigation efforts.

4 Lessons for effective climate change mitigation

The effectiveness of carbon pricing policies in China and the Scandinavian countries can be attributed to several factors. First, the long-term commitment to carbon pricing has provided a stable policy environment for businesses and households to invest in low-carbon technologies and practices. Governments in these countries have consistently demonstrated their commitment to addressing climate change and reducing GHG emissions, which has instilled confidence in the private sector to undertake low-carbon investments [9].

Second, their carbon pricing policies have been well-integrated with other energy and environmental policies, creating a coherent policy framework that promotes low-carbon development [12]. For instance, Scandinavian countries have combined carbon pricing with renewable energy support schemes, energy efficiency standards, and regulations to ensure a comprehensive approach to climate change mitigation [15]. In China, carbon pricing has been integrated with the country's broader climate and energy policies, such as the promotion of renewable energy and energy efficiency improvements [6].

Furthermore, both regions have developed robust monitoring, reporting, and verification (MRV) systems to ensure policy compliance and facilitate continuous improvement [16]. These systems are essential for accurately measuring emissions, tracking progress towards emissions reduction targets, and identifying areas for further improvement. In the European Union, the MRV system under the EU ETS is standardized across all member states, ensuring consistency and comparability of data [17]. In China, efforts have been made to improve the quality of emissions data and establish a national MRV system that builds on the experiences of the regional pilot ETS programs [26].

Additionally, public engagement and acceptance of carbon pricing policies have been crucial for their successful implementation. Citizens in Scandinavian countries generally support climate change mitigation efforts and recognize the need for effective policies to reduce GHG emissions [18]. In China, public awareness of climate change has been growing, and there is increasing recognition of the importance of carbon pricing policies in driving low-carbon development [35].

Lastly, the design features of carbon pricing policies, such as the scope, coverage, and stringency of carbon taxes and ETS programs, have contributed to their effectiveness [11]. For example, Sweden's high carbon tax rate and broad sectoral coverage have been key factors in driving emissions reductions and low-carbon investments [13]. Similarly, the gradual expansion of China's national ETS to cover more sectors and a larger share of the country's GHG emissions will be essential for enhancing the system's effectiveness [6].

In conclusion, the effectiveness of carbon pricing policies in China and the Scandinavian countries can be attributed to a combination of factors, including long-term commitment, policy integration, robust MRV systems, public engagement, and well-designed policy instruments. By addressing these factors, other countries can learn from their experiences and implement carbon pricing policies that effectively contribute to climate change mitigation efforts.

5 Conclusion

In summary, carbon pricing policies in China and the Scandinavian countries, with a particular focus on Sweden, have been effective in driving the adoption of low-carbon technologies and practices across the transportation, industrial, and building sectors, contributing to overall emissions reductions while maintaining economic growth. These policy instruments, such as carbon taxes and emissions trading systems, have demonstrated the potential to be powerful tools for tackling climate change when designed and implemented appropriately. By combining carbon taxes with participation in the EU ETS, integrating carbon pricing with other energy and environmental policies, such as renewable energy support schemes and energy efficiency standards, and fostering public engagement and acceptance, these countries offer valuable lessons for other nations seeking to implement effective carbon pricing policies for climate change mitigation.

In addition to their success in reducing emissions, the experiences of China and the Scandinavian countries highlight the importance of addressing challenges related to policy coherence, competitiveness, and distributional impacts. Ensuring the robustness and accuracy of emissions data, monitoring, reporting, and verification systems, and compliance mechanisms are crucial factors in enhancing the effectiveness and credibility of carbon pricing policies.

Moving forward, there is potential for further improvements in the design and implementation of carbon pricing policies, as well as the integration of these policies with complementary measures aimed at driving low-carbon development. By learning from the experiences of China and the Scandinavian countries, other nations can adopt tailored carbon pricing strategies that effectively contribute to global climate change mitigation efforts.

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