



Carbon pricing, carbon equity, and the RCEP framework

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ABSTRACT

Trade liberalization in the Regional Comprehensive Economic Partnership (RCEP) not only contributes to regional economic growth but also leads to an increase in energy consumption and carbon emissions, which may exacerbate climate change risks. This study aims to explore the carbon pricing issue in the context of the RCEP framework. Additionally, for the sake of carbon equity, we introduce a differentiated carbon pricing scheme based on the cost fairness principle (CPCF), and the unified carbon pricing was used for a cost effectiveness analysis. The empirical analysis was conducted with a global multi-regional computable general equilibrium model. The results show that with the help of trade liberalization, the RCEP's GDP, energy consumption, and carbon emissions may increase by 0.639%, 1.962%, and 1.897%, respectively. The CPCF scheme, wherein developed countries assume the primary abatement burden, can be used to offset the increase in carbon emissions from trade liberalization while RCEP members maintain positive economic growth. The total abatement cost of the CPCF for carbon offsets in the RCEP can be reduced via unified carbon pricing, and the cost-saving effect approaches 24.24%. Unified carbon pricing may result in a carbon price of US \$5.83 within the RCEP. As such, this study explores carbon pricing in the context of trade liberalization, and its findings will be valuable for the RCEP to achieve a win-win situation in terms of economic growth and climate change.

1. Introduction

The Regional Comprehensive Economic Partnership (RCEP), signed in November 2020, is a free trade agreement that promotes economic integration among the fifteen nations of China, Japan, South Korea, Australia, New Zealand, and 10 ASEAN member countries (Tian et al., 2022). It requires not only the removal of tariff trade barriers between the 15 countries, but also the removal of non-tariff trade barriers, such as quantitative restrictions, import licensing procedures, and fees and procedures related to imports and exports (Balistreri and Tarr, 2020). By reducing and eliminating tariff and non-tariff barriers, the RCEP aims to establish a modern, comprehensive, high-quality, and mutually beneficial economic partnership framework to facilitate the expansion of regional trade and investment, and contribute to global economic growth (Balistreri and Tarr, 2020).

Trade liberalization in the RCEP has brought opportunities for the implementation of carbon pricing, as climate change is also a common challenge for parties in this region. From a global perspective, many countries are reluctant to take meaningful measures to reduce carbon emissions due to economic concerns (Cui and Song, 2017). More specifically, countries with meaningful reduction

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measures may face higher costs than their international peers without abatement or comparable measures, which could result in competitive disadvantages and economic losses (Dong et al., 2015; Fan et al., 2022). However, this adverse scenario will change in the context of trade liberalization, which will boost member economies by improving imports and exports. Although imposing a carbon-pricing policy has a negative impact on the economy, this cost can be offset (or partially offset) by the benefits of free trade within the RCEP. Trade liberalization will provide opportunities for the RCEP to better balance economic growth and carbon emission reduction.

Carbon pricing under the RCEP framework needs to address the allocation of carbon emission reduction responsibilities among different countries, in which carbon equity is crucial. However, different people have different understandings of carbon equity, and thus arrive at different schemes for allocating abatement responsibilities among nations. So far, the academic community has proposed four principles of carbon equity: the sovereignty, egalitarian, ability to pay, and polluter pays principles (Cui and Song, 2017; Oberheitmann, 2010). These principles embody different perspectives of interest and, therefore, have different specific strengths, weaknesses, and possible remedies (Cui and Song, 2017; Ringius et al., 2002).

RCEP members include both developed and developing countries, in which different countries have different economic development stages and resource endowments. This fact implies that they produce the same product with different energy consumption and carbon emissions, and thus face different cost pressures and economic losses with the same carbon price constraint. Considering that many countries are reluctant to take meaningful abatement measures due to the international competitive disadvantage concerns (Cui and Song, 2017; Zhu et al., 2020), differentiated carbon pricing needs to take cost heterogeneity into account to improve policy acceptability. However, the design of differentiated carbon pricing requires fair and reasonable standards, or else it may distort international competitiveness. For example, unreasonable carbon pricing will lead to major changes in the relative prices of products between countries before and after the implementation of carbon abatement policies (Cui and Song, 2017).

To offset the increase in carbon emissions caused by trade liberalization of the RCEP, this study introduces a differentiated carbon pricing mechanism based on the cost fairness principle (CPCF), which has been discussed in previous studies (Cui et al., 2013; Cui and Song, 2017; Zhu et al., 2020). The CPCF adheres to the principle of common but differentiated responsibilities, allows different countries to adopt different emission reduction efforts, and links regional abatement efforts to their economic capacities, thus embodying the idea of the ability to pay principle. The fundamental idea of the CPCF is to maintain the relative competitive advantages of RCEP members before and after carbon pricing. While the proposed CPCF implies a loss in economic efficiency, it is able to maintain the relative competitiveness among countries, so that each country's economic output will not be much affected by the carbon abatement measures. This aspect is particularly important for emerging and developing countries reluctant to agree to climate policy measures because they fear that these would impede the economic development of their country. The question is whether the CPCF scheme can help the RCEP achieve carbon offset at a lower cost.

This study explores the coordination of carbon pricing under the RCEP framework. Specifically, we set up three policy scenarios: RCEP trade liberalization, the CPCF scheme, and unified carbon pricing within the RCEP. The CPCF scheme and unified carbon pricing follow the same carbon constraint, with the goal of offsetting the carbon emission increment caused by RCEP trade liberalization. To reveal the economic and environmental impacts of the different schemes, this study uses the global multi-regional dynamic computable general equilibrium (CGE) model for empirical analysis. Finally, sensitivity analysis was performed to test the robustness of the relevant conclusions. Our study makes a novel contribution to the literature because, to the best of our knowledge, it is the first attempt to explore the carbon pricing mechanism in the context of RCEP trade liberalization, which is of great practical significance for the RCEP to better balance economic growth and climate change.

The remainder of this paper is organized as follows. Section 2 describes previous studies on the same topic and identifies gaps that are addressed in this study. Section 3 presents the methodology, data, and policy scenarios used in the study. Section 4 presents the findings and interpretations of the study. Section 5 presents the sensitivity analysis. Section 6 presents conclusions and policy implications.

2. Literature review

As the world's largest free trade agreement, the RCEP marked a milestone in the development of regional trade agreements and has attracted substantial interest in recent studies. There are two main strands of literature relevant to the RCEP. The first focuses on its economic effects on trade liberalization, but has largely neglected environmental issues. The potential economic effects of the RCEP implementation have been explored from multiple perspectives, including welfare, trade, and industrial development. For example, Balistreri and Tarr (2020) estimated the welfare effects of the RCEP under different market structures, and found that substantial gains in regional welfare can be achieved through deep integration. In the long run, the trade benefits brought about by the RCEP are expected to strengthen the circular flow of international trade among participating countries (Zhang et al., 2023). At the country level, it is argued that joining the RCEP can expand trade volume and provide ample avenues for South Asian economies such as Bangladesh (Goswami et al., 2022). For larger economies, such as China, it may promote outward direct investment in other RCEP countries, drive industry transformation, and create potential jobs under the impact of COVID-19 (Deng et al., 2022; Liu et al., 2022; Wu et al., 2021). Moreover, developed countries like South Korea can also benefit from the RCEP, as argued by Ahmed et al. (2020), who stated that it will experience an additional 0.38% GDP growth due to this framework. Regarding the effects on specific industries, existing studies suggest that the operation of the RCEP may deepen industry cooperation between China and ASEAN countries, such as in photovoltaic products (Guo and Mai, 2022) and cross-border e-commerce (Cai et al., 2022).

The second literature strand addresses the environmental effects of the RCEP, including the energy efficiency and carbon emissions of the participating countries. RCEP countries account for nearly 30% of the world's total economy and population, and most have experienced rapid development during the past few decades (Al-Qudah et al., 2022). Thus, the RCEP regions are highly influential in

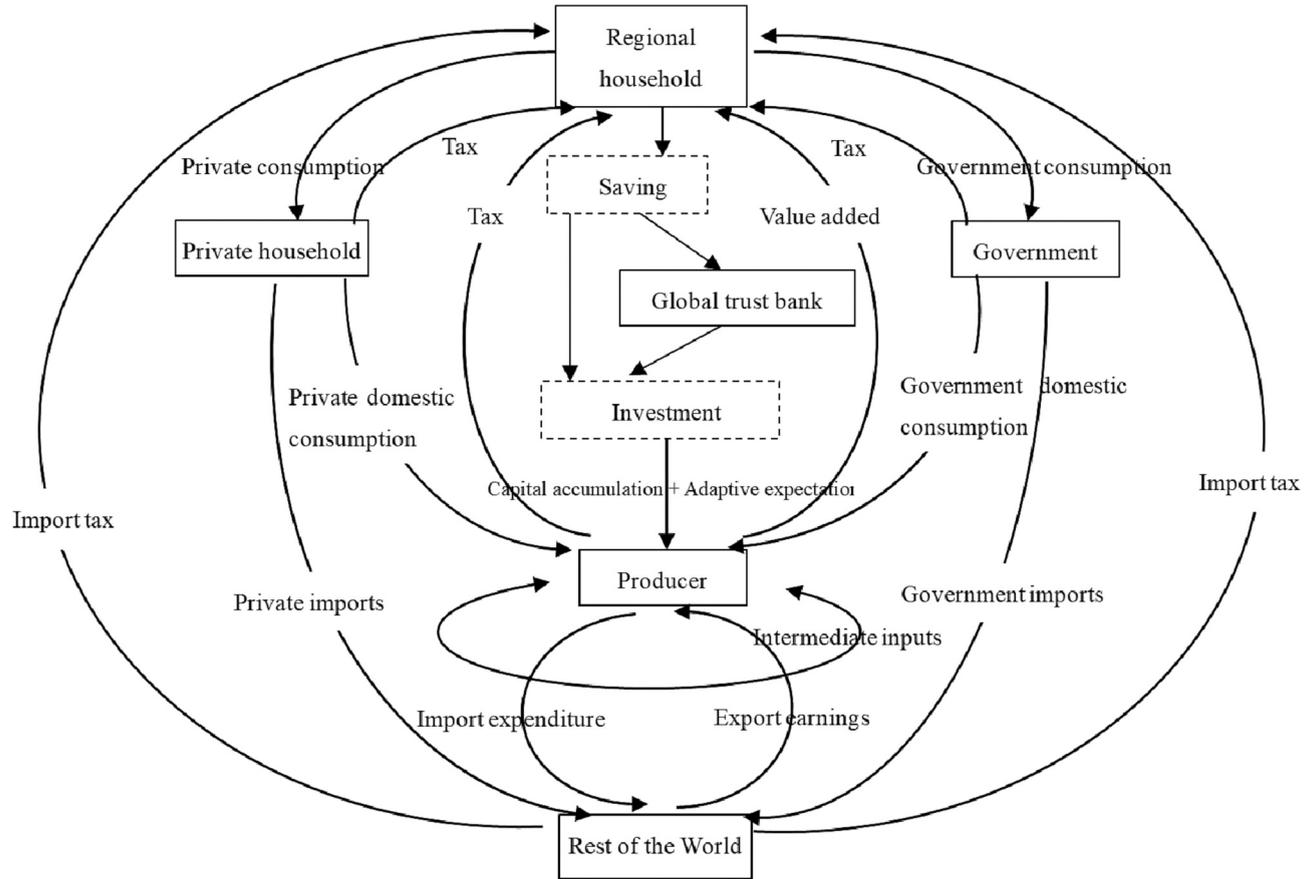


Fig. 1. The structure of the GdynE model. (Source: Based on Hertel, Tyner, & Birur (2010), modified by considering investment mechanisms.)

global energy consumption and carbon emissions (Fan et al., 2022; Jia and Yang, 2022). Most existing studies have used ex-post methods to investigate energy efficiency and changing carbon emission trends in RCEP countries. Zhang and Chen (2022) analyzed the energy efficiency of 13 RCEP countries using a three-stage SBM-DEA model and found that the energy efficiency of the RCEP was, on average, still poor, indicating an urgent need to optimize the industrial structure. Li et al. (2022) tracked economic development and power generation in RCEP countries from 2000 to 2018 through nighttime light data. Their results confirmed economic prosperity in the RCEP regions, but also warned that the accompanying environmental problems might be aggravated. Qian et al. (2022) studied the carbon emissions of RCEP countries from the perspective of global value chains and suggested that backward participation can increase carbon emissions through an increased trade scale. Latif et al. (2023) explored the factors influencing carbon emissions in RCEP countries using panel data from 1990 to 2020. The results demonstrated that carbon emissions are positively related to financial development and economic growth but might be mitigated by improving energy efficiency and developing renewable energy.

Despite the above-mentioned literature, the official enforcement of the RCEP in 2022 raises another novel question: Will trade liberalization further exacerbate regional carbon emissions and energy consumption in the future? To date, this has not been extensively explored. Studies have been conducted on the effects of free trade agreements on pollution emissions. For example, Bajona and Kelly (2012) performed a simulation using a dynamic general equilibrium model and showed that reducing tariffs can increase output and pollution. More recently, Tian et al. (2022) estimated the carbon emission burdens of the RCEP countries and found that complete tariff elimination among them would result in a 3.1% increase in global carbon emissions from fuel combustion. However, though this study revealed the potential negative impacts of the RCEP on global carbon emissions reduction, it did not answer the important question of how to offset this emission increment through reasonable policies. Few studies have extensively explored the balance between economic benefits and emission mitigation in RCEP countries. Therefore, this study fills this gap by proposing a carbon pricing mechanism in the context of the RCEP framework, which may help RCEP countries offset the incremental emissions induced by trade liberalization without much sacrifice of their economic gains.

3. Methodology, data, and policy scenarios

3.1. GdynE model

To explore the environmental and economic impacts of the RCEP trade liberalization, this study adopted a dynamic climate-economy computable general equilibrium model (GdynE) for empirical analysis. The GdynE model is a multiregional, multisector, recursive, and dynamic CGE model that combines the advantages of the GTAP-Dyn and GTAP-E models (Guo et al., 2021). In contrast to the GTAP-Dyn model, the GdynE model follows the production structure of the GTAP-E model, which considers energy as an intermediate input and describes the substitution relationship among capital, energy, and labor by introducing a nested production structure. Moreover, the GdynE model introduces a carbon tax levied on economic entities (governments, residents, and enterprises) that consume various types of fossil fuels in the economic system. This setting is particularly useful in simulating the impact of policy shocks on changes in the energy structure. Furthermore, compared with the GTAP-E model, the GdynE model adopts the investment mechanism of the GTAP-Dyn model, which distinguishes ownership of capital. As shown in Fig. 1, the GdynE model manages overseas investments of various countries through virtual global trust, and the investment income returns to the home country (Hertel et al., 1997; Lakatos and Walmsley, 2012). Given the increasing scale of transnational investments, ignoring the investment mechanism of capital ownership may lead to large deviations in policy evaluations. Owing to the special treatment of production structure and capital ownership, the GdynE model is particularly useful for exploring the environmental and economic impacts of the RCEP trade liberalization.

The GdynE model assumes that each country has a regional household account that collects all sources of income in the region, including labor and capital factor remuneration, as well as tariff income. Total expenditure includes government consumption, private consumption, and savings, satisfying the Cobb-Douglas functional form (Cui et al., 2023). To make use of price elasticity to calibrate the model, private consumption is characterized by a non-homothetic constant difference of elasticity and government consumption is assumed to follow a Cobb-Douglas function (Cui et al., 2019a, 2019b). The GdynE model is a powerful tool for international trade analysis, and the dimensionally large input-output tables, detailed trade and investment database, and its flexibility in regional disaggregation make it possible to focus on any regional setting or aggregation level (Guo et al., 2021).

Moreover, the GdynE model assumes that imports differ from domestic products and can be substituted imperfectly. Similarly, products from different countries cannot be perfectly substituted. All of these satisfy the Armington assumption. The model includes two types of tariff variables: import tariffs on all trading partners, denoted as tm , and import tariffs on a specified country, denoted as tms . As RCEP trade liberalization mainly involves tariff adjustments among its members, the simulation was carried out based on the variable tms . For non-tariff trade barriers, the policy impact can be simulated using the shocked variable ams .

3.2. Data Processing

The initial database of the GdynE simulation used in this study was the GTAP10 database, which contains input-output tables and bilateral trade statistics for 65 sectors and 141 regions, using 2014 as a reference year. To simplify our research, we aggregated the original data into 10 regions and 16 sectors by referring to Guo et al. (2021), which used the same methodology and database to investigate the change of global shipping carbon emissions resulting from trade conflicts. However, we made slight adjustments to the regions and separately listed Australia and New Zealand, as these two countries are important members of the RCEP. As a result, the new aggregated regions included China, Japan, South Korea (SoKorea), Australia (AUS), New Zealand (NZL), India, ASEAN, the United

States (US), the European Union (EU27), and the rest of the world (ROW). The reason for merging ASEAN members into one region, a type of division adopted by most scholars (Ling and Lv, 2022; Wen et al., 2022), was that this region has already achieved trade liberalization. The aggregated sectors include agriculture (Agr), coal, oil, gas, petroleum and coal products (Oil_pcts), electricity, food processing (ProcFood), textile and clothing (TextWapp), wood products (Lum), paper products and publishing (PPP), chemical (CHM), rubber and plastic products (RPP), metals, machinery, transport equipment (Transporteqi), and services.

One of the main contributions of this study is the development of a dynamic database for the global energy economy that matches the GdynE model. The simulation included two parts: historical calibration and policy simulation. The historical calibration period was 2014–2019, and two types of data were used to calibrate the model: (Ahmed et al., 2020) regional economic and employment data, including the real GDP, investment, consumption, import and export trade, population, and employment, and (Al-Qudah et al., 2022) regional energy and environmental data, including the consumption of coal, oil, natural gas, and refined oil, as well as changes in carbon emissions. Employment data for various regions were predominantly derived from the official websites of the World Bank and International Monetary Fund, and the consumption of various types of fossil fuels and regional carbon emissions were derived from British Petroleum (2022).

Historical calibration was used to determine the main variables of the model using existing macroeconomic data to obtain the relevant technological progress and displacement parameters. In contrast, policy simulation assumes the extrapolation of historical trends, supplemented by reasonable expectations of future macroeconomic growth, and constructs a reference scenario for policy shocks (Guo et al., 2021). For historical calibration, the exogenous variable *pop* was used to determine the regional population, and the exogenous variable *empl* was used to calibrate regional employment. Many macroeconomic indicators were endogenous variables in the model, which were thus exchanged for exogenous variables. Specifically, the real GDP (*qgdp*) was swapped with the output augmenting technology change (*aoreg*), private consumption (*yp*) was exchanged for the private consumption distribution parameter (*dppriv*), government consumption (*yp*) was swapped with the government consumption distribution parameter (*dpgov*), investment (*qcgds*) was swapped with its slack variable (*cgdslack*), export (*qxwreg*) was exchanged for its slack variable (*qxwslack*), and import (*qiwwreg*) was swapped with its slack variable (*qimslack*). For energy consumption and carbon emissions, regional consumption of various types of fossil fuels (*EgE*) was exchanged for its slack variable (*SlackEgE*), and regional carbon emissions (*gco2t*) was replaced with its slack variable (*gco2slack*). The slack variables were primarily used to measure the deviation between the model simulation results and actual values, a calibration method used in many CGE models (Cui et al., 2019a, 2019b; Song and Cui, 2016).

It should be noted that because of the substantial uncertainties resulting from the COVID-19 pandemic and the Russia-Ukraine War, this study will provide a comparative static analysis based on 2019 data; otherwise, the simulation results would highlight the combined effect of multiple events, rather than the single impact of the RCEP trade liberalization. The empirical simulation was conducted using the Rundynam software, and the Euler algorithm was used to solve the model. Value variables were measured based on constant prices in 2014.

3.3. The principle of CPCF

To offset the increase in carbon emissions caused by the trade liberalization of the RCEP, it is necessary to explore a fair and reasonable carbon pricing scheme among member countries. With regard to carbon equity, although the sovereignty, egalitarian, ability to pay, and polluter pay principles have been proposed to allocate carbon responsibilities, countries worldwide have not yet reached a consensus on which principle to adopt. This study does not discuss which principle is superior, but rather attempts to introduce the CPCF mechanism to explore whether it can help the RCEP achieve a win-win situation of climate change mitigation and economic growth. Considering that many countries are concerned about the loss of competitiveness and economic recession due to unilateral abatement measures, the CPCF may have higher policy acceptability because it can protect development rights and interests.

Here, we use a simple model to illustrate the concept of the CPCF scheme. For more details, please refer to Cui and Song (2017) and Zhu et al. (2020). Assume that two countries, A and B, have different resource endowments and economic development levels. Both countries have only one enterprise. The sale price of A is P_A , the carbon emissions per unit product are Q_A , the sale price of B is P_B , and the carbon emissions per unit product are Q_B . Further, assume that the two countries negotiated to implement differentiated carbon pricing policies, with the carbon prices for A and B being T_A and T_B , respectively. After introduction of the carbon pricing policies, the sales prices of P_A^* and P_B^* satisfy:

$$\begin{cases} P_A^* = P_A + T_A Q_A \\ P_B^* = P_B + T_B Q_B \end{cases} \tag{1}$$

To maintain the relative competitive advantages of A and B before and after carbon pricing, it is necessary to keep the relative product prices of the two countries unchanged; that is, $P_A^*/P_B^* = P_A/P_B$. At this time, the carbon prices in A and B satisfy:

$$\begin{aligned} \frac{P_A^*}{P_B^*} &= \frac{P_A + T_A Q_A}{P_B + T_B Q_B} = \frac{P_A}{P_B} \\ \Rightarrow \frac{Q_A}{P_A} T_A &= \frac{Q_B}{P_B} T_B \\ \Rightarrow E_A T_A &= E_B T_B \end{aligned} \tag{2}$$

where E_A and E_B are the carbon intensities of enterprises in countries A and B, respectively. Since we assume that each country has only one enterprise, they also have a carbon intensity GDP. As shown in Eq. (2), the CPCF implies that developed countries with lower carbon intensity need to implement higher carbon pricing, whereas developing countries with higher carbon intensity can implement lower carbon pricing. This setting considers the economic affordability of different countries, reduces the distortion of international comparative competitive advantages caused by differing emission reduction efforts, and protects the development rights and interests of different countries.

Eq. (2) can be extended to other countries. Suppose there are N countries and the carbon intensity of country k is E_k . To maintain the relative competitive advantages, carbon pricing in country k should satisfy:

$$E_1 T_1 = E_2 T_2 = \dots = E_N T_N \quad (3)$$

3.4. Policy scenarios

The guiding principles of the RCEP call on member governments to progressively eliminate tariff and non-tariff barriers on all trade in goods to substantially eliminate restrictions or discriminatory measures with respect to trade in services among RCEP members and to facilitate investment in the region (Balistreri and Tarr, 2020). Therefore, trade liberalization among RCEP member countries should include the elimination of tariff barriers and reduction of non-tariff barriers. Although the CPCF scheme can be used to offset the increase in carbon emissions caused by trade liberalization, it is not the most cost-effective method because countries generally have different carbon prices. Therefore, it is necessary to introduce a unified carbon pricing mechanism to study the minimum economic cost of the RCEP in the carbon offset.

Against this background, this study introduces three policy scenarios as listed in Table 1. Scenario 1 (S1) assumes that, after signing the RCEP, tariffs between member countries will be reduced to zero, and non-tariff trade barriers will be reduced by 5%, as suggested by previous studies (Liu & Chen, 2014; Xu & Jiang, 2021). A subsequent sensitivity analysis changed this parameter for the robustness test. Scenario 2 (S2) was an extension of S1. It is assumed that RCEP members will adopt a differentiated carbon-pricing mechanism to offset the increase in carbon emissions caused by RCEP trade liberalization. The carbon price in each member country meets the principle of the CPCF; that is, the carbon price is inversely proportional to the carbon intensity. Scenario 3 (S3) was an extension of S2. It is assumed that carbon emission rights can be traded among RCEP member countries and are mainly used to tap the abatement potential of different nations and achieve the total emissions target cost-efficiently. Although the total carbon emissions of the RCEP in S3 and S2 were identical, the regional carbon prices could differ. The former creates a unified carbon price under perfect market competition. It should be noted that the carbon pricing discussed in this study is an additional emission reduction level relative to existing emission reduction efforts; because the official effective date of the RCEP is January 2022, the increase in carbon emissions caused by trade liberalization is relative to the existing carbon emissions level. Therefore, for RCEP countries that have adopted carbon taxes, carbon prices should be placed under the baseline simulation.

Figure 2 shows the carbon prices in S2 and S3 obtained from the GdynE simulation. In S2, to offset the increase in carbon emissions caused by the trade liberalization of the RCEP, developed regions such as NZL, Japan, and AUS need to impose higher price constraints on their domestic carbon emissions, which are US \$15.63, US \$10.81, and US \$10.07, respectively. In contrast, China and ASEAN regions have relatively high carbon intensity due to their extensive economic development, unreasonable industrial structure, and incomplete industrialization process. As such, the carbon prices of the two regions are relatively low, with US \$3.65 and US \$4.65, respectively. As shown in Fig. 2, to offset the increase of carbon emissions in the RCEP under S1, the unified carbon price in S3 is US \$5.83. Compared to S2, this implies that developed regions such as NZL, Japan, Sokorea, and AUS will purchase emission rights to reduce their emission reduction burden, whereas developing countries such as China and ASEAN will obtain financial rewards through greater emission reduction.

4. Empirical analysis

The empirical study was conducted from two perspectives: macroeconomic indicators and energy and carbon emissions.

Table 1
Policy scenarios.

Scenario code	Scenario description
S1	zero import tariffs and 5% reduction in non-tariff trade barriers among all RCEP members
S2	zero import tariffs and 5% reduction in non-tariff trade barriers among all RCEP members + RCEP implements differentiated carbon pricing based on the cost fairness principle to meet the regional carbon emission increment of 0
S3	zero import tariffs and 5% reduction in non-tariff trade barriers among all RCEP members + RCEP implements unified carbon pricing to meet the regional carbon emission increment of 0

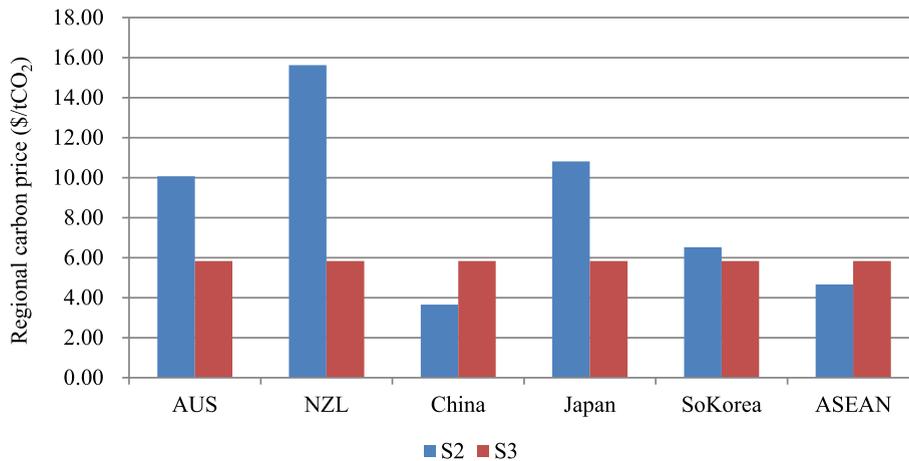


Fig. 2. Regional carbon prices in different scenarios (Sources: GdynE model simulation)

4.1. Changes in economic indicators

4.1.1. Changes in the regional real GDP

Table 2 lists regional GDP changes under the three policy scenarios. As shown, in S1, trade liberalization could indeed promote the economic growth of RCEP members, of which SoKorea and ASEAN had the highest GDP growth rates at 1.232% and 1.068%, respectively. This kind of economic integration is unfavorable to the economic growth of countries outside the region; for example, the GDP of India and the United States decreased by 0.043% and 0.014%, respectively. In general, under S1 the RCEP's GDP increased by 0.669%, the GDP of regions outside the RCEP (ORCEP) decreased by 0.033%, and the global GDP increased by 0.163%.

If the RCEP introduces the CPCF mechanism to offset the carbon emission increment in S1, all members will maintain their GDP growth, but the growth rates may decline compared with S1 due to the economic cost of carbon emission reductions. Since the national carbon price is relatively low compared to that of other RCEP members (Fig. 2), China's GDP growth rate increased slightly from 0.469% in S1 to 0.471% in S2. With regard to ORCEP, the GDP decline in all regions under S2 was narrower than that under S1; for example, the declines in the GDP of India and the United States were 0.035% and 0.013%, respectively. This implies that, although the CPCF is conducive to the ORCEP's economy, it cannot completely offset the economic losses caused by RCEP trade liberalization. Under the superposition of the CPCF and trade liberalization, the GDP of the RCEP increased by 0.639%, that of the ORCEP decreased by 0.031%, and the global GDP increased by 0.156%.

Under the unified carbon pricing scenario (S3), the RCEP reallocates emission reduction burdens, which has different economic effects. Compared with S2, the GDP growth rates of developed regions such as Japan, SoKorea, AUS, and NZL would increase because they adopted lower carbon prices. In contrast, China and ASEAN needed to increase their emission reduction burden, and their GDP growth rates would decline. As shown in Table 2, the GDP of the RCEP, ORCEP, and the global GDP increased by 0.652%, 0.033%, and 0.159%, respectively. Compared to S2, it can be inferred that under S3, the GDP of the RCEP increased by 0.013%, the GDP of the ORCEP decreased by 0.002%, and the global GDP increased by 0.003% after the introduction of unified carbon pricing.

In summary, the liberalization of the RCEP trade contributes to the economic prosperity of the region, while the introduction of the CPCF policy causes some harm to the economy. However, the GDP of member countries can still maintain growth, especially after the introduction of unified carbon pricing, and the abatement cost of the RCEP will decline further.

Table 2
Changes in regional real GDP (%).

	S1	S2	S3
AUS	0.669	0.645	0.652
NZL	0.780	0.733	0.766
China	0.469	0.471	0.471
Japan	0.787	0.651	0.721
SoKorea	1.232	1.173	1.178
ASEAN	1.068	1.061	1.058
India	-0.043	-0.035	-0.037
US	-0.014	-0.013	-0.014
EU27	-0.040	-0.032	-0.035
ROW	-0.041	-0.046	-0.046
RCEP	0.669	0.639	0.652
ORCEP	-0.033	-0.031	-0.033
Global	0.163	0.156	0.159

4.1.2. Changes in regional exports and imports

Table 3 reports regional export and import changes under the three policy scenarios. As shown, in S1, the elimination of tariffs and the reduction of non-tariff trade barriers could significantly improve import and export trade within RCEP. All members will experience some export increases, with the highest growth rate being 5.287% in SoKorea. According to GTAP10 data, RCEP members have imposed high trade barriers on SoKorea's products, such as ProcFood and Transporteqi. Therefore, the elimination of these tariffs will lead to a significant increase in SoKorea's exports. In terms of imports, SoKorea and Japan saw the largest increases, with 7.146% and 8.727%, respectively. Due to the effects of trade creation and transfer, the import and export trade of ORCEP regions will decline, with India's exports falling the least, at 0.469%, and the United States' imports falling the most, at 1.177%.

The introduction of carbon pricing (S2) increases the RCEP's production cost and weakens its international competitive advantage, as reflected by the narrowing of import and export growth in all regions. In contrast, the ORCEP region will benefit from improvement in competitive advantages and declines in regional imports and exports will slow. Specifically, compared to S1, the export growth rates of Japan and NZL decreased significantly, with values of 0.746% and 0.437%, respectively. Japan and SoKorea saw the largest decline in their import growth rates, with decreases of 1.685% and 1.302%, respectively. Meanwhile, the EU import rate decreased by 0.045%, showing the most evident improvement of all regions.

In the context of the unified carbon pricing policy (S3), developed countries such as AUS, NZL, and Japan will experience an increase in exports compared with S2 due to lower carbon prices. For example, the growth of AUS exports increased from 2.279% in S2 to 2.503% in S3. In contrast, China and ASEAN may export less because of the higher adopted carbon prices. China's export growth rate decreased from 2.070% in S2 to 1.835% in S3. The above results indicate that the implementation of the RCEP will significantly promote economic and trade cooperation in Asia, and that the increment in imports and exports of member countries will not be offset by the differentiated or unified carbon pricing policies.

4.1.3. Changes in China's sectoral output

Table 4 displays changes in China's sectoral output under the three policy scenarios. It can be seen that trade liberalization of the RCEP has a positive effect on China's sectoral output. With the expansion of export demand and the decrease of import intermediate costs, the output of China's agricultural and service sectors increased by US \$27.27 billion (2.34%) and US \$185.50 billion (1.43%), respectively. With regard to energy sectors, driven by the economic growth, China's Oil_pcts, electricity, and coal will experience some output increases; 1.83%, 1.43% and 1.53%, respectively. It also implies that RCEP trade liberalization will result in an increase in China's carbon emissions.

Compared with S1, the output changes in various sectors in China under the CPCF (S2) are characterized by differentiation. For example, the output growth rate of PPP increased from 0.54% in S1 to 0.59% in S2, while that of TextWapp decreased from 0.28% to 0.20%. China's sectoral output is mainly driven by four factors: the output increase resulting from trade liberalization of the RCEP; the output decrease resulting from the carbon pricing policy; competitive advantage changes due to the carbon pricing adopted by other RCEP members; and the flow of production factors among sectors, such as labor and capital, which tend to gather in sectors with more competitive advantages.

As shown in Table 4, the output growth rates of China's coal and Oil_pcts may fall to 1.00% and 1.72%, respectively, indicating that the introduction of carbon prices may inhibit energy demand and cause a decline in China's carbon emissions. In the case of S3, owing to the relatively high carbon price adopted by China, the output growth of some energy-intensive industries will experience some decreases. For example, the output growth rate of metals decreased from 0.46% in S2 to 0.41% in S3, whereas the decline rate of the CHM output increased from 0.14% to 0.19%. In general, the output of most sectors in China increased under all three scenarios.

4.2. Changes in energy and carbon emissions

4.2.1. Changes in regional energy consumption and carbon emissions

Table 5 reports regional energy consumption and carbon emission changes under the three policy scenarios. In S1, the trade liberalization resulted in a 1.962% increase in the RCEP's energy consumption and a 1.897% increase in carbon emissions, while the ORCEP's energy consumption decreased by 0.463% and carbon emissions decreased by 0.429%. As a result, global energy consumption

Table 3
Changes in regional exports and imports.

	Exports (%)			Imports (%)		
	S1	S2	S3	S1	S2	S3
AUS	2.797	2.279	2.503	5.650	5.138	5.267
NZL	2.103	1.710	1.979	3.526	2.778	3.215
China	2.519	2.070	1.835	3.921	3.942	3.927
Japan	2.524	1.873	2.259	7.146	5.461	6.207
SoKorea	5.287	4.495	4.607	8.727	7.425	7.552
ASEAN	1.282	1.110	1.049	1.944	1.765	1.680
India	-0.469	-0.465	-0.433	-0.869	-0.846	-0.869
US	-0.138	-0.097	-0.027	-1.177	-1.179	-1.223
EU27	-0.347	-0.299	-0.283	-0.607	-0.562	-0.588
ROW	-0.206	-0.255	-0.214	-0.654	-0.731	-0.747

Table 4
Changes in China's sectoral output.

	Percentage change(%)			Absolute value change (US\$ Bil)		
	S1	S2	S3	S1	S2	S3
Agr	2.34	2.48	2.54	27.27	28.86	29.60
Coal	1.53	1.00	0.64	4.53	2.94	1.90
Oil	0.73	0.39	0.34	1.19	0.63	0.55
Gas	-0.31	-2.61	-3.66	-0.04	-0.32	-0.45
Oil_pcts	1.83	1.72	1.64	15.56	14.63	13.99
Electricity	1.43	1.56	1.58	9.76	10.63	10.78
ProcFood	1.40	1.57	1.65	24.22	27.19	28.52
TextWapp	0.28	0.20	0.15	4.05	2.98	2.28
Lum	0.53	0.46	0.41	1.18	1.03	0.91
PPP	0.54	0.59	0.58	1.92	2.10	2.06
CHM	-0.13	-0.14	-0.19	-2.27	-2.43	-3.30
RPP	-0.02	-0.11	-0.20	-0.10	-0.61	-1.09
Metals	0.45	0.46	0.41	18.58	19.05	17.05
Machinery	0.00	-0.17	-0.29	-0.03	-7.75	-13.12
Transporteqi	0.07	0.15	0.13	0.84	1.87	1.68
Services	1.43	1.63	1.71	185.50	212.12	222.36

Table 5
Changes in regional energy consumption and carbon emissions.

	Energy consumption (%)			Carbon emissions (%)		
	S1	S2	S3	S1	S2	S3
AUS	2.427	-1.157	0.359	2.469	-2.257	-0.272
NZL	2.936	-3.125	0.702	4.221	-4.167	1.063
China	0.965	0.605	0.312	0.851	0.261	-0.153
Japan	6.426	1.129	3.625	7.105	-0.579	2.977
SoKorea	9.311	5.092	5.532	9.664	1.928	2.699
ASEAN	0.992	-0.808	-1.385	1.468	-1.148	-1.921
India	-0.629	-0.475	-0.496	-0.659	-0.491	-0.513
US	-0.373	-0.239	-0.267	-0.387	-0.243	-0.275
EU27	-0.430	-0.194	-0.236	-0.387	-0.149	-0.191
ROW	-0.495	-0.364	-0.393	-0.405	-0.271	-0.301
RCEP	1.962	0.672	0.683	1.897	0.000	0.000
ORCEP	-0.463	-0.309	-0.340	-0.429	-0.273	-0.305
Global	0.466	0.067	0.052	0.516	-0.162	-0.181

increased by 0.466% and carbon emissions increased by 0.516%. In terms of regions, SoKorea and Japan experienced the highest increases in energy consumption under S1, 9.311% and 6.426%, respectively, and the two countries also had the most obvious increases in carbon emissions, 9.664% and 7.105%, respectively. China's energy consumption and carbon emissions showed an increase of 0.965% and 0.851%, respectively. Unlike the above countries, ORCEP regions will experience some decreases in energy consumption and carbon emissions due to the decline of their economic growth.

If the CPCF scheme were introduced to offset the increase in carbon emissions caused by trade liberalization, energy consumption and carbon emissions in the RCEP regions would decrease to varying degrees compared to the S1 scenario. Among them, NZL showed the largest reduction in energy consumption and carbon emissions owing to the high implemented carbon price, with 3.125% and 4.167%, respectively. In S2, China's energy consumption and carbon emissions increased by 0.605% and 0.261%, respectively. Therefore, compared to S1, the CPCF scheme reduced China's energy consumption by 0.357% and carbon emissions by 0.585%. As shown in Table 5, the energy consumption and carbon emissions in areas outside the RCEP decreased to varying degrees, but the decline rates were lower than those under S1, indicating that the unilateral carbon emission reduction measures implemented by the RCEP may result in carbon leakage. By dividing the increase in ORCEP carbon emissions by the reduction in carbon emissions in the RCEP areas, the carbon leakage rate was estimated to be 12%.

Under the unified carbon pricing scenario (S3), with adopted higher carbon prices, the energy consumption of China and ASEAN both showed some decline compared to S2. In contrast, developed countries, such as Japan, SoKorea, and AUS, will experience an increase in energy consumption due to falling carbon prices. Specifically, China's carbon emissions increased by 0.261% in S2 and decreased by 0.153% in S3, whereas the decline in ASEAN carbon emissions increased from 1.148% (S2) to 1.921% (S3). As shown in Table 5, compared with S1, the ORCEP carbon emissions in S3 increased, indicating that carbon leakage occurred and approached 9.55% according to the GdynE model simulation. It can be seen that unified carbon pricing can reduce the carbon leakage of the RCEP's unilateral carbon abatement measures compared with differentiated carbon pricing.

4.2.2. Abatement cost and inter-regional fund transfer

Table 6 compares the abatement costs for S2 and S3. As shown in Table 6, to offset the increase in carbon emissions of the RCEP in S1, the differentiated carbon pricing introduced in S2 will result in a total abatement cost of US \$966.05 million, which is reduced to US \$731.86 million under S3, representing cost savings of 24.24%. In S3, developed countries, such as Japan, SoKorea, AUS, and NZL, are emission rights buyers, whereas developing nations, such as China and ASEAN, are emission rights sellers. More specifically, NZL could reduce its abatement costs by 40.63% by paying US \$11.74 million for emission rights, and Japan could reduce its abatement costs by 25.01% by paying US \$374.01 million for emission rights. In contrast, China could receive US \$238.41 million through an additional 40.94 million tons of CO₂ reduction, with cost savings of 57.39%, and ASEAN could obtain US \$81.52 million by reducing 13.98 million tons of CO₂, with cost savings of 27.48%.

5. Sensitive analysis

The sensitivity analysis focused on three variables. First, it varied the reduction ratio of RCEP non-tariff trade barriers. Second, it changed the elasticity of substitution between coal and non-coal in the production function. Third, it varied the Armington elasticities of domestic and imported products. All simulations were performed based on S2 to test the robustness of our main findings.

5.1. Sensitivity to non-tariff trade barriers

The analysis above assumed that the non-tariff trade barriers of the RCEP will be reduced by 5%. This section examines the effects of changes in the non-tariff trade barrier reduction levels. Specifically, we increased and decreased them by 20% at the base level to construct high- and low-reduction scenarios. A high reduction in non-tariff trade barriers will generate more economic growth, energy consumption, and carbon emissions; thus, to offset the increase in carbon emissions, RCEP members need to take more stringent carbon abatement measures, and vice versa. The carbon prices under the two scenarios fluctuated slightly and the ranking of regional carbon prices did not change, indicating the robustness of carbon prices under the CPCF scheme. Table 7 shows that changing non-tariff trade barriers did not affect our main findings. Under the CPCF scheme, RCEP members not only enjoy the economic growth resulting from trade liberalization but also ensure that the total carbon emissions of the region remain unchanged, achieving a win-win situation of economic growth and climate change mitigation.

5.2. Sensitivity to substitution elasticity between coal and non-coal

The substitution elasticity between coal and non-coal is an important input parameter for the GdynE model simulation and has a direct impact on the carbon pricing policy. The second sensitivity analysis focused on the value of the substitution elasticity between coal and non-coal. Based on the original value, we increased and decreased it by 20%, constructing high- and low-elasticity scenarios. As shown in Table 8, compared with the low-elasticity scenario, under the high-elasticity scenario, most RCEP members experience a decrease in their economic growth rate, a reduction in energy demand, and a lower carbon price. In fact, the lower the substitution elasticity between coal and non-coal, the higher the carbon price needed to force the decoupling of the energy system to achieve the carbon abatement goal, which in turn will lead to higher economic losses and greater energy demand declines. However, under the two scenarios, the carbon prices of the RCEP members fluctuated little, both maintained economic growth, and the regional ranking of relevant indicators were identical. This finding indicates that changing the elasticity of substitution between coal and non-coal did not affect our main findings. In other words, the RCEP can offset the increase in carbon emissions resulting from trade liberalization by introducing the CPCF scheme and achieving a win-win situation for economic growth and climate change mitigation.

5.3. Sensitivity to Armington elasticity of substitution of domestic and imported products

The final sensitivity analysis considered changes in Armington substitution elasticity. Armington substitution assumes that goods from import and domestic industries are heterogeneous. A higher Armington elasticity implies that domestic products are more easily substituted for imported products, and vice versa. The Armington elasticity value is closely related to the economic and environmental

Table 6
Regional cost saving effect of carbon emission reduction of S3 compared with S2.

	S2	S3			(S3-S2)/S2
	Total abatement cost (US\$ Mil)	Abatement cost (US\$ Mil)	Emission rights payment (US\$ Mil)	Total abatement cost (US\$ Mil)	Cost saving (%)
AUS	96.52	32.12	47.06	79.18	-17.96
NZL	25.79	3.57	11.74	15.31	-40.63
China	95.62	279.15	-238.41	40.74	-57.39
Japan	498.77	141.44	232.58	374.01	-25.01
SoKorea	164.38	132.43	28.55	160.99	-2.07
ASEAN	84.97	143.14	-81.52	61.62	-27.48
Total	966.05	731.86	0	731.86	-24.24

Note: regional marginal abatement cost was obtained from the GdynE model.

Table 7
Sensitivity to non-tariff trade barriers reduction of RCEP.

	High reduction of non-tariff trade barriers				Low reduction of non-tariff trade barriers			
	GDP (%)	Energy consumption (%)	Carbon emission (%)	Carbon price (\$/tCO ₂)	GDP (%)	Energy consumption (%)	Carbon emission (%)	Carbon price (\$/tCO ₂)
AUS	0.70	-2.36	-1.19	10.78	0.59	-2.15	-1.12	9.36
NZL	0.81	-4.42	-3.31	16.73	0.66	-3.92	-2.94	14.53
China	0.52	0.29	0.66	3.91	0.43	0.24	0.55	3.39
Japan	0.71	-0.72	1.11	11.57	0.59	-0.44	1.14	10.05
SoKorea	1.29	1.96	5.35	6.99	1.06	1.89	4.83	6.07
ASEAN	1.17	-1.19	-0.85	4.98	0.95	-1.11	-0.77	4.33
India	-0.04	-0.53	-0.51	0.00	-0.03	-0.45	-0.44	0.00
US	-0.01	-0.25	-0.25	0.00	-0.01	-0.23	-0.23	0.00
EU27	-0.03	-0.15	-0.20	0.00	-0.03	-0.14	-0.19	0.00
ROW	-0.05	-0.29	-0.39	0.00	-0.04	-0.26	-0.34	0.00

Table 8
Sensitivity to substitution elasticity between coal and non-coal.

	High elasticity between coal and non-coal				Low elasticity between coal and non-coal			
	GDP (%)	Energy consumption (%)	Carbon emission (%)	Carbon price (\$/tCO ₂)	GDP (%)	Energy consumption (%)	Carbon emission (%)	Carbon price (\$/tCO ₂)
AUS	0.65	-2.23	-1.09	9.71	0.64	-2.29	-1.23	10.45
NZL	0.74	-4.02	-2.95	15.07	0.73	-4.31	-3.31	16.21
China	0.47	0.26	0.61	3.52	0.47	0.27	0.60	3.78
Japan	0.66	-0.59	1.24	10.42	0.65	-0.55	1.02	11.21
SoKorea	1.17	2.00	5.20	6.29	1.17	1.86	4.98	6.77
ASEAN	1.06	-1.14	-0.77	4.49	1.06	-1.16	-0.84	4.82
India	-0.04	-0.51	-0.49	0.00	-0.04	-0.47	-0.46	0.00
US	-0.01	-0.25	-0.25	0.00	-0.01	-0.23	-0.23	0.00
EU27	-0.03	-0.16	-0.21	0.00	-0.03	-0.13	-0.18	0.00
ROW	-0.05	-0.28	-0.37	0.00	-0.05	-0.26	-0.36	0.00

effects of the RCEP trade liberalization. The original value was increased and decreased by 20% to construct two scenarios: high and low Armington substitution elasticity. As shown in Table 9, changing the Armington substitution elasticity did not affect our main findings. Although the values of the indicators in different regions differed, the change directions and regional rankings of the relevant indicators remained identical. All RCEP regions would experience some GDP increase while ensuring that total regional carbon emissions remain unchanged, indicating that the CPCF scheme is useful for the RCEP to achieve a win-win situation for economic growth and climate change mitigation.

6. Conclusions and policy implications

In the context of climate change mitigation, the establishment of the RCEP may be a suitable opportunity to implement carbon pricing policies in member countries for two reasons. First, the trade liberalization of the RCEP would offset the additional costs to the economy usually associated with imposing a carbon pricing policy. Second, the impact of the increased CO₂ emissions that arise due to trade liberalization can be reduced through carbon pricing. This study focused on the coordination of carbon pricing under the RCEP framework and explored a reasonable carbon pricing mechanism to achieve a win-win situation for economic growth and climate change mitigation in this region. To achieve this goal, this study introduced a differentiated carbon pricing mechanism based on the principle of cost fairness and used a global multi-regional CGE model to quantify its economic and environmental impacts. This study also compared the cost savings of differentiated and unified carbon pricing and provided a sensitivity analysis.

The empirical analysis yielded the following main findings: 1) RCEP trade liberalization will contribute to the region's economic prosperity, with a GDP growth of 0.639%, but it will also lead to a 1.962% increase in energy consumption and a 1.897% increase in carbon emissions; 2) the CPCF scheme, in which developed countries assume the main abatement burden, can be used to offset the increase in carbon emissions from the trade liberalization of RCEP, while member countries will maintain positive economic growth; 3) compared with CPCF, the unified carbon price will be more useful to reduce the economic cost of carbon offsetting in RCEP regions, and the total abatement cost of the latter is 24.24% lower compared to the former; 4) unified carbon pricing would result in a carbon price of US \$5.83 within the RCEP, with China and ASEAN being emission rights sellers due to their low abatement costs, and Japan, SoKorea, AUS, and NZL being emissions rights purchasers because of their higher abatement costs; 5) RCEP's adoption of the CPCF would lead to an increase in ORCEP carbon emissions, with a carbon leakage of 12%, which would drop to 9.55% under the unified carbon pricing scenario.

Table 9
Armington elasticity of substitution of domestic products and imported products.

	High Armington elasticity of substitution				Low Armington elasticity of substitution			
	GDP (%)	Energy consumption (%)	Carbon emission (%)	Carbon price (\$/tCO ₂)	GDP (%)	Energy consumption (%)	Carbon emission (%)	Carbon price (\$/tCO ₂)
AUS	0.65	-2.02	-1.04	9.49	0.64	-2.51	-1.29	10.69
NZL	0.74	-3.65	-2.85	14.72	0.72	-4.70	-3.41	16.58
China	0.49	0.20	0.54	3.44	0.45	0.32	0.67	3.87
Japan	0.67	-0.35	1.25	10.18	0.63	-0.81	1.01	11.47
SoKorea	1.20	2.15	5.19	6.15	1.15	1.71	4.99	6.92
ASEAN	1.07	-1.14	-0.81	4.38	1.05	-1.16	-0.80	4.94
India	-0.04	-0.47	-0.47	0.00	-0.03	-0.51	-0.48	0.00
US	-0.01	-0.23	-0.23	0.00	-0.01	-0.26	-0.25	0.00
EU27	-0.03	-0.18	-0.22	0.00	-0.03	-0.11	-0.16	0.00
ROW	-0.05	-0.24	-0.34	0.00	-0.05	-0.30	-0.39	0.00

RCEP trade liberalization will bring valuable opportunities for the introduction of a carbon pricing mechanism in the region because the abatement cost can be reduced by the economic dividend of free trade. This study recommends that RCEP regions adopt the CPCF as their potential carbon pricing option for two main reasons. First, the CPCF mechanism considers the economic affordability of different countries, reduces the distortion of international comparative competitive advantages caused by different emission-reduction efforts, and protects the development rights and interests of different countries; thus, it has strong policy acceptability. Second, the CPCF can offset the increase in carbon emissions caused by the RCEP's trade liberalization at a relatively low carbon price, while member countries can still maintain positive economic growth. The empirical results showed that under the CPCF scenario, the GDP growth rates of all RCEP regions were more than 0.4% compared with usual business. Additionally, the carbon price of developed countries did not exceed US \$16/ton CO₂, while that of developing countries was lower than US \$5/ton CO₂. In short, the CPCF will be valuable for RCEP regions to achieve a win-win situation in terms of economic growth and climate change mitigation.

Looking ahead, RCEP countries should strengthen cooperation on carbon emission reduction and try to establish a unified carbon market to reduce total abatement costs. The empirical results show that the total abatement cost of the RCEP's carbon offset can be reduced by approximately 24% under a unified carbon market compared with the CPCF, indicating its significant cost-saving effects. However, the establishment of a unified carbon market involves negotiations among many sovereign countries, and its promotion faces political, economic, and cultural challenges that are not easily overcome in the short term. To this end, it is recommended that the RCEP regions first pilot differentiated carbon pricing mechanisms. In the future, with the continuous improvement of the carbon market system and the supervision and implementation mechanisms of various countries, it will be possible to break market segmentation and build a unified carbon trading platform in the RCEP region.

Despite its significant contributions, this study had several limitations. First, to facilitate analysis, this study aggregated the GTAP10 database into 10 regions and 16 sectors and, although this approach is widely used in academia, the sectoral and regional aggregation may have had a slight impact on simulation results. Second, it provided a relatively static analysis and did not consider the dynamic impacts of relevant policies. This is because COVID-19 and the Russia-Ukraine war have had a significant impact on the global economy and there are great uncertainties in the future economic growth and energy consumption of various countries, which cannot be effectively quantified. Third, this study did not consider the potential political conflict between countries, since RCEP members include many US allies, such as Japan and South Korea; with the continuous intensification of conflict between China and the US, the development of the RCEP may be affected by external political forces. Future studies should address these limitations.

Data availability

Data will be made available on request.

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References

- Ahmed, Y. N., Delin, H., Reeberg, B. G., & Shaker, V. (2020). Is the RCEP a cornerstone or just collaboration? Regional general equilibrium model based on GAMS. *Journal of Korea Trade (JKT)*, 24(1), 171–207.
- Al-Qudah, A. A., Al-Okaily, M., & Alqudah, H. (2022). The relationship between social entrepreneurship and sustainable development from economic growth perspective: 15 'RCEP' countries. *Journal of Sustainable Finance & Investment*, 12(1), 44–61. <https://doi.org/10.1080/20430795.2021.1880219>
- Bajona, C., & Kelly, D. L. (2012). Trade and the environment with pre-existing subsidies: A dynamic general equilibrium analysis. *Journal of Environmental Economics and Management*, 64(2), 253–278. <https://doi.org/10.1016/j.jeem.2012.01.007>

- Balistreri, E. J., & Tarr, D. G. (2020). Comparison of deep integration in the Melitz, Krugman and Armington models: The case of the Philippines in RCEP. *Economic Modelling*, 85, 255–271. <https://doi.org/10.1016/j.econmod.2019.05.023>
- Cai, L., Cheng, J., & Wang, W.-X. (2022). The impact of trade facilitation on China's cross-border E-commerce exports: A focus on the trade facilitation index in RCEP member countries. *Journal of Korea Trade (JKT)*, 26(7), 109–126. <https://doi.org/10.35611/jkt.2022.26.7.109>
- Cui, L., Li, R., Song, M., & Zhu, L. (2019a). Can China achieve its 2030 energy development targets by fulfilling carbon intensity reduction commitments? *Energy Economics*, 83, 61–73. <https://doi.org/10.1016/j.eneco.2019.06.016>
- Cui, L., & Song, M. (2017). Designing and forecasting the differentiated carbon tax scheme based on the principle of ability to pay. *Asia-Pacific Journal of Operational Research*, 34(01), 1740004. <https://doi.org/10.1142/S0217595917400048>
- Cui, L., Song, M., & Zhu, L. (2019b). Economic evaluation of the trilateral FTA among China, Japan, and South Korea with big data analytics. *Computers & Industrial Engineering*, 128, 1040–1051. <https://doi.org/10.1016/j.cie.2018.04.029>
- Cui, L., Yue, S., Nghiem, X.-H., & Duan, M. (2023). Exploring the risk and economic vulnerability of global energy supply chain interruption in the context of Russo-Ukrainian war. *Resources Policy*, 81, Article 103373. <https://doi.org/10.1016/j.resourpol.2023.103373>
- Cui, L., Zhu, L., & Fan, Y. (2013). A feasibility analysis of China's active emission reduction strategies in the context of carbon tariffs. *Journal of Management Science*, 26(01), 101–111.
- Deng, X., Tang, W., Zhu, H., & Xing, Z. (2022). Influencing factors of China's direct investment in RCEP countries: Evidence from panel quantile regression. *Applied Economics*, 1–18. <https://doi.org/10.1080/00036846.2022.2114996>
- Dong, Y., Ishikawa, M., & Hagiwara, T. (2015). Economic and environmental impact analysis of carbon tariffs on Chinese exports. *Energy Economics*, 50, 80–95. <https://doi.org/10.1016/j.eneco.2015.04.008>
- Fan, Y., Liang, Z., & Yao, X. (2022). Regional power system transitions towards carbon neutrality: The case of North China. *Economic and Political Studies*, 10(4), 416–441. <https://doi.org/10.1080/20954816.2022.2067516>
- Goswami, G. G., Khan, F., Labiba, K., Achol, F., Saha, T. K., & Zulfikar, A. (2022). Should Bangladesh join regional comprehensive economic partnership (RCEP)? The gravity explanation of Bangladesh dilemma. *International Journal of Emerging Markets*. <https://doi.org/10.1108/IJOEM-03-2022-0442>
- Guo, J., Huang, Q., & Cui, L. (2021). The impact of the Sino-US trade conflict on global shipping carbon emissions. *Journal of Cleaner Production*, 316, Article 128381. <https://doi.org/10.1016/j.jclepro.2021.128381>
- Guo, Q., & Mai, Z. (2022). Do Chinese photovoltaic products have trade potential in RCEP countries? A BP neural-network-improved trade gravity model analysis. *Sustainability*, 15(1), 463. <https://doi.org/10.3390/su15010463>
- Hertel, T. W., Brockmeier, M., & Swaminathan, P. V. (1997). Sectoral and economy-wide analysis of integrating central and eastern European countries into the EU: Implications of alternative strategies. *European Review of Agricultural Economics*, 24(3–4), 359–386. <https://doi.org/10.1093/erae/24.3-4.359>
- Hertel, T. W., Tyner, W., & Birur, D. (2010). The global impacts of biofuel mandates. *The Energy Journal*, 31(1), 75–100.
- Jia, Z., & Yang, X. (2022). Assessment of the role of renewable energy financing and information and communication technology in carbon neutrality: Evidence from RCEP economies. *Environmental Science and Pollution Research*. <https://doi.org/10.1007/s11356-022-24354-1>
- Lakatos, C., & Walmsley, T. (2012). Investment creation and diversion effects of the ASEAN–China free trade agreement. *Economic Modelling*, 29(3), 766–779. <https://doi.org/10.1016/j.econmod.2012.02.004>
- Latif, Y., Shunqi, G., Fareed, Z., Ali, S., & Bashir, M. A. (2023). Do financial development and energy efficiency ensure green environment? Evidence from R.C.E.P. economies. *Economic Research-Ekonomska Istrazivanja*, 36(1), 51–72. <https://doi.org/10.1080/1331677X.2022.2066555>
- Li, J., He, S., Wang, J., Ma, W., & Ye, H. (2022). Investigating the spatiotemporal changes and driving factors of nighttime light patterns in RCEP countries based on remote sensed satellite images. *Journal of Cleaner Production*, 359, Article 131944. <https://doi.org/10.1016/j.jclepro.2022.131944>
- Ling, D., & Lv, C. (2022). Research on the impact of RCEP on China's manufacturing output and trade: Based on GTAP simulation. *IBusiness*, 14(02), 41–55. <https://doi.org/10.4236/ib.2022.142004>
- Liu, B., & Chen, S. (2014). Research on economic effects of reducing TBT under RCEP framework: An empirical analysis based on GTAP model. *Journal of International Trade*, 6, 91–98 (In Chinese).
- Liu, Y., Chen, X., & Tian, Y. (2022). Modelling the impact of RCEP agreement on the economic and trade environment of Beijing. *Discrete Dynamics in Nature and Society*, 2022, 1–7. <https://doi.org/10.1155/2022/9237940>
- Oberheitmann, A. (2010). A new post-Kyoto climate regime based on per-capita cumulative CO₂-emission rights—Rationale, architecture and quantitative assessment of the implication for the CO₂-emissions from China, India and the annex-I countries by 2050. *Mitigation and Adaptation Strategies for Global Change*, 15(2), 137–168. <https://doi.org/10.1007/s11027-009-9207-4>
- Petroleum, B. (2022). Statistical Review of World Energy | Energy economics | Home. Bp Global. <https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html>
- Qian, Z., Zhao, Y., Shi, Q., Zheng, L., Wang, S., & Zhu, J. (2022). Global value chains participation and CO₂ emissions in RCEP countries. *Journal of Cleaner Production*, 332, Article 130070. <https://doi.org/10.1016/j.jclepro.2021.130070>
- Ringius, L., Torvanger, A., & Underdal, A. (2002). Burden sharing and fairness principles in international climate policy. *International Environmental Agreements*, 2(1), 1–22. <https://doi.org/10.1023/A:1015041613785>
- Song, M., & Cui, L.-B. (2016). Economic evaluation of Chinese electricity price marketization based on dynamic computational general equilibrium model. *Computers & Industrial Engineering*, 101, 614–628. <https://doi.org/10.1016/j.cie.2016.05.035>
- Tian, K., Zhang, Y., Li, Y., Ming, X., Jiang, S., Duan, H., Yang, C., & Wang, S. (2022). Regional trade agreement burdens global carbon emissions mitigation. *Nature Communications*, 13(1), 408. <https://doi.org/10.1038/s41467-022-28004-5>
- Wen, H., You, Y., & Zhang, Y. (2022). Effects of tariff reduction by regional comprehensive economic partnership (RCEP) on global value chains based on simulation. *Applied Economics Letters*, 29(20), 1906–1920. <https://doi.org/10.1080/13504851.2021.1966361>
- Wu, P., Xiao-chuan Weng, C., & Joseph, S. A. (2021). Crossing the Rubicon? The implications of RCEP on anti-monopoly enforcement on dominant E-commerce platforms in China. *Computer Law and Security Review*, 42, Article 105608. <https://doi.org/10.1016/j.clsr.2021.105608>
- Xu, L., & Jiang, S. (2021). Hedging effect of trade agreements: A comparative analysis based on RCEP and CPTPP. *Asia-Pacific Economic Review*, 6, 52–59 (In Chinese).
- Zhang, C., & Chen, P. (2022). Applying the three-stage SBM-DEA model to evaluate energy efficiency and impact factors in RCEP countries. *Energy*, 241, Article 122917. <https://doi.org/10.1016/j.energy.2021.122917>
- Zhang, W., Cao, S., Zhang, X., & Qu, X. (2023). COVID-19 and stock market performance: Evidence from the RCEP countries. *International Review of Economics and Finance*, 83, 717–735. <https://doi.org/10.1016/j.iref.2022.10.013>
- Zhu, L., Cui, L., & Schleich, J. (2020). Designing a globally acceptable carbon tax scheme to address competitiveness and leakage concerns. *Climate Change Economics*, 11(02), 2050008. <https://doi.org/10.1142/S2010007820500086>