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Kailan Tian

Academy of Mathematics and Systems Science

Yu Zhang

Academy of Mathematics and Systems Science

Yuze Li

Boston University

Xi Ming

University of Chinese Academy of Sciences

Shangrong Jiang

University of Chinese Academy of Sciences <https://orcid.org/0000-0002-2780-9075>

Hongbo Duan (✉ hbduan@ucas.ac.cn)

University of Chinese Academy of Sciences <https://orcid.org/0000-0001-5143-4413>

Cuihong Yang

Institute of Systems Science, China

Shouyang Wang

Academy of Mathematics and Systems Science

Article

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Posted Date: August 26th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-800470/v1>

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Version of Record: A version of this preprint was published at Nature Communications on January 20th, 2022. See the published version at <https://doi.org/10.1038/s41467-022-28004-5>.

Regional trade agreement burdens global carbon emission mitigation

Kailan Tian¹, Yu Zhang¹, Yuze Li², Xi Ming³, Shangrong Jiang³, Hongbo Duan^{3*}, Cuihong Yang^{1,3*}, Shouyang Wang^{1,3*}

1. Academy of Mathematics and Systems Science, Chinese Academy of Sciences, Beijing 100190, China

2. Questrom School of Business, Boston University, Boston 02215, USA

3. School of Economics and Management, University of Chinese Academy of Sciences, Beijing 100086, China

Abstract

Regional trade agreements (RTAs) have been widely adopted to facilitate international trade and cross-border investment and ultimately promote economic development.

However, ex ante measurements of the environmental effects of RTAs to date have not been well conducted. Here, we estimate the CO₂ emission burdens of the Regional Comprehensive Economic Partnership (RCEP) after evaluating its economic effects.

We find that trade among RCEP member countries will increase significantly and economic output will expand with the reduction of regional tariffs. However, the results

show that complete tariff elimination among RCEP members would increase the yearly global CO₂ emissions from fuel combustion by about 3.12%, which doubles the annual

average growth rate of global CO₂ emissions in the last decade. The emissions in some developing members will surge. We therefore stress the necessity of balancing carbon

mitigation and the pursuit of economic profitability. The technological advancement of emission mitigation and more effective climate policies for international trade are

urgently required to avoid undermining international efforts to reduce global emissions.

Keywords

RCEP; Trade and welfare; Carbon mitigation; Input-output analysis; Sectoral linkage

Introduction

Regional trade agreements (RTAs) have been sweeping the world and have become ubiquitous in efforts to facilitate international trade and investment¹⁻³. After an 8-year-long negotiation, the Regional Comprehensive Economic Partnership (RCEP) finally concluded in November 2020 and became the largest RTA in the world in terms of both economic size and population. According to the Schedule of Tariff Commitments in the RCEP Agreement, over 90% of the trade in goods will eventually have zero tariffs, and most of them will be duty-free immediately or within ten years after the agreement enters into force. Tariff elimination in the region will reduce trade and production costs, resulting in considerable trade-creation and production-boosting effects.

However, increased international production fragmentation has raised concerns about the trade-climate dilemma (or pollution haven effect) of international trade⁴⁻¹⁰. That is, international trade increases global or regional emissions if developed economies with cleaner production technology and more stringent environmental policies transfer their polluting industries or production activities to developing countries, leading to emission leakage. Most of the RCEP member countries are typical developing economies that are less emission efficient in their manufacturing industries. In 2018, the amount of CO₂ emitted by RCEP member countries accounted for a high share (39.13%¹¹) of global CO₂ emissions from fuel combustion. Therefore, the rapid growth of production activities and trade in an increasing number of less developed nations could impose non-negligible burdens on global and national emission

mitigation. Previous work deals with the economic effects of RTAs, and the other deals with the environmental side effects of international trade. The first strand of the literature focuses on quantifying the economic welfare effects of RTAs¹²⁻¹⁷ and has largely neglected environmental problems. Conversely, the second strand has substantially accounted ex post for the large carbon flows between countries via international trade¹⁸⁻²⁷.

In fact, few studies have ex ante quantified the environmental effects of a trade agreement. In this study, we aim to estimate such burdens after evaluating the economic effects of RCEP tariff reductions. The quantification of both RCEP economic gains and environmental burdens has important policy implications for balancing economic development and the responsibility of carbon emission mitigation when implementing RTAs. We estimate how and to what extent RCEP tariff reductions affect trade and economic welfare using a multi-sector and multi-country general equilibrium model¹². It captures sectoral heterogeneity, inter-sectoral linkages, and trade in intermediate products. Due to such features and its tractability, this quantitative trade model has become the workhorse for evaluating the possible consequences of tariff changes in an era of global production networks or global value chains^{29, 30}.

We find that the RCEP tariff reduction will unleash trade-creation effects, which are determined by the magnitude of tariff reduction, export bundles, trade elasticity, and inter-sectoral linkages in each country. In addition, all member countries' economic welfares will improve. To reveal through what channel welfares are improved, we further decompose the total welfare effects into volume of trade effect and terms of

trade effect, which are further decomposed separately into the results of trade with RCEP members versus trade with the rest of the world. However, our results also show that complete tariff elimination within the RCEP bloc would increase the yearly global CO₂ emissions by 3.12% if the emission intensities (CO₂ emissions per unit of output) keep unchanged. Given the fact that the annual average growth rate of global CO₂ emissions from fuel combustion in the last decade was about 1.53%¹¹, 3.12% represents a substantial burden on global CO₂ emission mitigation. The increased carbon emissions are driven by the rise of production for both domestic expenditures and trade. Trade changes would also increase considerable CO₂ emissions in the RCEP members. The environmental burdens on some developing countries such as Vietnam and Thailand will surge. As a result, we emphasize that technological advancements in reducing pollutant intensity are urgently required in more developing countries to offset the extra emissions caused by the RCEP. We also suggest that more effective climate policies for international trade should be designed and implemented.

Results

Economic effects from RCEP tariff elimination

In this subsection, we evaluate how and to what extent trade and welfare are affected by tariff reductions committed in the RCEP Agreement. Our estimation draws on three types of datasets: input-output (I.O.) tables, bilateral trade flows, and bilateral tariff data. Supplementary note 1 provides detailed descriptions of all the data used in our evaluation. We set the effective applied ad valorem tariff rates in 2019 as the base world

tariff structure before the RCEP enters into force. The effects of the RCEP tariff changes are evaluated by changing the tariff structure among RCEP member countries and leaving the tariff structure unchanged for countries outside the agreement.

Fig. 1 presents the aggregate changes in multilateral trade for RCEP member countries when tariffs within the bloc decline to zero after the agreement enter into force. Unsurprisingly, tariff elimination will gradually unleash the agreement's trade-creation effect and substantially strengthen the trade linkages between these countries before the RCEP. We also observe that the trade effects vary across members. First, the RCEP will significantly increase trade between China, Japan, and South Korea. Specifically, China's exports to Japan and South Korea will increase by 17.61% and 33.85%, and Japan's exports to China and South Korea will increase by 29.14% and 58.62%, respectively. Second, the RCEP will boost more trade for some ASEAN economies. For example, Indonesia's exports to China, South Korea, Thailand, and Vietnam will increase quite markedly by 109.75%, 118.79%, 91.41%, and 103.03%, respectively. Similar effects will occur for certain other ASEAN economies, such as Malaysia, the Philippines, Thailand, and Vietnam. It is apparent that tariff elimination in the RCEP bloc will improve not only South-North but also South-South trade. The equilibrium model indicates that the trade effects are determined by the magnitude of tariff reduction, export bundles, trade elasticity, and the intermediate input structure for the production of each sector in each country. The divergent effects shown in Fig. 1 are the complete results of these differently weighted factors. Another observation is that some bilateral trade (e.g., the exports of Singapore to Australia and Japan) will decline

after the RCEP enters into force. This negative effect arises from trade diversion. For example, Singapore was already an almost entirely free-trade country before the RCEP. The RCEP tariff reduction substantially reduces the costs of trade with other members and raises their relative competitiveness. This process facilitates trade diversion from Singapore.

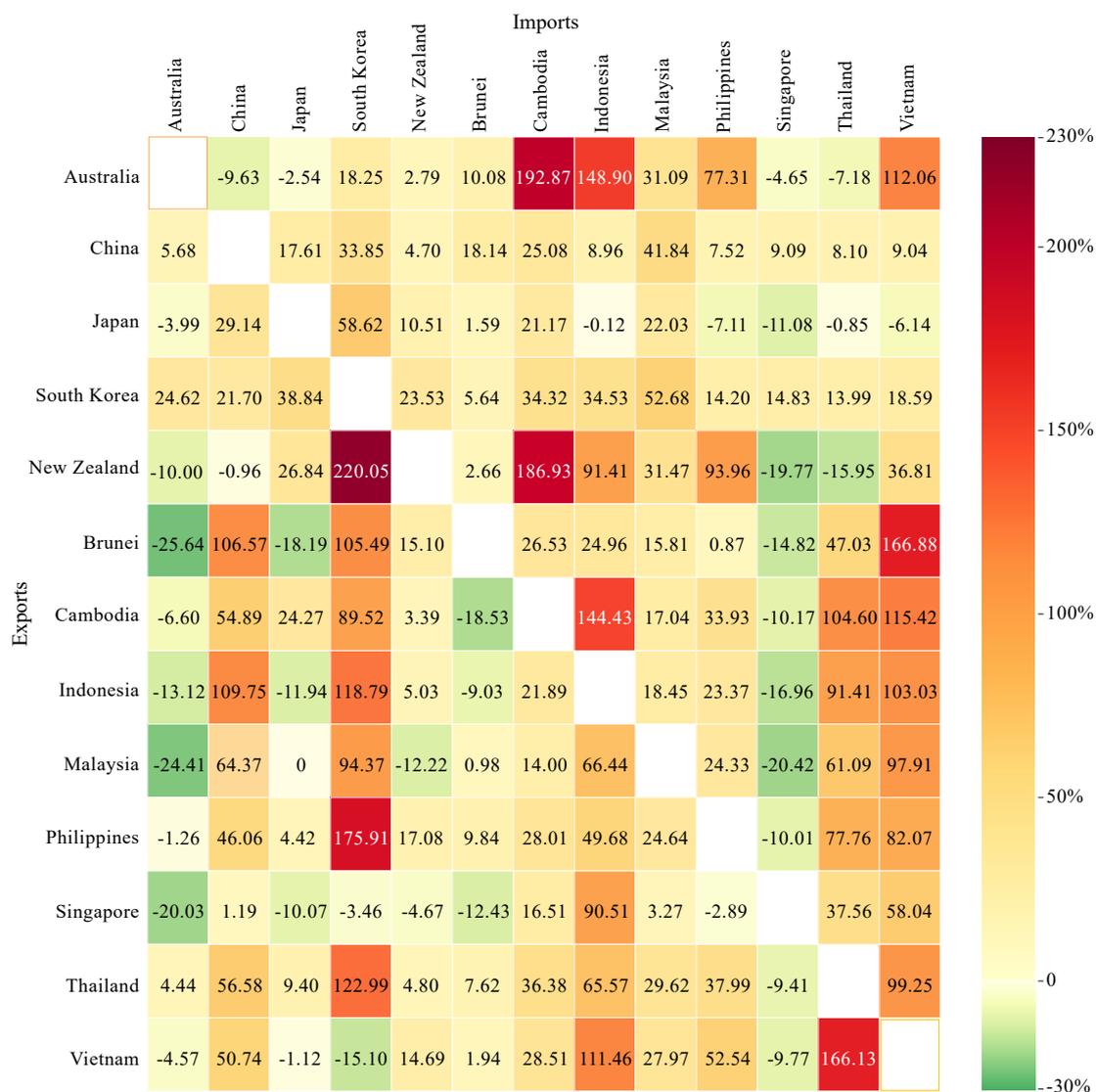


Fig. 1 Trade effects of the RCEP tariff elimination on member countries (%). The figure presents the change rates in multilateral trade for the situation in which trade in goods among the RCEP members have zero tariffs. Two ASEAN countries (Laos and Myanmar) are classified into the rest of the world because input-output tables for Laos and Myanmar are not available. We thus cannot provide results for these two countries. The results for the cases in which the tariffs decline to the committed level in year 1, 5, 10, and 20 after the RCEP enters into force are provided in Supplementary Table 1. The results for any other years are also available upon request.

Table 1 presents the results of welfare effects for RCEP members. It shows that all members benefit from the RCEP tariff reductions, with most small countries gaining more than large ones. The first column presents that all RCEP members' real wages will increase, with Cambodia increasing the most. The second column shows that the welfare (the summation of labour income, tariff revenues, and trade deficits) of Vietnam, Cambodia, and Singapore will increase the most, by 15.63%, 8.54%, and 3.79%, respectively. The effects for large economies such as China and Japan are smaller.

Table 1 Welfare effects of the RCEP tariff elimination on member countries

Members	Real wage	Welfare				
		Total	Volume of trade		Terms of trade	
			RCEP	RoW	RCEP	RoW
Australia	100.25%	0.20%	0.00%	0.00%	0.12%	0.07%
China	100.36%	0.34%	0.16%	0.01%	0.08%	0.09%
Japan	100.28%	0.28%	0.05%	0.00%	0.09%	0.13%
South Korea	102.38%	3.28%	4.51%	-0.53%	-0.43%	-0.28%
New Zealand	100.38%	0.47%	0.01%	0.01%	0.27%	0.18%
ASEAN						
Brunei	100.47%	0.59%	0.00%	0.00%	0.48%	0.11%
Cambodia	111.86%	8.54%	5.19%	-0.53%	1.75%	2.13%
Indonesia	100.88%	0.81%	0.36%	0.03%	0.23%	0.19%
Malaysia	104.68%	1.31%	1.18%	-0.13%	0.11%	0.14%
Philippines	102.01%	0.52%	0.53%	-0.03%	-0.04%	0.06%
Singapore	103.52%	3.79%	0.00%	0.00%	1.71%	2.08%
Thailand	103.15%	1.82%	2.50%	-0.19%	-0.42%	-0.07%
Vietnam	105.60%	15.63%	10.17%	-0.38%	3.14%	2.70%

Note: The table presents the changes in real wage and welfare for RCEP members if trade in goods among the members becomes duty-free. The total welfare effects are decomposed into volume of trade effect and terms of trade effect, which are further decomposed separately into the results of trade with RCEP members (columns 3 and 5) versus trade with the rest of the world (RoW, column 4 and 6).

To reveal how each member's welfare is improved, we decompose the total welfare effects into volume of trade effect (columns 3 and 4) and terms of trade effect (columns 5 and 6), which are further decomposed separately into the results of trade

with RCEP members versus trade with other economies outside the RCEP Agreement (the rest of the world, RoW). Columns 3 and 4 show that trade with RCEP members rather than the RoW is the most important contributor to the increase in all members' volume of trade. Comparing with the results in columns 5 and 6, we can find that creating more trade within the RCEP bloc also makes the most significant contribution to the increase in welfare for member countries—South Korea, Cambodia, Malaysia, the Philippines, Thailand, and Vietnam. Additionally, trade reductions with the RoW generate slightly negative welfare effects for most members. The reason for such negative effects stems from the RCEP diverting trade from non-RCEP member countries.

Columns 5 and 6 show that the aggregate terms of trade for almost all members improve, whereas South Korea's and Thailand's terms of trade deteriorate slightly. This differential performance can be attributed to the divergent changes in the export prices of each country, as terms of trade compare the price of a country's export with the price of its import. The model shows that export prices are determined by the unit costs of input bundles, namely, the combination of labour costs (i.e., wages) and the prices of intermediate inputs. Column 1 shows that the RCEP will increase the real wages of all members, which increases export prices. However, other things being equal, the prices of intermediate inputs will decline with the reductions in tariffs on imported intermediates. Such effects can further be propagated through input-output linkages. As a result, the change in the prices of intermediate inputs decreases export prices. Ultimately, for most RCEP members, the increase in real wages is larger than the

decrease in the prices of intermediate inputs, which results in a positive effect on terms of trade. For other economies, the contrary is the case.

Supplementary Table 2 provides the welfare effects of RCEP tariff reductions on economies outside this agreement. The effects are twofold. On the one hand, as explained above, the agreement generates trade diversion towards RCEP members. On the other hand, in an era of increased international fragmentation, the production activities of trade products in countries outside the RCEP require intermediate inputs from RCEP members. The decreased prices of such intermediate products due to RCEP tariff reductions also change the production costs, export prices, and terms of trade in economies outside the RCEP. As a result, the effects are negative for some non-RCEP economies but positive for others. However, the impact is very small.

For each RCEP member, we calculate the sectoral contribution to its aggregated change in volume of trade and terms of trade. First, as shown in Fig. 2, the contribution varies considerably across countries and sectors. For example, mining is the sector with the most significant contribution to the change in Australia's terms of trade, whereas electrical equipment is the greatest contributor for China and Japan. Second, agriculture (and food products for some countries) makes a significant contribution to changes in the volume of trade in many countries, including China, Japan, South Korea, New Zealand, the Philippines, and Thailand. The reason is that agriculture is strongly protected in most countries, as the current tariffs are relatively high. For example, the average tariffs applied by Japan to its imported food products and agriculture in 2019 were 10.74% and 5.84%, respectively, which were the largest and second-largest import

tariffs among all Japanese goods sectors. Agriculture (and food products) is a homogeneous goods sector with high import tariff trade elasticity. A slight reduction in the tariffs for this sector can improve the trade volume considerably because it is relatively easy to change suppliers. Petroleum in some countries is similarly affected for similar reasons.

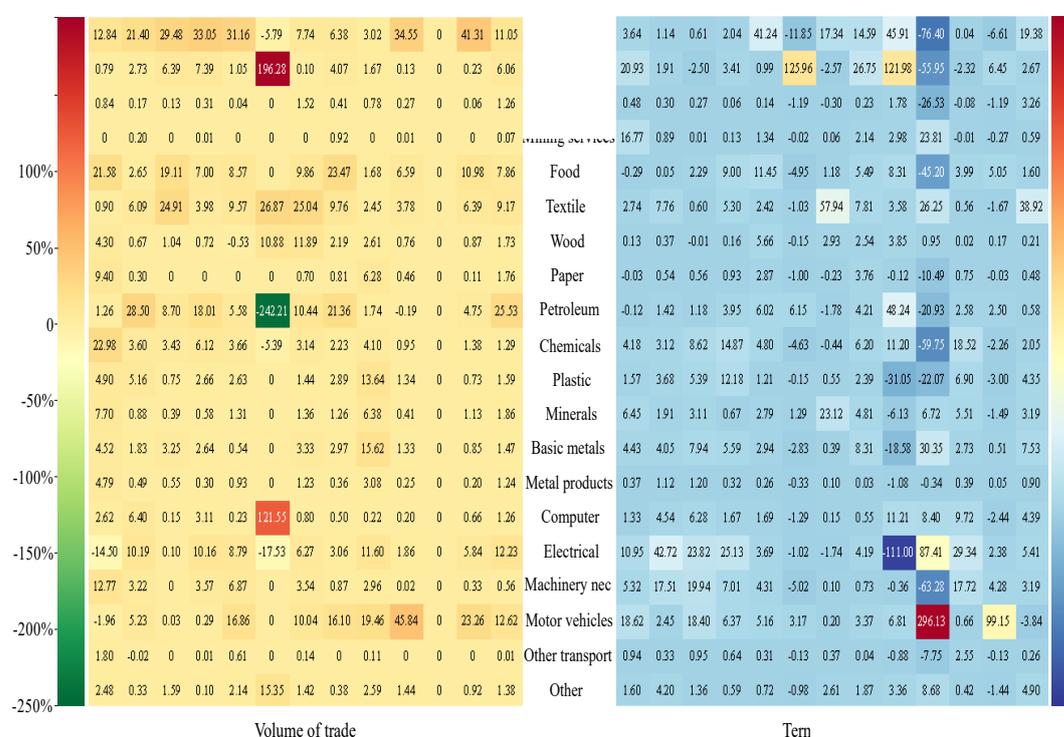


Fig. 2 Sectoral contribution to the welfare changes in RCEP members (%). The left graph presents the sectoral contribution to the aggregate changes in the volume of trade in the case that all trade in goods among RCEP members are duty-free, while the right graph presents the results for terms of trade. For a country, the column-wise summation of all sectors' contributions equals 100%. The description of the tradable sectors is provided in Table A1 of Supplementary note 1.

Another notable observation is that a handful of sectors – electrical equipment, machinery and equipment, and motor vehicles – explain a high proportion of the changes in terms of trade in many countries (China, Japan, South Korea, and some ASEAN economies). This is the combined result of tariff reduction, the share of

intermediate inputs required in the production process, and inter-sectoral linkages. Although the tariff reductions in these technology-intensive sectors are not the largest, they are considerable for some countries. More importantly, these sectors use a considerably larger share of intermediate inputs in production than other sectors. They also have stronger input-output linkages with other sectors. Therefore, a decrease in the unit production costs in these sectors has a larger multiplicative effect and thus a larger impact on terms of trade.

Carbon emission burdens of RCEP tariff reductions

The synergy of tariff elimination within the RCEP bloc substantially reduces the costs of intra-regional trade and production and thus increases the outputs of the member countries. As a result, carbon emissions will also increase significantly if the emission intensities (emissions per unit of output) do not decrease enough to offset the extra emissions caused by the increase in production outputs. Assuming the emission intensities of all countries stay at the same level as that in the year 2015, the global CO₂ emissions from fuel combustion would increase by 251.35 million tonnes (Mt; 0.75% compared to the amount in 2018) when the tariff structure changes to that specified for the first year after the RCEP enters into force. When the tariffs continue to decline to the level in the fifth and tenth years and then to zero, global CO₂ emissions will increase by 463.72 Mt (1.38%), 756.38 Mt (2.26%), and 1046.45 Mt (3.12%), respectively. Recalling that global CO₂ emissions grew at an annual average rate of 1.53%¹¹ in the last decade, these results indicate substantial burdens on carbon emission mitigation.

The increased CO₂ will be emitted mainly by RCEP member countries. In the situation of all trade in goods in the RCEP region becoming duty-free, the production of RCEP members would increase emissions by 789.05 Mt CO₂ (subplot D in Fig. 3), accounting for 75.40% of the increased global emissions. Amongst, Mainland China will be the largest contributor in terms of absolute value (495.73 Mt CO₂, 47.37% of the increased global emissions), followed by the ASEAN economies (164.72 Mt CO₂, 15.74%) and Japan (52.66 Mt CO₂). In terms of magnitude, Vietnam will increase the most (16.51%), followed by Malaysia (16.09%) and Thailand (13.58%). The results indicate that the emission intensities in these countries must decrease by the same magnitude to ensure that the CO₂ emissions do not increase. The magnitude of the decrease should be larger if countries aim to reduce their emissions. Such an ambitious target could be a non-negligible burden, especially for some developing ASEAN economies.

In subplot E of Fig. 3, we also present the ratio of welfare change to the CO₂ emission change rate for RCEP members. The ratio gives the welfare gains at the cost of a 1% increase in carbon emissions. In terms of this ratio, Vietnam, Singapore, and Cambodia are the greatest gainers, whereas China and Japan rank at the lower end.

The increased carbon emissions are driven by the rise of production for both domestic expenditures and trade. As mentioned above, the RCEP tariff reductions bring mainly trade-creation effects within the RCEP bloc and cause trade diversion between RCEP members and non-RCEP economies. An RCEP member may emit more CO₂ in its increased trade with other RCEP members and reduce carbon emissions because of

its decreased trade with non-RCEP economies. We employ the environmentally extended inter-country input-output (ICIO) model to account for the comprehensive carbon emission changes due to trade changes. The results show that trade changes in the case of all trade in goods within the RCEP bloc becoming duty-free would increase CO₂ emissions for China, the ASEAN countries, South Korea, Japan, Australia, and New Zealand by 130.17 Mt, 70.36 Mt, 27.24 Mt, 22.52 Mt, 4.82 Mt, and 0.52 Mt, respectively.

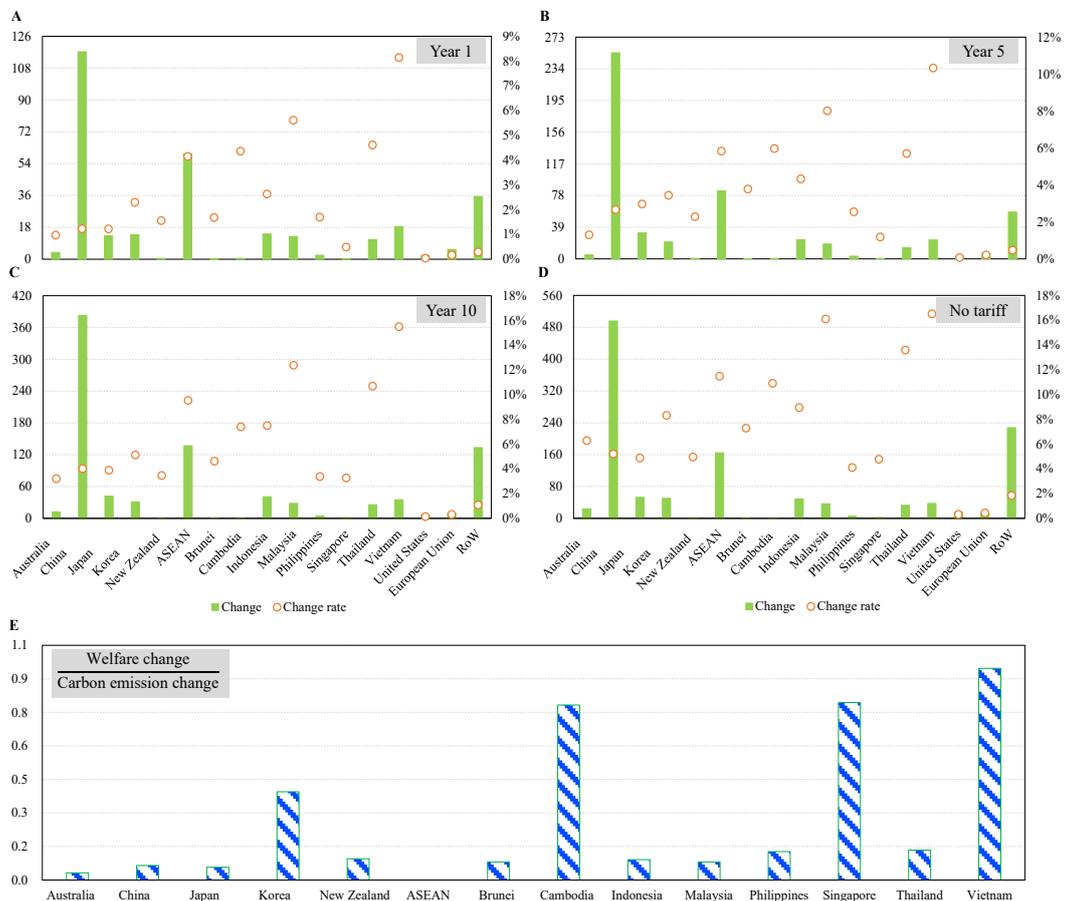


Fig. 3 CO₂ emission burdens of RCEP's tariff reductions. The subplots A, B, and C present the changes and change rates in the amount of CO₂ emissions emitted by different economies for the cases in which the tariffs within RCEP bloc decline to the level in year 1, 5, and 10 after the RCEP enters into force, respectively. Subplot D presents the corresponding results for the case in which trade in goods among RCEP members is ultimately duty-free. Subplot E gives the ratio of economic welfare change to the CO₂ emission change rate for RCEP members. Here, Laos and Myanmar are still classified into the rest of the world (RoW) due to the same reason as given in the note of Fig. 1.

We also find that trade changes slightly increase the amount of CO₂ (61.19 Mt) emitted by RoW (non-RCEP economies). The emission effects of RCEP on non-RCEP economies are twofold. On the one hand, RCEP tariff reductions reduce the direct exports of some non-RCEP economies to RCEP members for reasons we discussed in the previous section. This will reduce the emissions of some non-RCEP economies. On the other hand, the increased production for trade within the RCEP bloc requires more intermediate inputs from some economies outside the RCEP. The economic activities associated with the increased production of such intermediate products generate more CO₂ emissions in non-RCEP economies. Due to the increased international production fragmentation, the emissions generated by these indirect linkages can be substantial. The fact that the RCEP increases overall emissions by economies outside indicates that the indirect effects are larger than the direct effects.

Fig. 4 visualizes increased CO₂ emissions due to changes in bilateral trade flows, which tells us who emits increased CO₂ for whom. It shows the amount of CO₂ emitted by a region of origin for the production of its increased exports to the destination. The largest flow is 44.28 Mt CO₂ for China's increased exports to the ASEAN countries. Other large flows include emissions for the increased exports of the ASEAN countries to China (40.24 Mt CO₂), China to Japan (36.07 Mt CO₂), and China to South Korea (27.83 Mt CO₂). Fig. 4 also shows that the increase in exports of Japan (20.40 Mt CO₂) and South Korea (29.33 Mt CO₂) generates a relatively small increase in the CO₂ emissions of these countries. However, their imports generate considerable CO₂ emission increases (57.83 and 60.29 Mt CO₂) in the source countries. The results

indicate that developing RCEP members including China and some ASEAN economies will emit increasing CO₂ for the developed members.

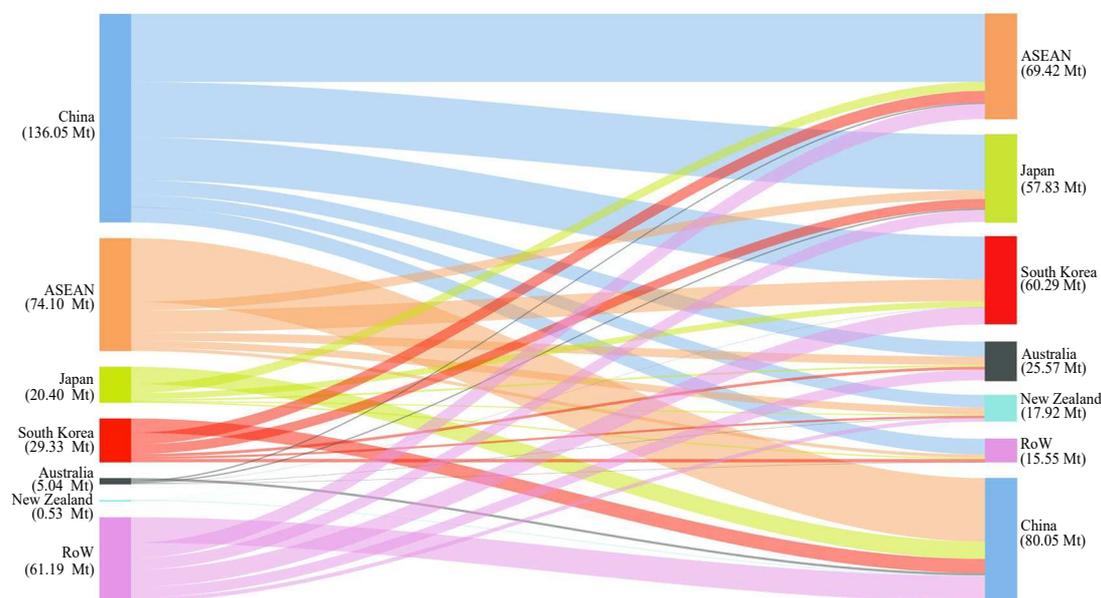


Fig. 4 Increased bilateral CO₂ emission flows in trade. The graph distinguishes seven regions as the origin (the left) and destination (the right). These are: China, the ASEAN (not including Laos and Myanmar), Japan, South Korea, Australia, New Zealand, and the rest of the world (RoW). The graph presents the increased amount of CO₂ emitted in the region of origin for its production of exports to a destination.

Fig. 5 shows the sectoral contribution to aggregate CO₂ emission changes generated by trade changes for RCEP members. The exports of electrical equipment contribute the most to China (14.53%), the ASEAN countries (12.73%), Japan (18.72%), and South Korea (23.65%). The other two large contributors are machinery and equipment (second largest for China and the ASEAN countries, third-largest for Japan and South Korea) and computer, electronic, and optical products (second for South Korea, third for China, and fifth for Japan). The motor vehicle industry makes the second-largest contribution (17.75%) to Japan, but its contribution to other countries is relatively small, indicating Japan's strong comparative advantage in this industry. For Australia and New Zealand, the increased trade generates a very small increase in

emissions. The major contributors are mining for Australia and agriculture for New Zealand.

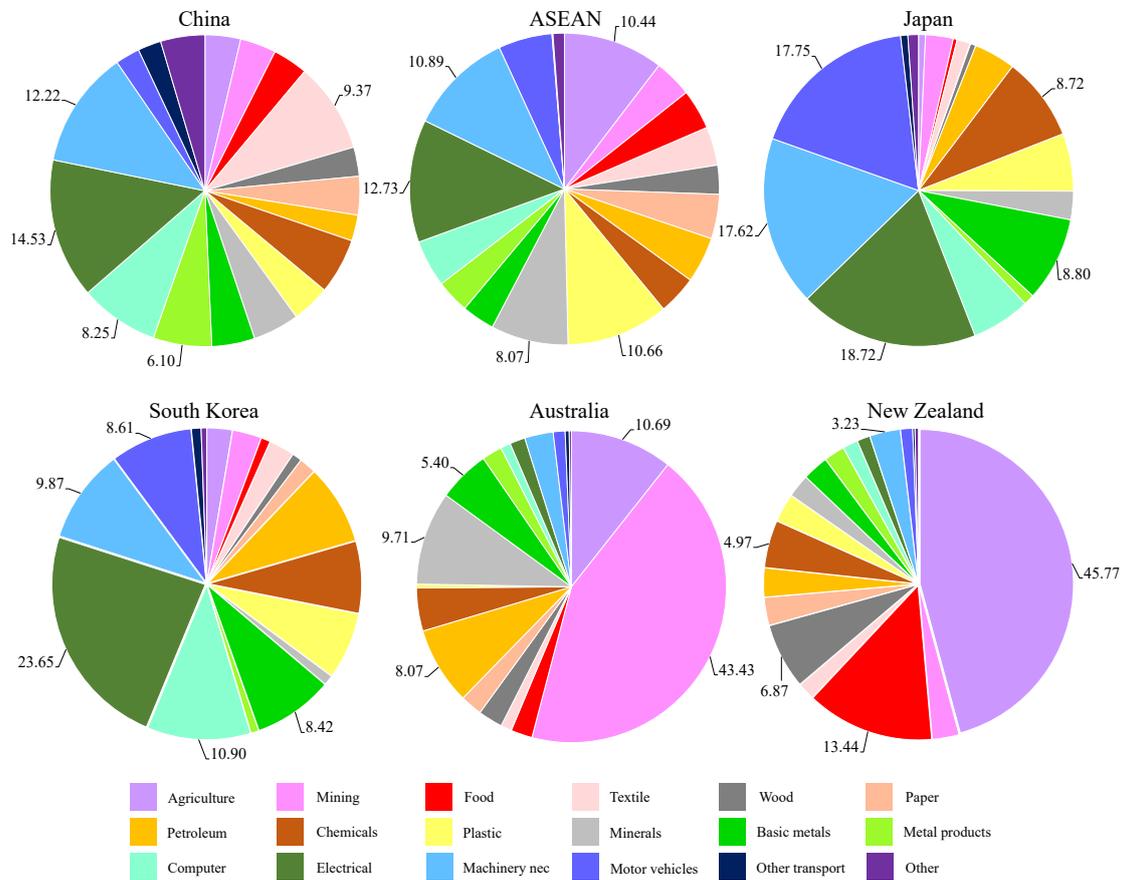


Fig. 5 Sectoral contribution to CO₂ emissions in trade. The pie charts present for RCEP members the sectoral contribution to their CO₂ emission changes caused by trade changes. The sector classification is the same as in Fig.2, but here we aggregate the three mining-related sectors (mining energy, other mining, and mining service) into one mining sector.

The finding that RTAs increase participants' economic welfare at the cost of environmental burdens can be explained by the fact that in real economic interactions, what, how much, and with whom to trade are still determined based on economic profitability rather than environmental considerations. In a Ricardian world, a country exports more products in which it has a comparative advantage in terms of production. The advantage is defined as using fewer of the resources under consideration. Traditionally, labour was such a resource, and additional trade generated from lower

trade costs leads to increased welfare and emissions in each of the trading countries. Alternatively, if we consider environmental aspects, the story changes. For instance, if we define the advantage as generating fewer emissions in producing a certain product³⁴, increased trade in this product will reduce emissions in both countries.

Discussion

The world trade system has been seriously undermined due to huge shocks, such as the COVID-19 global pandemic, the United States-China trade conflict, and Brexit, which to some extent have stimulated the formation of more RTAs. In this paper, we estimate the economic gains and the corresponding carbon emission burdens of the RCEP. The results show that RCEP tariff elimination will substantially reduce intra-regional trade costs and product prices, increase the comparative advantage of regional products, and ultimately improve the welfare of all member countries. Meanwhile, we point out that policymakers should pay attention to the environmental impacts of the RCEP since our results indicate non-negligible increases in potential CO₂ emissions caused by the RCEP. However, we emphasize that anti-globalization is far from a possible strategy for global emission mitigation. Despite de-globalization could reduce international trade and the corresponding embodied carbon emissions in the short term^{35, 36}, it harms the economic welfare of all countries and threatens international efforts to fight climate change in the longer run. Returning to autarky cuts off developing countries' opportunities to participate in global production networks and then upgrade their emission technologies through learning-by-doing. In addition, anti-globalization will

hinder international cooperation that aims to mitigate global emissions³⁷.

Instead, we emphasize that technological advancements in reducing pollutant intensity are urgently required in more developing countries. We find that the carbon emission intensities (CO₂ emissions per unit of output) in all member countries should decline to offset the extra emissions caused by the RCEP, particularly for the developing member countries. Our calculations based on data for 2015 show that the emission intensities of China (2.83 times) and most ASEAN economies, such as Vietnam (2.25 times), Malaysia (2.11 times), and Thailand (2.04 times), were more than twice that of Japan. On the one hand, developing nations should make efforts (e.g., by strengthening technological research and development) to reduce their emission intensity gap with developed nations. For example, at the Paris Climate Change Conference in 2015, China committed to achieving a peak in its carbon emissions by 2030 and reducing its emission intensity substantially. In 2021, China pledged to achieve carbon neutrality before 2060, which is largely consistent with the 1.5 °C warming limit³⁸. The country is making greater efforts and taking more effective measures to achieve this challenging goal, including improving technologies, transforming its energy structure, and developing a circular economy. On the other hand, it is also crucial for developed RCEP members to facilitate the transfer of cleaner production technologies to the developing members when implementing the trade agreement. This process will help accelerate improvements in emission performance in developing countries.

Our findings also suggest that more effective climate policies for international trade should be designed and implemented as we find that some members will emit

increasing CO₂ for other countries. The premise is a robust and fair accounting system to assign responsibility for internationally traded emissions. The production-based accounting (PBA) system is the currently widely adopted scheme in practice, but it ignores carbon leakages through international trade. Consumption-based accounting (CBA) considers the emissions embodied in trade but fails to stimulate the producing countries to clean up their export industries.³⁹ Researchers^{34, 39-42} have proposed adjusted accounting systems to share producer and consumer responsibility⁴³⁻⁴⁵ by crediting trade that reduces global emissions and penalizing trade that increases global emissions. Despite these efforts in academia, national and global climate policies have so far not adopted such systems of credits and penalties. Among a long list of researchers, we call for the idea of countries working together to design robust and environmentally fair accounting tools, develop and implement effective global and regional climate policies, and share the responsibility of global emission mitigation⁴⁶⁻
49.

This study has potential extensions that are worthy of pursuit. We currently do not consider the influence mechanism by which the barriers in services trade and investment in the RCEP region will also decrease under the agreement. Both international trade and cross-border investment can influence a country's economic welfare and environmental issues. Although global flows of foreign direct investment (FDI) shrank in recent years^{50, 51} and fell sharply by one third⁵² in 2020 as a result of the COVID-19 pandemic, FDI among RCEP members will likely continuously increase after the RCEP enters into force. Increasing FDI may facilitate relocating some climate-

unfriendly industries or production activities from industrialized RCEP members to developing countries^{23, 24}. As a result, FDI may magnify the environmental burdens on developing RCEP members. Future studies are expected to provide quantitative analyses of the effects of qualitative cross-border investment rules in the RCEP Agreement on the volume and direction of FDI flows. More in-depth analyses are also expected to allocate the carbon footprints of FDI flows and explore the scheme of sharing environmental responsibility between FDI home and host countries.

Methods

Quantifying the economic effects

This section outlines the model that we employ to quantify the effects of RCEP tariff reductions on trade and welfare. Here, we provide a brief introduction and the main equations. A more detailed description of the model can be found in Caliendo and Parro (2015)¹². The world consists of n countries and there are m sectors in each country. Countries are denoted by s and r and sectors by i and j . The households in country r derive utility from consuming final products C_r^j . The function is Cobb-Douglas and given by

$$u(C_r) = \prod_{j=1}^m C_r^j \alpha_r^j, \text{ where } \sum_{j=1}^m \alpha_r^j = 1. \quad (1)$$

There is a continuum of intermediate products ω^j produced in sector j . Primary inputs (labour) and a bundle of intermediate inputs from all sectors are used for the production of ω^j in country r . The production technology is

$$q_r^j(\omega^j) = z_r^j(\omega^j) [lab_r^j(\omega^j)]^{\gamma_r^j} \prod_{i=1}^m [int_r^{i,j}(\omega^j)]^{\gamma_r^{i,j}},$$

where $z_r^j(\omega^j)$ denotes the efficiency in producing ω^j in country r . $lab_r^j(\omega^j)$ is labour and

$int_r^{i,j}(\omega^j)$ are the intermediate inputs from sector i required in the production of ω^j . γ_r^j denotes the share of value-added in production output, and $\gamma_r^{i,j}$ denotes the share of products from sector i used as intermediate inputs in the production of ω^j , with $\sum_{i=1}^m \gamma_r^{i,j} + \gamma_r^j = 1$. The cost of an input bundle is given by

$$c_r^j = B_r^j w_r \gamma_r^j \prod_{i=1}^m P_r^i \gamma_r^{i,j}, \quad (2)$$

where w_r denotes the wage rate, P_r^i gives the price of intermediate inputs from sector i , and B_n^j is a constant. c_r^j clearly incorporates all the inter-sectoral linkages which can be obtained from input-output tables.

In an open economy, producers minimize their production costs and purchase intermediate products from suppliers across countries. However, trade is costly. We denote k_{rs}^j as the bilateral trade cost for country r 's imports of sector j products shipped from country s . It consists of an ad-valorem tariff (τ_{rs}^j) and iceberg trade cost (d_{rs}^j), $k_{rs}^j = (1 + \tau_{rs}^j)d_{rs}^j$. Using Eaton and Kortum's (2002)²⁸ representation of technologies which allows production efficiency to distribute Fréchet, we can derive the price of the intermediate product as

$$P_r^j = G^j \left[\sum_{s=1}^n \lambda_s^j (c_s^j k_{rs}^j)^{-\theta^j} \right]^{-1/\theta^j}, \quad (3)$$

where G^j is a constant, λ_s^j reflects absolute advantage as a higher value indicates more likely a draw of high efficiency, and θ^j captures comparative advantage as a lower value indicates a higher dispersion of efficiency. λ_s^j and θ^j reflect Ricardian trade⁵³.

The properties of Fréchet distribution further enable us to derive the bilateral trade share as

$$\pi_{rs}^j = \frac{\lambda_s^j [c_s^j k_{rs}^j]^{-\theta^j}}{\sum_{n=1}^n \lambda_n^j [c_n^j k_{rn}^j]^{-\theta^j}}. \quad (4)$$

As shown, any changes in tariffs (τ_{rs}^j) can affect trade costs (k_{rs}^j) and thus directly affect trade shares. Equations (2) and (3) show that changes in tariffs also affect the cost of input bundle (c_s^j)

and thus have an indirect effect on trade.

The total expenditure on the products of sector j in country r is the summation of firms' expenditures on intermediate products and households' expenditures on final products. It is given by

$$X_r^j = \sum_{i=1}^m \gamma_r^{j,i} \sum_{s=1}^n X_s^i \frac{\pi_{sr}^i}{1+\tau_{sr}^i} + \alpha_r^j I_r, \quad (5)$$

where

$$I_r = w_r L_r + R_r + D_r \quad (6)$$

represents the total household income in country r , i.e., the sum of labour income ($w_r L_r$), tariff revenues (R_r) and trade deficits (D_r). In particular, $R_r = \sum_{j=1}^m \sum_{s=1}^n \tau_{rs}^j M_{rs}^j$, where $M_{rs}^j = X_r^j \frac{\pi_{rs}^j}{1+\tau_{rs}^j}$ is country r 's import of sector j products from country s . The trade deficit of a country is the summation of sectoral deficits, $D_r = \sum_{j=1}^m D_r^j$, and sectoral deficit is given by $D_r^j = \sum_{s=1}^n M_{rs}^j - \sum_{s=1}^n E_{rs}^j$, where $E_{rs}^j = X_s^j \frac{\pi_{sr}^j}{1+\tau_{sr}^j}$.

The next step is to solve for changes in wages and prices given that the tariff structure τ is changed to τ' . Instead of solving for two equilibria under τ and τ' , Caliendo and Parro (2015)¹² propose solving for an equilibrium in relative changes so that it is not necessary to estimate some parameters that are difficult to identify. Let a variable with a circumflex “ \hat{x} ” denote its relative change. The equilibrium in relative changes satisfies the following conditions:

$$\hat{k}_{rs}^j = (1 + \tau_{rs}^{\prime j}) / (1 + \tau_{rs}^j) \quad (7)$$

$$\hat{c}_r^j = \hat{w}_r \gamma_r^j \prod_{i=1}^m \hat{p}_r^i \gamma_r^{i,j} \quad (8)$$

$$\hat{p}_r^j = \left[\sum_{s=1}^n \pi_{rs}^j (\hat{c}_s^j \hat{k}_{rs}^j)^{-\theta^j} \right]^{-1/\theta^j} \quad (9)$$

$$\hat{\pi}_{rs}^j = \left[\frac{\hat{c}_s^j \hat{k}_{rs}^j}{\hat{p}_r^j} \right]^{-\theta^j} \quad (10)$$

$$X_r^{\prime j} = \sum_{i=1}^m \gamma_r^{j,i} \sum_{s=1}^n X_s^{\prime i} \frac{\pi_{sr}^{\prime i}}{1+\tau_{sr}^{\prime i}} + \alpha_r^j I_r' \quad (11)$$

$$\sum_{j=1}^m \sum_{s=1}^n X_r^{j'} \frac{\pi_{rs}^{j'}}{1+\tau_{rs}^{j'}} - D_r' = \sum_{j=1}^m \sum_{s=1}^n X_s^{j'} \frac{\pi_{sr}^{j'}}{1+\tau_{sr}^{j'}} \quad (12)$$

$$I_r' = \widehat{w}_r w_r L_r + R_r' + D_r'. \quad (13)$$

Introducing into the model the changes in tariff structure, we can solve for changes in (total and bilateral) trade flows, real wages (w_r/P_r), welfare (I_r/P_r), and production output for each country. The change in welfare can be decomposed into volume of trade effect and terms of trade effect. The welfare change can also be calculated at both the bilateral and sectoral levels. We can calculate the change in volume of trade and terms of trade between country s and r , and the change in a specific sector j of country r .

Accounting for the carbon emission changes

The RCEP tariff reductions lead to changes in multilateral trade flows resulting in trade-related carbon emissions changes. We adopt the environmentally extended ICIO model (see Table A2 in Supplementary note 1 for the stylized table) to account for the carbon emission changes. Denote the following as the flows of final products among different countries:

$$\mathbf{F} = \begin{bmatrix} \mathbf{f}^{11} & \dots & \mathbf{f}^{1r} & \dots & \mathbf{f}^{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \mathbf{f}^{r1} & \dots & \mathbf{f}^{rr} & \dots & \mathbf{f}^{rn} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \mathbf{f}^{n1} & \dots & \mathbf{f}^{nr} & \dots & \mathbf{f}^{nn} \end{bmatrix}.$$

And,

$$\mathbf{A} = \begin{bmatrix} \mathbf{A}^{11} & \dots & \mathbf{A}^{1r} & \dots & \mathbf{A}^{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \mathbf{A}^{r1} & \dots & \mathbf{A}^{rr} & \dots & \mathbf{A}^{rn} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \mathbf{A}^{n1} & \dots & \mathbf{A}^{nr} & \dots & \mathbf{A}^{nn} \end{bmatrix}$$

is the global direct input-output coefficient matrix. Its typical element a_{ij}^{sr} provides the intermediate input from sector i ($= 1, \dots, m$) in country s ($= 1, \dots, n$) used by sector j ($= 1, \dots, m$) in country r ($= 1, \dots, n$) for producing one unit of output. \mathbf{A}^{rr} and \mathbf{f}^{rr} provide intra-

country flows of intermediate products and final products. \mathbf{A}^{sr} and \mathbf{f}^{sr} ($s \neq r$) represent trade in intermediate products and trade in final products, respectively. According to the standard input-output model³¹, the gross output vector \mathbf{y} is

$$\mathbf{y} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{Fu}, \quad (14)$$

where \mathbf{I} is an $(nm \times nm)$ identity matrix, and \mathbf{u} is a summation vector of appropriate length with all elements being ones.

Let \mathbf{w} be the CO₂ emission coefficient vector, the elements of which provide the emissions per unit of output. Then, the CO₂ emission vector \mathbf{e} can be written as

$$\mathbf{e}\mathbf{u} = \mathbf{w}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{Fu}. \quad (15)$$

The left side of (15) equals the summation of CO₂ emissions in all sectors in the world, which equals global CO₂ emissions. This equation can be adapted to allow us to calculate the CO₂ emissions (e^r) in a specific country r . This can be obtained by replacing the vector \mathbf{w} in (15) with a vector \mathbf{w}^r . The new vector has equal length, but only the CO₂ emission coefficients for the sectors in country r are retained while all other elements are set as zeros. This yields

$$e^r = \mathbf{w}^r(\mathbf{I} - \mathbf{A})^{-1}\mathbf{Fu}. \quad (16)$$

Equation (16) allows us to calculate, for example, the part of Thailand's CO₂ emissions that are generated by the exports of final products from Japan to final users in China. The production processes for trade between Japan and China may consume intermediate products from Thailand, of which the production emits CO₂ in Thailand. Using the global Leontief inverse, we can take fully into account these indirect effects in equation (16).

To calculate the CO₂ emission changes in country r , we compare two situations. The first is the actual situation, and the second is the case in which multilateral trade flows are changed due to

RCEP tariff reductions. Moving forward from equation (16), we develop the following equation:

$$\Delta e^r = \mathbf{w}^r (\mathbf{I} - \tilde{\mathbf{A}})^{-1} \tilde{\mathbf{F}} \mathbf{u} - \mathbf{w}^r (\mathbf{I} - \mathbf{A})^{-1} \mathbf{F} \mathbf{u}, \quad (17)$$

where

$$\tilde{\mathbf{A}} = \begin{bmatrix} \mathbf{A}^{11} & \dots & \tilde{\mathbf{A}}^{1r} & \dots & \tilde{\mathbf{A}}^{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \tilde{\mathbf{A}}^{r1} & \dots & \mathbf{A}^{rr} & \dots & \tilde{\mathbf{A}}^{rn} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \tilde{\mathbf{A}}^{n1} & \dots & \tilde{\mathbf{A}}^{nr} & \dots & \mathbf{A}^{nn} \end{bmatrix}, \text{ and } \tilde{\mathbf{F}} = \begin{bmatrix} \mathbf{f}^{11} & \dots & \tilde{\mathbf{f}}^{1r} & \dots & \tilde{\mathbf{f}}^{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \tilde{\mathbf{f}}^{r1} & \dots & \mathbf{f}^{rr} & \dots & \tilde{\mathbf{f}}^{rn} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \tilde{\mathbf{f}}^{n1} & \dots & \tilde{\mathbf{f}}^{nr} & \dots & \mathbf{f}^{nn} \end{bmatrix}.$$

Equation (17) enables us to consider the changes in both trade in final products and trade in intermediate products. The changes in bilateral trade flows can be obtained at the sectoral level after solving the Caliendo and Parro (2015)¹² model described above. However, this model does not enable us to calculate the respective magnitudes of change for final product trade and intermediate product trade. We thus use the same magnitude when conducting the calculation.

Data availability

National and ICIO tables are from the most recent OECD Input-Output Database⁵⁴ (2018 edition, <https://stats.oecd.org/>), and bilateral trade flows are obtained from the United Nations Commodity Trade (U.N. Comtrade) database (<https://comtrade.un.org/data/>). Bilateral tariff data are from World Integrated Trade Solution (WITS) software (<https://wits.worldbank.org/>). The committed tariff reductions among RCEP parties come from the Schedule of Tariff Commitments in the RCEP Agreement. The schedule provides detailed data for each RCEP party's commitments to tariff reduction for each year after the date of the entry into force of the RCEP Agreement. International Energy Agency (<https://www.iea.org/data-and-statistics>) provides sectoral CO₂ emissions data¹¹, and the most recent available data are for 2018. We include maximum number of economies, conditional on obtaining reliable data. We ultimately obtain 60 economies and a constructed RoW

with 36 sectors in each economy. Trade and tariff data are for 2019, and we employ the most recent available input-output tables for 2015, assuming that input-output coefficients in 2019 are not much different than those in 2015. Supplementary note 1 provides more detailed descriptions of all data used in our evaluation. Supplementary Tables 1 and 2 provide additional results. All datasets generated in this study are available upon request.

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