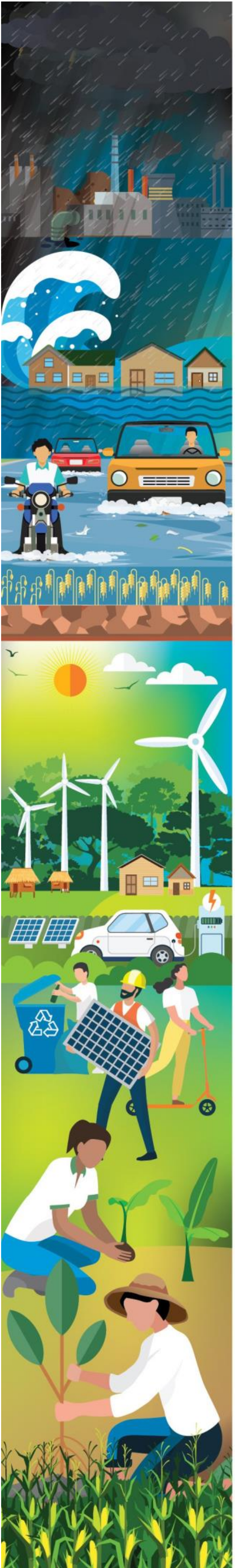

BACKGROUND PAPER

A Computable General Equilibrium Analysis of Carbon Pricing in Asian Economies

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A Computable General Equilibrium Analysis of Carbon Pricing in Asian Economies

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Note: In this report, "$" refers to United States dollars.

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ABBREVIATIONS

BCA	-	Border Carbon Adjustment
CBAM	-	Carbon Border Adjustment Mechanism
CCL	-	Climate Change Levy
CES	-	constant elasticity of substitution
CGE	-	Computable General Equilibrium
CO_2	-	carbon dioxide
ETS	-	emissions trading scheme
EU	-	European Union
GDP	-	gross domestic product
GHG	-	greenhouse gas
GTAP	-	Global Trade Analysis Project
IPCC	-	Intergovernmental Panel on Climate Change
LDE	-	least developed economy
MRIO	-	multiregional input-output
MT	-	metric ton
NDC	-	Nationally Determined Contribution
nec	-	not elsewhere classified
NGHG	-	non-CO_2
OECD	-	Organisation for Economic Co-operation and Development
PRC	-	People’s Republic of China
RCA	-	revealed comparative advantage
ROK	-	Republic of Korea
SSP	-	shared socioeconomic pathway
TFP	-	total factor productivity
UK	-	United Kingdom
US	-	United States

ABSTRACT

Carbon pricing is generally considered an important means of driving reductions in carbon dioxide emissions but also brings risks related to reductions in competitiveness for those economies implementing carbon pricing schemes and increasing the risk and extent of carbon leakage. This background paper uses a Computable General Equilibrium model to estimate the impact on competitiveness and carbon leakage of carbon pricing in Asia. Results suggest that imposing carbon pricing unilaterally across Asian subregions can be expected to lead to some loss of competitiveness. Such results call for increased global coordination in developing carbon pricing schemes to avoid or minimize losses to individual economies. They also highlight the important role that revenue from carbon pricing schemes can play in shifting economies to more sustainable means of production that can both increase the impact of carbon pricing schemes on emissions and allow for more equitable competitiveness impacts across economies. Convergence in emissions intensities toward the cleanest producers, for example, is shown to have positive impacts on competitiveness in economies with relatively dirty technologies, further reducing the extent of carbon leakage.

Keywords: emissions, carbon pricing, computable general equilibrium

I. INTRODUCTION

Mitigating the threat of climate change will require fundamental changes in production and consumption (IPCC 2018). Carbon pricing is widely considered necessary to stimulate innovation and minimize the cost of the transition to more sustainable production and consumption. Carbon pricing schemes, such as carbon taxes or emissions trading schemes (ETS), are powerful and efficient means of encouraging a shift toward low-carbon technologies. By putting a price on carbon to reflect the societal costs of emissions, carbon pricing provides an incentive for firms and consumers to switch away from emissions-intensive products and production techniques toward cleaner, low-carbon alternatives, further encouraging firms to invest in innovation in low-carbon technologies. If the carbon price is passed along to consumers, it can also provide an incentive for consumers to switch to low-emissions goods and services.

The potential benefits of carbon pricing have resulted in an expansion in the number of carbon pricing policies. According to the World Bank (2022), the number of jurisdictions with carbon pricing schemes has increased in recent years, with around 70 carbon pricing initiatives implemented in 39 national jurisdictions, although such schemes cover only 23% of carbon emissions schemes.[1] Carbon pricing is also prominent in Nationally Determined Contributions (NDCs) submitted for the Paris Agreement, with 52% of countries intending to use carbon pricing mechanisms (Carbon Pricing Leadership Coalition 2019). According to the World Bank (2022), however, just 4% of emissions are covered by a carbon price in the range needed to prevent average global temperatures from increasing by 2°C, with this price estimated at between \$50 and \$100 per ton of carbon dioxide (CO_2) (Carbon Pricing Leadership Coalition 2019).

Despite the potential that carbon pricing has for encouraging a shift toward greener production techniques, two major concerns dominate the discussion: competitiveness and carbon leakage. The impact of carbon pricing on competitiveness is ambiguous. While the imposition of carbon pricing will increase costs for local firms, subject to the carbon price, it can also be an incentive to modernize production techniques, leading to improvements in productivity and competitiveness. This latter argument is consistent with the Porter Hypothesis (Porter 1991), whereby carbon pricing encourages innovation in new green technologies, leading to improvements in productivity for firms as they seek to avoid the burden of carbon pricing.

[1] World Bank Carbon Pricing Dashboard: https://carbonpricingdashboard.worldbank.org/ (accessed 12 May 2024).

Through such efforts, firms may see increased demand and profits, in part because of increased customer awareness of climate issues. However, productivity improvements in response to carbon pricing could also be the result of other forces. In heterogeneous firm models, for example, carbon pricing may force smaller and more inefficient firms out of the market, leading to a reallocation of resources toward more productive firms. An improvement in productivity in response to carbon pricing could also result from an industry being driven down its supply curve. The extent to which productivity improvements owing to these developments can be associated with improvements in competitiveness is unclear, suggesting that a focus on productivity as the main indicator of competitiveness may not be ideal. In the analysis below, therefore, we consider alternative indicators of competitiveness—namely, output and exports.

The negative impacts of carbon pricing on competitiveness are likely to depend upon several factors. One factor is the presence of substitutes: the competitiveness of producers of emissions-intensive products faces threats from producers of low emissions-intensive substitutes. A further factor is the extent of global carbon pricing. With carbon pricing not occurring globally, there is a risk that firms operating in countries with carbon pricing may lose market share and see reduced profits, with production shifting to countries where carbon pricing is absent (or where carbon is at a lower price). These two examples have an important distinction, however. While the former is desirable—with production moving from emissions-intensive to less emissions-intensive production—the shifts in the latter case do not represent a move toward more emissions-efficient production, and could lead to the reverse. Regarding the latter, a further important aspect is the extent of pass-through. While producers would be expected to pass through the higher costs associated with carbon pricing to consumers, this may be less possible in a situation of strong global competition, leaving firms subject to carbon pricing at a disadvantage.

Related to the competitiveness issue is the possibility of carbon leakage, whereby carbon-intensive production stages are shifted from countries with carbon pricing to countries with less stringent carbon markets and regulations. The potential for carbon leakage relies upon differences in carbon intensities across countries as well as an open trade regime with low trade costs that allows for production to shift across borders. The trade dimension will be sector and product specific, with differences in policy-related trade costs at the sector and product level, and the trade costs of bulky, low value-added goods being relatively large. The presence of carbon leakage has several negative implications. By shifting production beyond legislative boundaries, carbon leakage makes it more difficult for national governments to legislate against carbon emissions. Since production will be shifted to countries with weaker environmental legislation and, consequently, more emissions-intensive production techniques, this redirection is also likely to result in higher emissions for a given level of production. Such an outcome is further likely to lead to push back from local producers, which could lead to a reversal of climate policies.

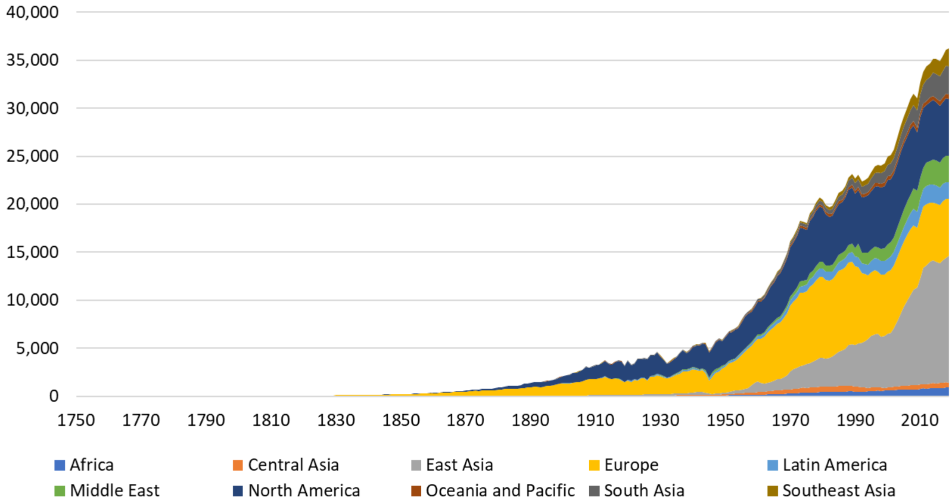
Identifying the potential for competitiveness effects and carbon leakage is crucially important as both have the potential to derail efforts to improve environmental outcomes. Competitiveness concerns are particularly important to those firms and industries that are energy intensive since their ability to engage in carbon-reducing changes in their production processes may be limited. These groups can form strong lobby groups, limiting the ability of national governments to implement and strengthen carbon pricing. Indeed, it can be argued that competitiveness concerns have driven recent changes within the European Union (EU), most notably through implementation of its Carbon Border Adjustment Mechanism (CBAM). While this is intended to level the playing field and to encourage trade partners to increase their ambitions regarding carbon change, competitiveness concerns of firms in the EU have likely also played a role in the formulation of this policy. Border Carbon Adjustment (BCA) mechanisms remain rare, however, meaning that countries and regions considering implementing carbon pricing need to assess how carbon price differentials could result in the relocation of emissions-intensive production to other countries and regions.

Existing studies take two general approaches to estimating the effect of carbon pricing on competitiveness—usually captured by indicators such as the output and export levels of firms, sectors, or countries—and carbon leakage. One is to adopt a modeling approach, with Computable General Equilibrium (CGE) models often employed to estimate the impact of potential carbon pricing initiatives on competitiveness. A second is the ex-post analysis of carbon pricing using regression-based approaches, often with the intention of identifying causal effects of carbon pricing. Ex-post analyses often distinguish between short- and long-term effects. Short-term effects occur when firms lose market share to competitors in regions without carbon pricing. Long-term effects are present when rates of return on capital are affected, and firms choose to relocate their investments and capital to countries with lower carbon prices and restrictions.

Each of these approaches has its own advantages and disadvantages, with modeling approaches relying on a set of behavioral assumptions and elasticities that are estimated using past data. Neither the behavioral assumptions nor the elasticities may hold in a future scenario of higher carbon prices and changed attitudes to climate change. Regression-based approaches consider impacts of existing carbon pricing initiatives that are restricted to a relatively small number of jurisdictions and to relatively low carbon prices, leading to concerns around external validity and the impacts on competitiveness from extending carbon pricing to new jurisdictions.

Driven by relatively rapid levels of development and their increasingly central role in international trade and global production networks, Asian economies account for an increasing share of global CO_2 emissions (Figure 1). In 1970, Asian economies[2] accounted for around 18% of global emissions in production, a share that rose to around 24% in 2000 and was above 50% (52%) by 2019.

Figure 1: Global Annual Emissions of Carbon Dioxide (million metric tons)



Note: Data excludes CO_2 emissions associated with land use, land-use change, and forestry. The regional grouping adopted is a combination of ADB's and the World Bank's regional groupings.
Source: Gütschow, et al. 2016. The PRIMAP-Hist National Historical Emissions Time Series. Earth System Science Data 8.; Gütschow, Günther, and Pflüger. 2021. The PRIMAP-Hist National Historical Emissions Time Series (1750–2019) v2.3.1.

Despite the rising importance of Asia in terms of global emissions, there remain relatively few carbon pricing initiatives in the continent: most existing schemes are in Europe. According to Letourneau (2023), within Asia and the Pacific,[3] carbon pricing schemes exist in the People's Republic of China (PRC), Japan, Kazakhstan, the Republic of Korea (ROK), and New Zealand. The existing schemes also vary widely, with that in the PRC covering electricity generation only while New Zealand's ETS covers all sectors. Carbon prices are also low relative to schemes in the EU, with the price per ton in 2023 being around $9 in the PRC, $2

[2] Asian economies refer to regional member economies (developed and developing) of the Asian Development Bank.
[3] Asia and the Pacific comprises the regional member economies (developed and developing) of the Asian Development Bank.

in Japan, $1 in Kazakhstan, $19 in the ROK, and $52 in New Zealand in 2022 (Letourneau 2023). In contrast, the EU's ETS price in 2022 was around $80.

With concerns around the effects of climate change increasing, and with the urgent call to increase ambitions toward mitigation, there is strong momentum to consider the move toward carbon pricing across Asia. This paper employs a CGE model to assess the potential impact of carbon pricing on competitiveness and carbon leakage in the continent. The approach proceeds by considering the implementation of carbon pricing for different Asian subregions separately, allowing for an estimate of the effects of such an extension of carbon pricing on competitiveness in these subregions, before considering carbon pricing across the whole region, examining competitiveness impacts *vis-à-vis* the rest of the world. In the analysis, it is assumed that the EU's CBAM is in place and that it is extended to other Organisation for Economic Co-operation and Development (OECD) economies. Moreover, it is also assumed that Asian economies implement carbon pricing at a price consistent with estimates of the price needed to limit temperature rises to 2ºC, with a carbon price of $100 per metric ton used in the analysis. Finally, the analysis includes a scenario capturing the diffusion of green technologies, highlighting that carbon pricing can only go so far in mitigating climate change, with innovation and technological diffusion being crucial in these efforts.

The remainder of the paper proceeds as follows. Section II provides a brief overview of the existing literature considering the competitiveness effects of carbon pricing. Section III provides an overview of the computational model used to estimate the effects of alternative carbon pricing schemes in Asia. Section IV describes the modeling scenarios, Section V reports the broad macroeconomic impacts of the scenarios modeled, as well as more detailed estimated impacts at sector level, and Section VI concludes.

II. LITERATURE REVIEW

Arlinghaus (2015) reviews the evidence from early regression-based studies of carbon pricing and competitiveness, arguing that the estimated competitiveness effects of carbon pricing are generally small, with the implication that carbon pricing is an efficient and effective means of reducing carbon emissions. The survey identified just a small number of studies suitable for comparison, however. At the firm level, the studies of Martin, Muuls, and Wagner (2011) and Martin, de Preux, and Wagner (2014) compared UK firms that had to pay the full Climate Change Levy (CCL) with those that were exempt, finding that the CCL had an impact on emissions abatement but not on the competitiveness of affected firms. Similarly, Flues and Lutz (2015) find no evidence of impacts of cross-firm variations in the German electricity tax on turnover, investments, turnover abroad, value-added, or employment for firms in the manufacturing sector. Considering the carbon tax in the Canadian province of British Columbia and focusing on the agriculture sector and aggregate data, Rivers and Schaufele (2014) find no link between the carbon tax and agricultural trade.

An exception to these examples is Commins, et al. (2009). Considering the impact of energy taxes and the EU's ETS on firms, they find that they have a negative impact on firm employment. Conversely, the policies are found to have a positive impact on total factor productivity (TFP), returns to capital, and investment, with effects found to differ across sectors. Results for TFP are consistent with the Porter Hypothesis of increased innovation, while other results suggest the substitution of capital for labor. Other studies focusing on the EU ETS tend to find no effect of the ETS on firm competitiveness as measured by employment, profits, or revenue. These include studies by Petrick and Wagner (2014) and Anger and Oberndorfer (2008) using firm data for German manufacturing, Chan, Li, and Zhang (2013) for 10 countries in the power, cement, and steel sectors, and Abrell, Ndoye Faye, and Zachmann (2011) for firms from a broader set of EU countries.

Considering impacts of the EU's ETS on firm exports for 14 European countries, Costantini and Mazzanti (2012) find that the ETS has a negative impact on exports for all sectors, while environmental and energy taxes on trade have positive effects on exports. Reinaud (2008) considers the opposite, examining whether the ETS results in an increase in net imports of aluminum. The analysis suggests the reverse, with a negative relationship between the carbon price and net imports observed.

The review of Arlinghaus (2015) further considers evidence on the extent of pass-through. Considering the power sector and data for Germany and the Netherlands, Sijm, Neuhoff, and Chen (2006) find pass-through rates of between 60% for off-peak and 117% for peak hours in Germany, with rates of between 64% and 81% in the Netherlands in 2005. Also looking at the power market, Fabra and Reguant (2013) find average pass-through rates of 80%, with 100% during times of peak demand. These and other estimates provide strong support for the presence of strong pass-through of carbon pricing, which likely limits the impact of carbon pricing on profits. The higher prices present the risk of consumers switching to suppliers not subject to carbon pricing but, given the limited extent of energy trading with non-EU countries owing to segmented markets and the structure of transmission networks, the risk of this was limited.

The example of the energy sector may not be generalizable to other sectors, particularly the highly tradable manufacturing sector. By examining whether prices diverged between the EU and the US, De Bruyn, et al. (2010) examine the extent of pass-through for energy-intensive sectors such as iron and steel. Their results suggest pass-through rates of 100% for iron, steel, and refineries, with ambiguous results for chemicals. Using data for various sectors in the UK, Oberndorfer, Alexeeva-Talebi, and Loeschel (2010) estimate pass-through rates of 50% for diesel, 75% for gasoline, and rates of 50%–100% for different chemical products. Estimated pass-through rates are lower for other sectors, with rates of 0%–25% for glass and 30%–40% for ceramic bricks. While there is substantial variation in estimates by study and product, the results suggest that in most cases there is substantial cost pass-through, meaning that producers do not bear the major share of the carbon cost.

Further evidence of the effects of carbon pricing on competitiveness come from Dechezleprêtre and Sato (2017), who undertake a review of existing studies and conclude that there are some short-term impacts of carbon pricing on trade but that these tend to be small and concentrated in a small number of sectors. The study concludes that longer-term impacts on investment decisions are also small and concentrated in certain sectors.

More recent evidence is found in the work of Casey, et al. (2020), who consider subnational carbon pricing in the US and its effect on plant-level competitiveness. They find that carbon prices reduce employment in regulated regions, while raising employment in nearby states. The aggregate effect of subregion carbon pricing is limited, however, suggesting that domestic plants in other states, rather than foreign facilities, benefit from state-wide carbon pricing. Basaglia, Isaksen, and Sako (2024) consider the effects of compensation mechanisms for carbon-intensive firms in the UK, finding that firms benefiting from such compensation increase production and electricity use relative to uncompensated firms.

Several reviews of modeling estimates already exist, including Ekins and Speck (2012), and Oberndorfer and Rennings (2006) on environmental tax reforms and the EU ETS. Evidence from model-based exercises reviewed by these studies also generally suggest small effects of carbon pricing schemes on competitiveness, although results vary substantially with the assumptions on reference scenarios, model assumptions, and whether and how revenue from carbon pricing is recycled.

There are several CGE studies of carbon pricing within Asia. Ojha, Pohit, and Ghosh (2020) estimate a CGE model for India, examining whether a carbon tax can achieve the triple aim of reducing emissions, increasing gross domestic product (GDP), and increasing inclusivity.

Results suggest it is not possible for carbon taxes to achieve this trilemma: emissions reductions can be accompanied by increased GDP at the expense of inclusivity or by increased inclusivity at the expense of GDP, but all three are not achievable. Impacts of carbon taxes on output are generally small and can be positive, though this depends on the approach to recycling the tax revenue. Recycling arrangements that are broad in their scope are more likely to have positive impacts on GDP than are arrangements targeting clean energy production.

Cao, Ho, and Ma (2020) consider carbon pricing in the PRC, arguing that the choice of substitution elasticities is crucial in driving the results in CGE models. Rather than using elasticities estimated from aggregate data, they use firm-level data to estimate elasticities. The resulting elasticities of substitution between capital and labor are found to be lower than those estimated from aggregate data, while energy elasticities are higher. Simulating the impact of the PRC's carbon pricing policies—specifically the PRC's commitment to reduce emissions by 60%–65% from 2005 levels by 2030—the authors find that the higher energy elasticities make it easier to reduce carbon emissions through carbon pricing policies, with the lower capital–labor elasticity leading to smaller increases in GDP over the period 2017–2030. Differences in GDP are small, however, suggesting little impact of carbon pricing policies on competitiveness.

Takeda (2021) uses a CGE model to examine the impact of a reduction in CO_2 emissions of 80% in Japan, further examining the impact of BCAs and different reduction rates in less developed regions. Results suggest substantial impacts on the Japanese economy of the reduction in CO_2 emissions, though changes in reduction rates in less developed regions have only a small impact on Japan. The presence of a BCA in Japan is also estimated to have a large impact on output in the energy sector, though aggregate welfare and GDP effects are small.

Approaches other than CGE modeling have also been considered. Schotten, et al. (2021), for example, use an input-output model to estimate the impact of a carbon price and the CBAM on the competitiveness of EU sectors, focusing on the sector's production costs, export price competitiveness (to non-EU and other EU states), and competitiveness within the EU domestic market. Since input-output models do not allow for substitution between production factors, the production structure is assumed fixed. The authors thus consider their estimates to account for the first-order impacts of carbon pricing in the short run. The paper adopts several scenarios for domestic carbon pricing and the CBAM in the EU, with prices considered to be around €50. Their results suggest the impact of carbon pricing on competitiveness will be modest—between 0% and 2% for most sectors and economies. There are differences across EU economies, however, with price effects tending to be larger in Central and Eastern European economies, reflecting their more carbon-intensive production methods.

III. METHODOLOGY

To undertake the analysis, we employ a large-scale CGE model of the global economy to estimate the overall economic impact of national carbon pricing by Asian economies, including sectoral and macroeconomic effects, on different economies and regions. The CGE model has multiple economies, multiple sectors, intermediate linkages, and multiple factors of production, as developed in Bekkers and Francois (2018) and Bekkers, Francois, and Rojas-Romagosa (2018), and is calibrated using the Global Trade Analysis Project (GTAP) database.[4] The approach also allows for an estimation of the impact of carbon taxes on emission patterns. This impact follows from changes in the mix of production, the level of overall activity, and how goods and services are produced. All these changes are driven by a combination of taxes (domestic and border carbon taxes).

A. Overview of the CGE Model

The CGE model is a large-scale economic model that translates the impact of carbon pricing (domestic and/or at the border) on economic activity at the industry level into economic effects at the national and global levels. The estimated economic effects include detailed information regarding changes in values, quantities, and prices for domestic activities and associated trade flows. Given the general equilibrium nature of these models (meaning that sectors interact through both supply linkages and factor markets), complex interactions are captured. In particular, the model simulates the changes in specific economic activities (sectors) that result from changes in carbon pricing policies.

In general, a CGE model consists of three main elements. The underlying general equilibrium economic model itself (the mathematical structure), the multiregional input-output (MRIO) data integrated with the model, and a set of exogenous parameters and variables (e.g., elasticities) that determine the endogenous reactions, as well as policy variables. The combination of these three elements yields a general equilibrium (calibrated) baseline in which all the accounting and market clearing conditions are met.

[4] Version 11 with base year 2017 (see Aguiar et al., 2019).

In the model, there is a single representative composite household in each region, with expenditures allocated over personal consumption and savings. The composite household owns endowments of the factors of production and receives income by selling these factors to firms. It also receives income from tariff revenue and rents accruing from import/export quota licenses. Part of the income is distributed as subsidy payments to some sectors, primarily in agriculture.

The remaining structure of the model largely follows the standard GTAP model (Corong, et al. 2017), with the addition of a micro-founded theoretical model based on the Eaton and Kortum (2002) approach to model trade. The main difference from the GTAP model, therefore, is the incorporation of the Eaton and Kortum demand structure, from which we derive the gravity equation for our structural estimation of the trade elasticities and changes in trade costs (see Bekkers and Francois 2018; Bekkers, Francois, and Rojas-Romagosa 2018). It is a structurally estimated model, meaning the trade elasticities are taken from econometric estimations based on the underlying data that are later used in the model.[5] The implementation follows Bekkers, Francois, and Rojas-Romagosa (2018) and Bekkers, et al. (2023), with extensions that allow for directly estimating changes in several greenhouse gas (GHG) emissions (together with changes in other air pollutants).[6] In the application here we focus specifically on CO_2.

The model setup and calibration combine features of the older CGE models (see Dixon and Jorgenson 2013) with the micro-foundations of the more recent quantitative trade models (see Costinot and Rodríguez-Clare 2014 for an overview). This means that, analytically, we model trade linkages with the improved micro-founded Eaton and Kortum (2002) structure, while at the same time we work with structurally estimated trade parameters based on a gravity model derived from the same structural general equilibrium model. Thus, we employ a state-of-the-art CGE model that deals with recent academic criticism of standard CGE models—i.e., that models should be micro-founded based on recent trade theory and that the main parameters

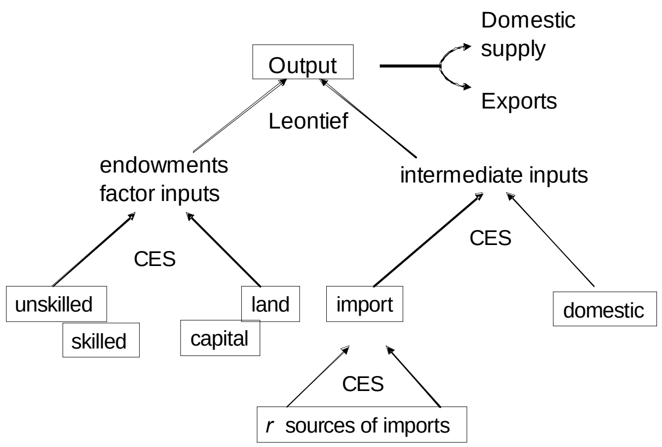
5 For technical details regarding the CGE model and the structural estimation of trade elasticities and non-trade measures, see Bekkers et al. (2023).

6 Available benchmark GHG emissions data cover CO_2, CH_4, N_2O, and fluorinated gases. They are derived from data from the International Energy Agency and the Food and Agriculture Organization of the United Nations (various releases), with the methane and CO_2 accounts data from Fernández-Amador et al. (2017) and GTAPv11 satellite accounts data, reported as CO_2 metric ton equivalents for non-CO_2 GHG (NGHG) emissions (see Fernández-Amador et al. 2017 for a discussion on conversion rates). The NGHG data cover atmospheric emissions of black and organic carbon compounds, carbon monoxide, atmospheric ammonia, non-methane volatile organic compounds (short and long cycle), nitrogen oxides, SO_2, and particulate matter 10 micrometers or less in diameter and 2.5 micrometers or less in diameter. The NGHG indicators cover important contributors to smog and acid rain, tropospheric ozone depletion, degradation of human health, and damage to sustainability of agricultural and ecosystems. They are derived from GTAP satellite accounts data (see Ahmed et al. 2014; Burcu Irfanoglu and van der Mensbrugghe 2015; Baldos 2017; and Chepeliev 2018).

of the model should be structurally estimated using the same underlying data (see Costinot and Rodríguez-Clare 2014; Bekkers, et al. 2018).

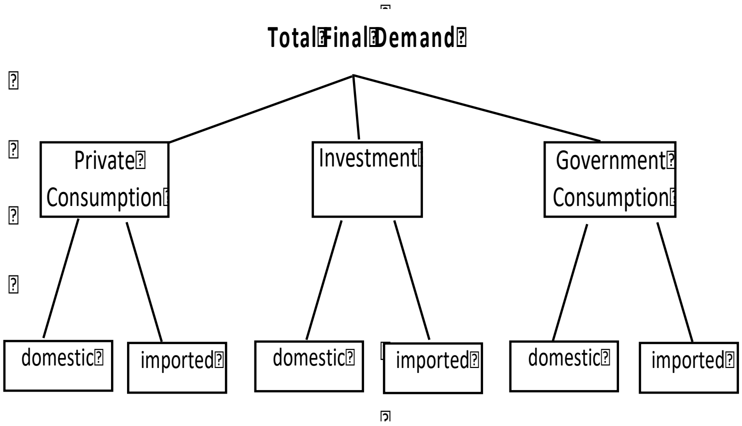
In the structural general equilibrium model, the "whole" economy for the relevant aggregation of economic agents is specified as a set of simultaneous equations. This means that the entire economy is classified into production and consumption sectors. These sectors are then modeled collectively. Production sectors are explicitly linked together in value-added chains from primary goods, through higher stages of processing, to the final assembly of consumption goods for households and governments. These links span borders as well as industries. The link between sectors is both direct, such as the input of steel into the production of transport equipment, and indirect, as with the link between chemicals and agriculture through the production of fertilizers and pesticides. Sectors are also linked through their competition for resources in primary factor markets (capital, labor, and land). The general conceptual structure of a regional economy in our structural general equilibrium model is detailed in Figure 2 and Figure 3.

Figure 2: Production Structure in the CGE model



CES = constant elasticity of substitution, CGE = computable general equilibrium.
Source: Authors.

Figure 3: Consumption Structure in the CGE Model



CGE = computable general equilibrium.
Source: Authors.

On the production side, firms produce output, employing land, labor, capital, and natural resources, and combine these with intermediate inputs, within each region/country. Intermediate inputs can be sourced from domestic and foreign sources to produce outputs in the most cost-efficient way that technology allows. In technical terms, we model a combination of value-added and intermediate inputs, where intermediates (both imported and domestic) are combined through an aggregator along with value-added. Both value-added itself (e.g., labor and capital) and intermediate inputs involve what is known as constant elasticity of substitution (CES)-based aggregator functions. Perfect competition is assumed in all sectors, but products from different regions are assumed to be imperfect substitutes. Firm output is then purchased by consumers, government, the investment sector, and other firms, as detailed in Figure 3. Firm output can be and also is sold for export. In the model, arable land is employed only in the agriculture sectors, while capital and labor (both skilled and unskilled) are mobile between all production sectors. While capital is assumed to be fully mobile within regions, land, labor, and natural resources are not.

Taxes are included at several levels in the modeling. Production taxes are placed on intermediate or primary inputs, or on output. Tariffs are levied at the border. Additional internal taxes are placed on domestic or imported intermediate inputs and may be applied at differential rates that discriminate against imports. Where relevant, taxes are also placed on exports, and on primary factor income. Additionally, where relevant (as indicated by social accounting data), taxes are placed on final consumption and can be applied differentially to consumption of domestic and imported goods. Carbon taxes are applied to the carbon released in domestic production and extended to trade under the CBAM. Carbon intensity in production is linked to inputs and activities in our benchmark satellite accounts data, which link International Energy Agency emissions data at sector level to core GTAP data.

The initial condition of any CGE model is that supply and demand are in balance at some equilibrium set of prices and quantities where workers are satisfied with their wages and employment, consumers are satisfied with their basket of goods, producers are satisfied with their input and output quantities, and savings are fully expended on investments. Adjustment to a new equilibrium, governed by behavioral equations and parameters in the model, is driven largely by price equations that link all economic activity in the market. For any perturbation to the initial equilibrium, all endogenous variables (i.e., prices and quantities) adjust simultaneously until the economy reaches a new equilibrium. Constraints on the adjustment to a new equilibrium include a suite of accounting relationships that dictate that, in aggregate, the supply of goods equals the demand for goods, total exports equal total imports, all (available) workers and capital stock is employed, and global savings equals global investment. Economic behavior drives the adjustment of quantities and prices, given that consumers maximize utility given the price of goods and consumers' budget constraints and producers minimize costs, given input prices, the level of output, and production technology.

Policy experiments consist of a shock to one or more exogenous variables (e.g., carbon taxes) that generates changes in the prices and quantities of the endogenous variables such that a new general equilibrium is reached (the counterfactual scenario). The CGE model computes changes in the allocation of activities, intermediate inputs, labor, and natural resources across sectors and regions resulting from the policy shock, with the behavioral equations in the economic model determining how the endogenous variables react, while the underlying baseline data and the exogenous parameters (i.e., the various elasticities in the model) determine the size and scope of the adjustments. To evaluate trade policy changes, such as the implementation of a carbon pricing scenario, the baseline (business-as-usual) scenario with no policy effects is compared with the counterfactual scenario that includes the changes in policy. The effect of the policy change is then quantified as the difference between the two.

Following full implementation of carbon prices in the scenarios discussed below, there is an adjustment period where different sectors expand and contract, reflecting the new relative prices (and comparative advantages) resulting from the modeled policy changes. Our estimates are "long run," meaning implementation and its effects are fully built into new (post-implementation) values. This involves what is known as a long-run model closure, allowing us to compare an actual reference year with an alternative of that same version of that same year where adjustments to policy changes have fully worked their way through the economic system (see Baldwin and Francois 1999; Bekkers, et al. 2020). We report values as differences with respect to the benchmark year. In some cases, the environmental impact will run in one direction (e.g., a rise in CO_2 emissions in a sector in one country); in others, it will run in the other direction. The use of a multi-country, multisector model is intended to capture this range of effects across countries and sectors, with the net effects being a combination (i.e., the sum) of these changes across sectors and countries.

In the experiments themselves, we follow the literature and employ recursive dynamics to link changes in investment expenditure to changes in capital stocks. This involves a fixed savings rate, with changes in savings following from changes in income levels. This change is then transmitted into investment and hence into changes in capital stocks (see Francois, McDonald, and Nordstrom, 1997; also Bekkers, et al., 2020; for technical discussions). We focus on a comparison of a representative year (the benchmark year), comparing the actual year with how the same year would have looked if the policy had been implemented in the past with enough time for capital markets to adjust (again, see Francois, et al. 1997).

B. Sectoral and Regional Aggregation

One final step in model construction is the definition of the sectoral and regional aggregation to be employed. By this, we mean the specification of sectors and regions for the analysis. The aggregation process identifies those sectors that will receive detailed analysis (within the limits of the global dataset). In other words, this stage of model construction determines those sectors that are to be analyzed independently, and those that are instead to be aggregated into broader sectors. The underlying MRIO data used in the CGE model are taken from the GTAP database, which has data for 65 sectors and 141 regions.

For this study, we have aggregated sectors to allow us to concentrate on the key results. The sector aggregation was chosen to allow breakout of CBAM target sectors to the extent possible, with the resulting aggregation having 23 sectors. The regional aggregation includes 18 regions, allows for the modeling of Asian subregion-specific carbon pricing schemes, with the aggregation further distinguishing between least developed economies (LDEs) in South Asia and Southeast Asia. Table 1 presents the basic aggregation scheme. Table 2 provides more detail on regions.

Table 1: Model Regions and Sectors for CGE-Based Analysis

Model regions	Model sectors	
OECD Asia	Agriculture, forestry, fishing	Electricity*
ADB Central and West Asia	Mining	Gas manufacture, distribution*
East Asia	Food	Transport, nec*
LDE South Asia	Textiles	Commercial services
Other South Asia	Wood*	Public services
LDE Southeast Asia	Chemicals, rubber, plastics*	
Other Southeast Asia	Pharmaceuticals	
Pacific	Ferrous metals*	
PRC	Nonferrous metals*	
India	Metal products*	
ROK	Mineral products, nec*	
EU	Computers, electronics, and optics	
OECD Europe	Machinery and equipment, nec	
Eastern Europe	Motor vehicles	
North America	Motor vehicles and parts	
Latin America	Manufactures, nec	
West Asia and North Africa	Construction	
Sub-Saharan Africa	Petrochemicals, coal products*	

ADB = Asian Development Bank, CGE = computable general equilibrium, EU = European Union, LDE = least developed economies, nec = not elsewhere classified, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China, ROK = Republic of Korea.
Note: * ETS sectors.
Source: Authors.

Table 2: Notes on Regions

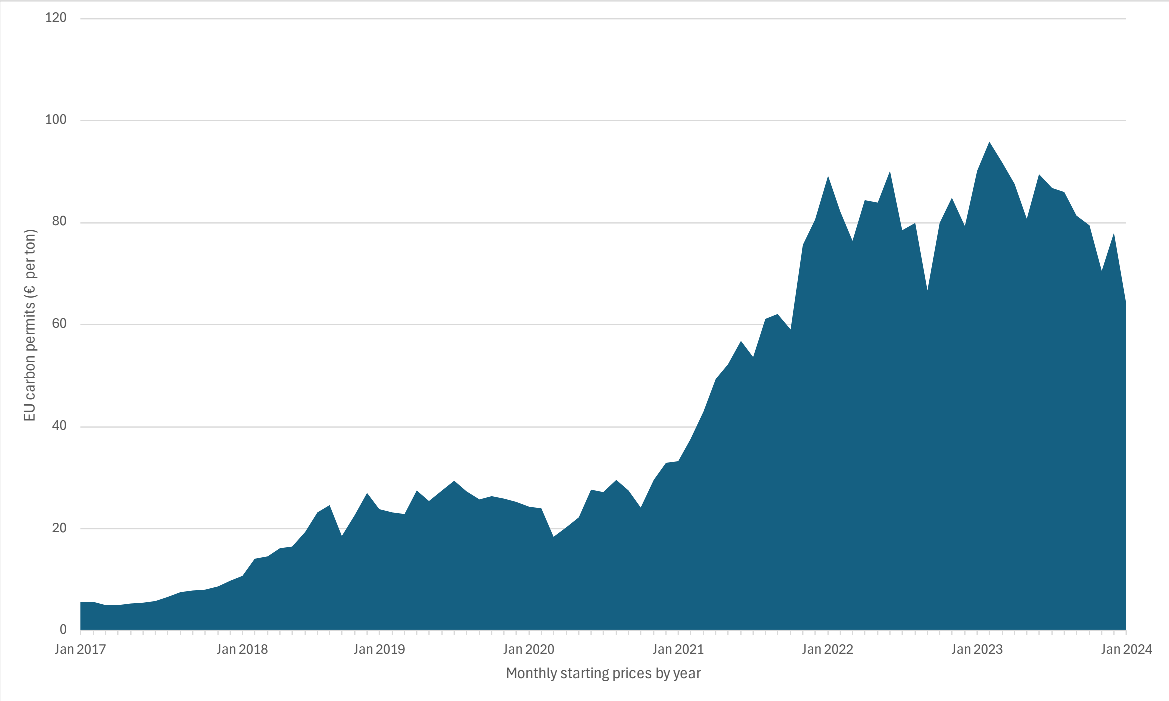
Model Regions	Details
OECD Asia	Australia, Japan, New Zealand
ADB Central and West Asia	Afghanistan, Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyz Republic, Pakistan, Tajikistan, Turkmenistan, Uzbekistan
East Asia	People's Republic of China; Hong Kong, China; Republic of Korea; Mongolia; Taipei,China
LDE South Asia	Bangladesh, Nepal
Other South Asia	Bhutan, India, Maldives, Sri Lanka
LDE Southeast Asia	Cambodia, Lao People's Democratic Republic, Myanmar, Timor-Leste
Other Southeast Asia	Brunei Darussalam, Indonesia, Malaysia, Philippines, Singapore, Thailand, Viet Nam
Pacific	Oceania (excluding OECD Asia)
PRC	People's Republic of China
India	India
ROK	Republic of Korea
EU	European Union member states
OECD Europe	European Economic Area/European Free Trade Association
Eastern Europe	Eastern Europe
North America	United States, Canada, Mexico, other North America
Latin America	Central and South America
West Asia and North Africa	Excludes ADB countries in West Asia
Sub-Saharan Africa	Sub-Saharan Africa

ADB = Asian Development Bank, EU = European Union, LDE = least developed economies, OECD = Organisation for Economic Co-operation and Development.
Source: Authors.

IV. MODELING CARBON PRICING SCHEMES—SCENARIOS

This section outlines the methodology employed to conduct the assessment of implementing national carbon pricing schemes in Asia. To model the impact of carbon pricing schemes, we start with the status quo. Critical here is the price of carbon in the European market. Figure 4 shows historical prices. From 2017 to mid-2020, prices faced by European firms in sectors under the EU's ETS increased to between €20 and €30 per ton. Since then, the tightening of the ETS regime has meant a price increase to around €75 per ton at the start of 2024, with peak prices approaching €100 per ton. Some daily spot prices since 2020 have exceeded €100.

Figure 4: European Carbon Permit Prices



EU = European Union.
Source: Trading Economics. EU Carbon Permits (accessed 10 May 2024).

The first scenario captures two dynamics (Table 3). First, an increase in the carbon price from a price of €18 (the approximate price in 2017) to €100 per metric ton. Second, the imposition of the CBAM on all ETS sectors at the same price of €100 per metric ton. This scenario provides estimates of the impact of rising carbon prices in the EU—on both domestic and imported intermediates—on indicators of competitiveness and emissions globally. Relatedly, the second scenario adopts a similar approach but assumes that a higher carbon price and a CBAM are imposed by the whole of the OECD and not just the EU.

The following four scenarios extend an ETS and a CBAM (at a price of €100 per metric ton) in turn to non-LDE Southeast Asia, non-LDE East Asia, non-LDE South Asia, and non-LDE Other Asian economies. In all cases, it is assumed that an ETS and a CBAM are also imposed by the whole of the OECD. The intention is to isolate impacts on competitiveness and emissions from the expansion of carbon pricing on both domestic and imported inputs to different Asian subregions. While economies and regions have implemented national carbon pricing without BCA, the fear of carbon leakage is an important factor in dissuading politicians from proposing carbon pricing schemes. As a means of mitigating this problem, a BCA is assumed alongside carbon pricing on national production. By allowing for carbon pricing in specific subregions only, the approach allows for the possibility that other subregions could benefit in terms of competitiveness from carbon pricing in specific subregions. Scenario 7 then considers the situation in which all non-LDE Asian economies impose an ETS and a CBAM, thus removing or limiting any intra-Asian competitiveness effects from partial adoption of carbon pricing. Given the additional challenges that LDEs face, it is reasonable to expect that LDEs may impose a lower carbon price and that they may be relatively late in adopting a CBAM. As such, scenario 8 imposes an ETS and a CBAM on LDEs at a carbon price of €50 per metric ton, while further assuming that the OECD plus all other non-LDE Asian economies impose an ETS and a CBAM at the higher price.

Finally, we introduce a scenario in which we assume convergence in Asia toward the emissions intensity of the OECD. Specifically, we assume the OECD imposes a carbon price of €100 per metric ton along with a BCA, while the emissions intensity of non-LDEs converges by 25% and that of LDEs by 75% to the intensity in the OECD. This scenario is intended to capture the effects of green technology diffusion to economies away from the frontier, which would be expected to reduce emissions irrespective of carbon pricing. Given the design of the experiments, the impact of policies implemented under each scenario will be driven in part by current structures of production and carbon intensity across countries and regions.

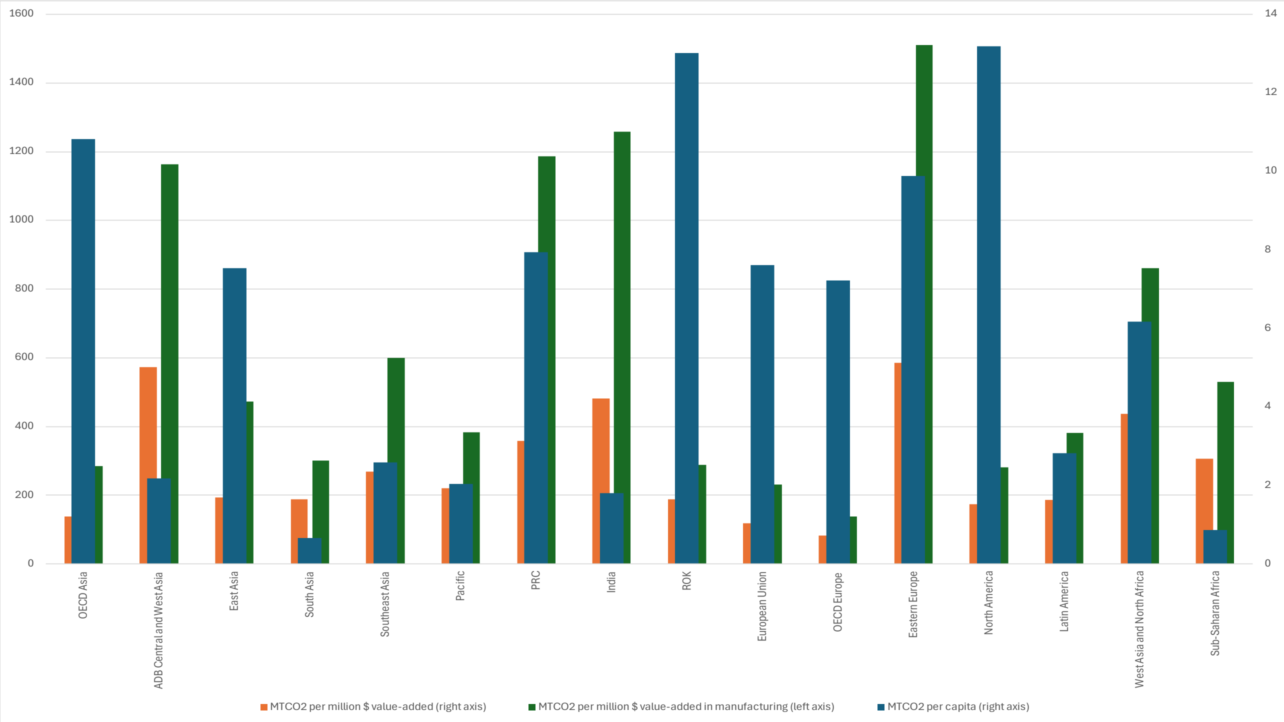
Figure 5 summarizes the current pattern of carbon intensity based on the model benchmark data. The pattern illustrates the differential role played by on the one hand scale (MT CO_2 per capita), where countries with greater output per capita see greater emissions per capita, and on the other hand the mix of what is produced, and how it is produced (allocation and technique). For example, the ROK scores relatively low on emissions per unit value-added overall, and per unit value-added in manufacturing. However, because of the scale of its economy, emissions per capita are relatively high. In contrast, the PRC scores relatively high by all measures, with both scale and the combination of allocation and technique contributing to emission levels.

Table 3: Overview of Carbon Pricing Scenarios

Scenario 1	- **European economies impose tighter ETS carbon allocations, with a resulting €100/MT price.** - **CBAM taxes are imposed for ETS sectors.**
Scenario 2	- All OECD economies impose tighter ETS carbon allocations, with a resulting €100/MT price. - CBAM taxes are imposed for ETS sectors.
Scenario 3	- OECD economies impose tighter ETS carbon allocations, with a resulting €100/MT price. - Non-LDE Southeast Asian countries impose tighter ETS carbon allocations, with a resulting €100/MT price. - CBAM taxes are imposed for ETS sectors.
Scenario 4	- OECD economies impose tighter ETS carbon allocations, with a resulting €100/MT price. - Non-LDE East Asian countries impose tighter ETS carbon allocations, with a resulting €100/MT price. - CBAM taxes are imposed for ETS sectors.
Scenario 5	- OECD economies impose tighter ETS carbon allocations, with a resulting €100/MT price. - Non-LDE South Asian countries impose tighter ETS carbon allocations, with a resulting €100/MT price. - CBAM taxes are imposed for ETS sectors.
Scenario 6	- OECD economies impose tighter ETS carbon allocations, with a resulting €100/MT price. - Non-LDE Other Asian countries impose tighter ETS carbon allocations, with a resulting €100/MT price. - CBAM taxes are imposed for ETS sectors.
Scenario 7	- OECD economies impose tighter ETS carbon allocations, with a resulting €100/MT price. - All non-LDE Asian countries impose tighter ETS carbon allocations, with a resulting €100/MT price. - CBAM taxes are imposed for ETS sectors.
Scenario 8	- OECD economies impose tighter ETS carbon allocations, with a resulting €100/MT price. - All non-LDE Asian countries impose tighter ETS carbon allocations, with a resulting €100/MT price. - All LDE Asian countries impose tighter ETS carbon allocations, with a resulting €50/MT price. - CBAM taxes are imposed for ETS sectors.
Scenario 9	- OECD economies impose tighter ETS carbon allocations, with a resulting €100/MT price. - CBAM taxes are imposed for ETS sectors. - Non-LDE developing Asia converges 25% to average OECD emission intensity in ETS sectors. - LDE Asia converges 75% to average OECD emission intensity in ETS sectors.

CBAM = carbon border adjustment mechanism, ETS = emissions trading scheme, LDE = least developed economies, MT = metric ton; OECD = Organisation for Economic Co-operation and Development.
Note: During the phase in period, the CBAM regime will not apply to all ETS sectors. However, the CBAM system is expected to be expanded to all ETS sectors after the phase-in period.
Source: Authors.

Figure 5: Patterns of CO2 Intensity



ADB = Asian Development Bank, CO_2 = carbon dioxide, MT CO_2 = metric tons of carbon dioxide, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China, ROK = Republic of Korea.
Source: Calculations based on model database.

V. THE ESTIMATED IMPACT OF CARBON PRICING SCENARIOS

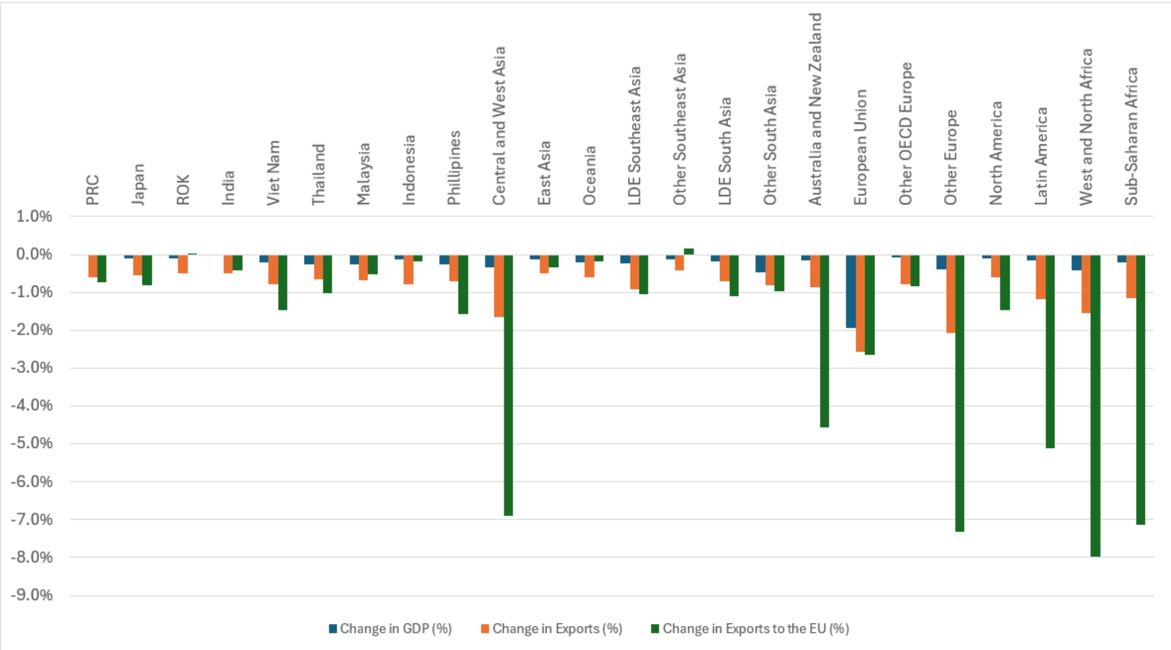
We turn next to estimated results from the application of our general equilibrium model to the scenarios defined in Table 3. Initially, we discuss the imposition of a CBAM and a higher ETS price in the EU and the OECD to examine the effects of these on Asian economies, before presenting results for the remaining scenarios in which subsets of Asian economies impose an ETS and a CBAM.

A. Estimated Impact of ETS and CBAM Imposed by EU and OECD

Beginning with the imposition of a higher carbon price and a CBAM by the EU, Figure 6 reports the estimated economic impacts, focusing on (percentage) changes in GDP, aggregate exports, and exports to the EU. The results suggest that increasing the carbon price and imposing a CBAM in the EU results in lower global output levels and exports. Such results are consistent with strong income effects, with the higher costs of production in the EU leading to lower global output. Conversely, substitution effects work to partially cancel themselves out. On the one hand, the higher ETS price in the EU encourages carbon leakage out of the EU, with positive effects on output and exports in some regions. On the other hand, imposition of a CBAM has the opposite effect, reducing carbon leakage and offsetting the positive impacts on output and exports in other regions.

The EU is most strongly affected, with GDP estimated to fall by almost 2%. Effects in other regions are generally muted, with those regions closer to the EU (e.g., Other Europe, West and North Africa, Central and West Asia) tending to see somewhat larger declines than other regions. Even in these cases, however, reductions in GDP are estimated at less than 0.5%. Impacts on exports tend to be greater, with reductions of more than 1% in the EU, Other Europe, North and West Africa, Sub-Saharan Africa, Latin America, and Central and West Asia. Of the Asian regions, therefore, Central and West Asia is the most affected, reflecting its proximity (and strong trade ties) to the EU and its relatively carbon intensity. Conversely, other Asian economies and regions see smaller reductions in exports, with reductions relatively small in the PRC, India, Japan, the ROK, and Other Southeast Asia. Similar patterns are observed when looking at the reduction in exports to the EU, with some other Asian regions and economies (e.g., the Philippines, Viet Nam, LDE South Asia, and LDE Southeast Asia) also seeing relatively large declines in exports to the EU.

Figure 6: Impact of EU ETS and CBAM on Economic Outcomes

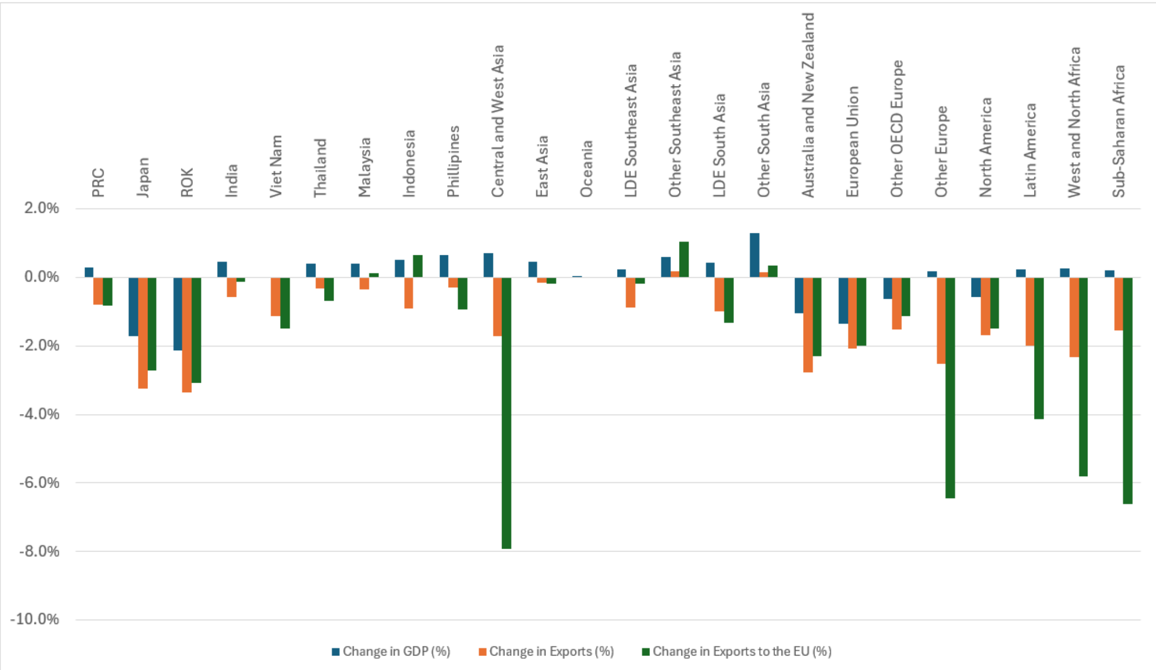


CBAM= carbon border adjustment mechanism, ETS = emissions trading scheme, EU = European Union, GDP = gross domestic product, LDE = least developed economies, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China, ROK = Republic of Korea.
Source: ADB calculations using data from GTAP 11 and International Energy Agency (both accessed November 2023).

The extension of an ETS and a CBAM to the rest of the OECD has more heterogeneous effects on output and exports (Figure 7). Effects on output and exports within the EU are somewhat smaller than is the case where only the EU implements an ETS and a CBAM.

Conversely, the negative effects on output and exports in other OECD regions (Japan, the ROK, Other OECD Europe, North America) become larger, with reductions in output and exports being relatively large in Japan and the ROK. In terms of exports, reductions continue to be relatively large in those economies and regions that are close to Europe (where most of the OECD countries are), especially in different parts of Africa, Other Europe, and Central and West Asia. The extension of an ETS and a CBAM to North America also results in larger reductions in exports in Latin America. In many Asian economies and regions, however, output (and in some cases exports) is estimated to rise. This is especially true for Other South Asia, Central and West Asia, Other Southeast Asia, the Philippines, Indonesia, and Thailand. These changes likely reflect carbon leakage, with downstream production shifting out of the OECD to these economies. While reductions in exports are often lower than in the case of an EU ETS and CBAM only, the fact that exports continue to decline under this scenario in these regions suggests much of this leakage is intended to serve domestic demand. Overall, however, the extension of an ETS and a CBAM to the OECD leads to relatively large substitution effects for various economies and regions in Asia, resulting in higher output in these economies and regions.

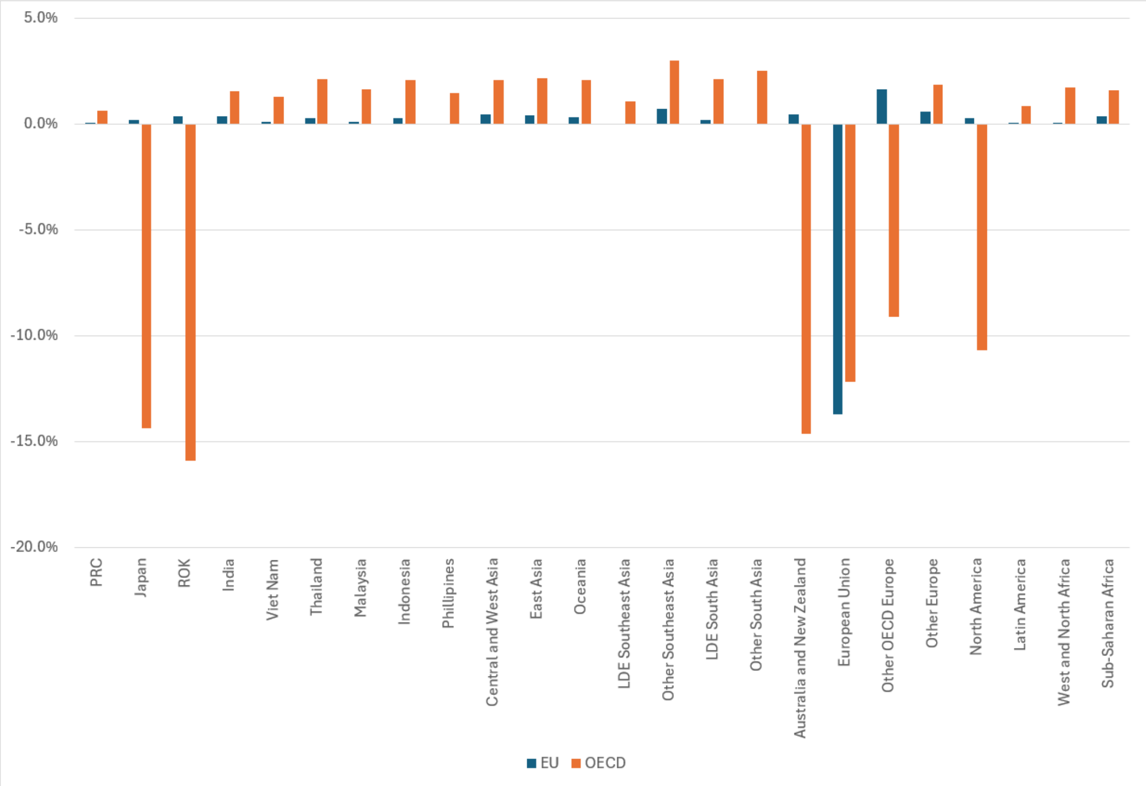
Figure 7: Impact of OECD ETS and CBAM on Economic Outcomes



CBAM = carbon border adjustment mechanism, ETS = emissions trading scheme, GDP = gross domestic product, LDE = least developed economy, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China, ROK = Republic of Korea.
Source: ADB calculations using data from GTAP 11 and International Energy Agency (both accessed November 2023).

Beyond the economic effects, ETSs and CBAMs are intended to reduce GHG emissions, with ETSs focused on domestic emissions and CBAMs on the emissions embodied in imports. At the same time, as we have seen they can also lead to carbon leakage, which can offset some of the emissions reductions (especially if that carbon leakage is to economies with high emissions intensities). Figure 8 reports the estimated percentage change in emissions in each economy and region. The figure shows that imposition of an ETS and a CBAM has substantial impacts on those economies and regions implementing them, with reductions of nearly 14% in the case of the EU in the first scenario and reductions ranging from 9% (Other OECD Europe) to 16% (ROK) when the OECD imposes an ETS and a CBAM. In other regions, emissions tend to increase, with these increases being larger in the case of the OECD imposing an ETS and a CBAM, owing to the higher levels of carbon leakage in this scenario. In the case of the EU imposing an ETS and a CBAM, the results suggest emissions in the EU will fall by 455 million metric tons, while they will increase by 74 million metric tons in other regions. As such, we can estimate carbon leakage at around 16%. The estimates in the case of the OECD imposing an ETS and a CBAM are largely similar. Emissions in the OECD are estimated to fall by 1,474 million metric tons, while increases in other regions are estimated at 265 million metric tons, giving a leakage rate of around 18%, slightly higher than in the EU only case.

Figure 8: Estimated Impact on CO_2 Emissions from ETS and CBAM in EU and OECD



CBAM= carbon border adjustment mechanism, CO_2= carbon dioxide, ETS = emissions trading scheme, EU = European Union, LDE = least developed economy, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China, ROK = Republic of Korea.
Source: ADB calculations using data from GTAP 11 and International Energy Agency (both accessed November 2023).

B. Impact of ETS and CBAM Imposed in Asian Regions

Table 4 reports estimated changes in GDP (in %) in response to the imposition of an ETS and a CBAM in different Asian subregions. The approach assumes that both the EU and the OECD also impose an ETS and a CBAM, meaning that the reported effects also include the effects of carbon pricing in these regions. A first thing to note is that, when a particular subregion imposes carbon pricing, it suffers relatively large reductions in output. In the case of East Asia, for example, output is estimated to fall by more than 2% in the PRC and 1.15% in the rest of East Asia.

In Asian OECD economies, carbon pricing in other Asian regions offsets some of the reduction in output that their carbon pricing has created. In the case of East Asia imposing carbon pricing, the reduction in output in Japan and the ROK is estimated at 0.3% and 1.06%, respectively, versus declines of 1.7% and 2.2% in the case where only the OECD imposes carbon pricing. This highlights the potential for carbon leakage within Asia in response to carbon pricing by subsets of economies. This is further seen when looking at output responses in other Asian economies and regions in response to carbon pricing in other subregions. Again, considering the case of East Asia, the imposition of carbon pricing is estimated to lead to substantial gains in GDP in other Asian economies and subregions, with estimated increases of 4.6% in Other South Asia, 2.9% in Central and West Asia, 2.4% in the Philippines, 2.2% in Thailand, and 1.96% in Other Southeast Asia, among others.

Similar patterns are observed when looking at carbon pricing in other subregions. In the case of Southeast Asia, large reductions in output are estimated in Thailand (4.9%), Malaysia (2.6%), and Viet Nam (2.1%), with increases estimated for LDE Southeast Asia (1.4%), Other South Asia (1.3%), Central and West Asia (0.8%), India (0.5%), and the PRC (0.3%). When imposing carbon pricing in South Asia, large declines in output are observed in Other South Asia (3.2%) and India (2.9%), with the largest increases in Central and West Asia (1.2%), the Philippines (1.1%), Indonesia (0.83%), and Thailand (0.81%). In the case of Other Asia-Pacific, reductions in output are observed in Central and West Asia (1.85%) and Oceania (-2.55%), with the main beneficiaries being Other South Asia (1.46%), the Philippines (0.72%), and Other Southeast Asia (0.58%).

Combined, these results highlight the potential loss of competitiveness from imposing carbon pricing unilaterally. Output in those subregions imposing an ETS and a CBAM are consistently observed to see relatively strong reductions in output, with other Asian economies and subregions benefiting in terms of output. A coordinated policy of carbon pricing across the region (excluding LDE economies), however, is estimated to have two main effects. First, it encourages carbon leakage to non-Asian regions, with output in West and North Africa estimated to increase by 2.3%, and with relatively large increases in Latin America (1.4%), Other Europe (1.8%), Sub-Saharan Africa (1.4%), and North America (0.8%). Second, it continues to create winners and losers within Asia. Reductions in output are estimated for the PRC, India, Viet Nam, Thailand, Malaysia, East Asia, and Oceania, while Indonesia, the Philippines, Central and West Asia, Other and LDE Southeast Asia, and Other and LDE South Asia are estimated to see output increase. Similar patterns are found to hold when introducing a (lower-priced) ETS and CBAM in LDE Asia. In this scenario, LDE Asia is still estimated to see an increase in output from region-wide carbon pricing, though the extent of this increase is diminished by its own carbon price. In other words, even uniform carbon pricing in the region can have distributional consequences, depending on the carbon intensity and structure of production of the different economies and subregions.

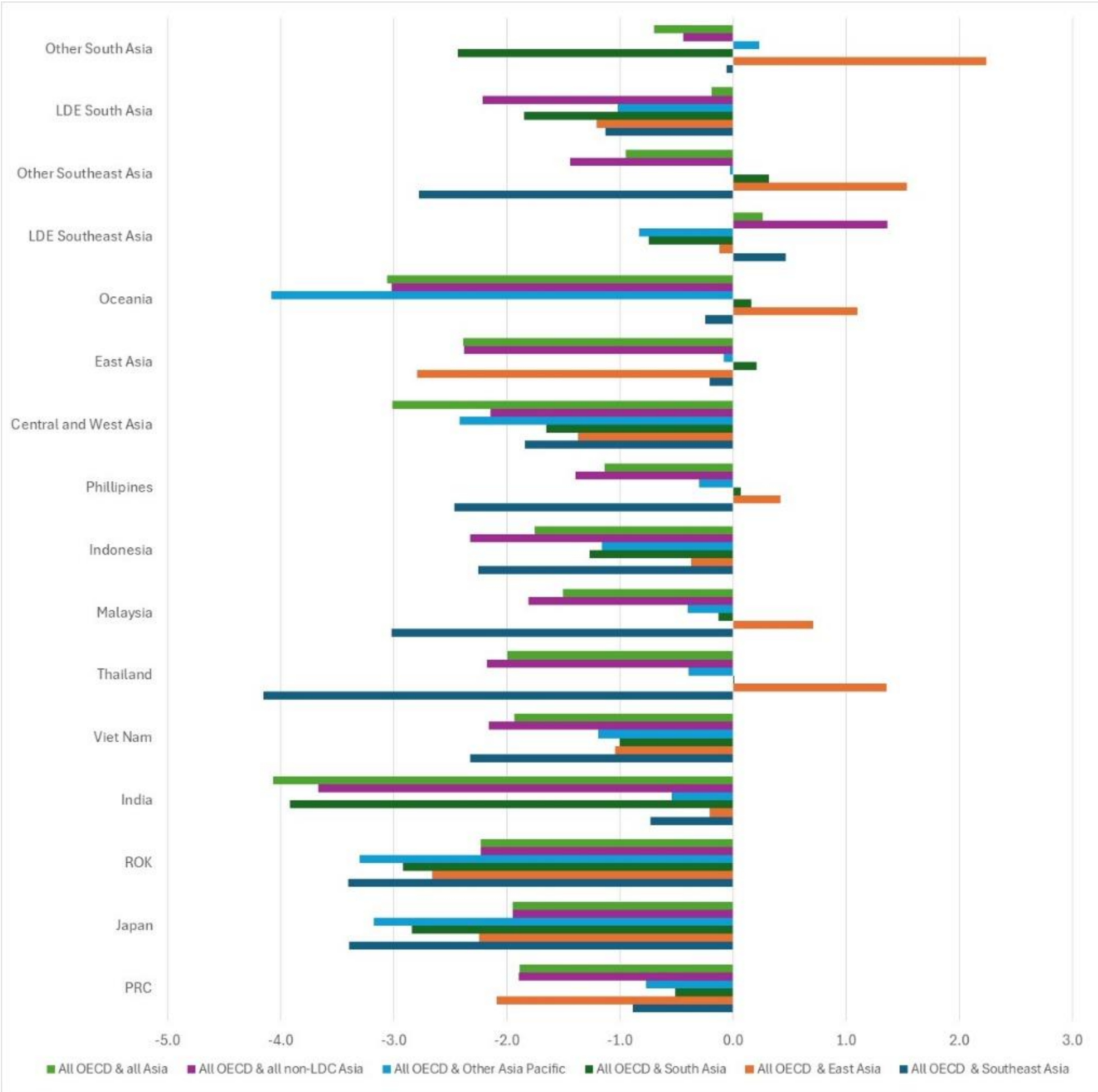
Table 4: Estimated Output Changes in Response to Carbon Pricing in Asia and the Pacific

	All OECD and Southeast Asia	All OECD and East Asia	All OECD and South Asia	All OECD and Other Asia Pacific	All OECD and All Non-LDE Asia	All OECD and All Asia
PRC	0.3407	-2.154	0.4676	0.3249	-1.895	-1.8877
Japan	-1.6571	-0.3337	-1.3754	-1.6572	0.1678	0.1816
ROK	-2.0761	-1.0633	-1.8304	-2.0809	-0.6154	-0.6037
India	0.5104	1.3271	-2.9321	0.4915	-1.9243	-1.9401
Viet Nam	-2.0597	0.4699	0.1317	-0.0072	-1.3804	-1.3153
Thailand	-4.872	2.1988	0.812	0.4413	-2.6475	-2.4464
Malaysia	-2.5635	1.7627	0.6883	0.4194	-0.8469	-0.7329
Indonesia	-0.5161	1.9027	0.8256	0.5613	1.2111	1.298
Philippines	-1.559	2.3714	1.1088	0.7272	0.7227	0.8009
Central and West Asia	0.8039	2.8697	1.2326	-1.8522	0.9279	0.8852
East Asia	0.5087	-1.1506	0.77	0.5276	-0.7165	-0.7032
Oceania	-0.093	0.7397	0.1626	-2.5592	-1.836	-1.7984
LDE Southeast Asia	1.4175	1.2474	0.486	0.2883	2.7261	1.5324
Other Southeast Asia	-1.4587	1.9633	0.8606	0.582	0.1991	0.3789
LDE South Asia	0.4706	1.6787	0.6085	0.4943	1.9687	1.001
Other South Asia	1.3019	4.6052	-3.2355	1.4601	0.2938	0.222
Australia and **New Zealand**	-1.0721	-0.6577	-0.9653	-1.0322	-0.5863	-0.5772
European Union	-1.3137	-0.2824	-1.1092	-1.3083	0.0952	0.1075
Other OECD Europe	-0.6134	-0.1336	-0.5107	-0.6081	0.0278	0.0346
Other Europe	0.1987	1.4594	0.4626	0.2151	1.845	1.8607
North America	-0.526	0.4891	-0.3251	-0.5194	0.8412	0.8545
Latin America	0.2677	1.1431	0.4458	0.2792	1.4242	1.4434
West and North Africa	0.2639	1.86	0.5743	0.2971	2.263	2.3045
Sub-Saharan Africa	0.2364	1.1138	0.4165	0.2572	1.3846	1.4018

LDE = least developed economies, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China, ROK = Republic of Korea.
Source: ADB calculations using data from GTAP 11 and International Energy Agency (both accessed November 2023).

Figure 9 reports the estimated impacts on exports of the same set of scenarios regarding carbon pricing in Asia. In terms of the estimated impacts on those economies and subregions implementing carbon pricing, the pattern of results is generally in line with those for output, with exports declining substantially. For the other economies and subregions not subject to carbon pricing, however, there are often differences between the output and export effect. In the case of carbon pricing by East Asia, for example, India, Viet Nam, Indonesia, Central and West Asia, LDE Southeast Asia, and LDE South Asia are all estimated to see increases in output but also to see reductions in exports. Such results highlight that, while carbon pricing in one subregion can lead to increased output in other subregions, this does not necessarily equate to an increase in exports and global competitiveness. This further suggests that, in these cases, the increased output is linked to serving a higher share of domestic demand. Similar findings are observed when considering the imposition of carbon pricing in other subregions, with LDE South Asia, Central and West Asia, and Indonesia being the economies and subregions most likely to see increased output but reduced exports in response to carbon pricing in other subregions.

Figure 9: Estimated Changes in Exports in Response to Carbon Pricing in Asia and the Pacific

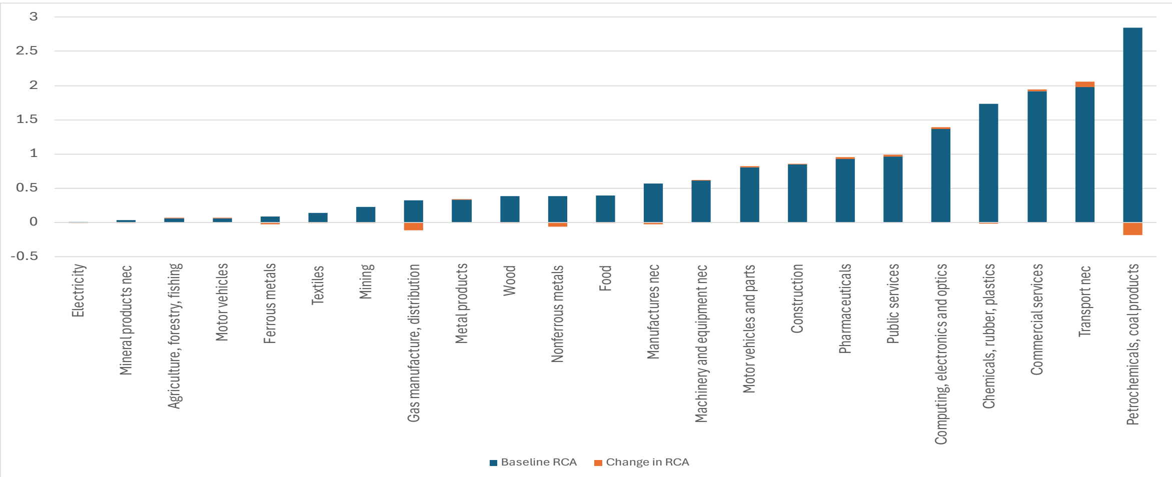


LDE = least developed economy, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China, ROK = Republic of Korea.
Source: ADB calculations using data from GTAP 11 and International Energy Agency (both accessed November 2023).

Turning to sectoral effects, we consider impacts on a commonly used measure of international competitiveness, the revealed comparative advantage (RCA) index. This captures whether an economy has a higher share of exports in a sector/product in its export basket than a comparator economy/region (usually the world), with those that do being considered to have a comparative advantage in that sector/product.[7]

Figure 10 reports the estimated level and changes in RCA for Other Southeast Asia in response to the imposition of carbon pricing in that region. Prior to the policy change, Other Southeast Asia had comparative advantage in Computers, Chemicals, Commercial services, Transport, and Petrochemicals. Following the imposition of carbon pricing, Other Southeast Asia is still estimated to have comparative advantage in these sectors, with little change in the values of the RCA indicator. There are some negative impacts on RCA in ETS sectors such as Petrochemicals, Gas manufacture, and Nonferrous metals, and some small positive changes in some others (e.g., Transport), but overall estimated changes in the RCA index are minor. This outcome is also true when we consider the individual Southeast Asian economies included in the analysis (Figure 11). While the initial RCAs differ substantially across these economies, the changes in the RCA in response to the imposition of carbon pricing in the region are generally small and do not in any case lead to a shift from having a comparative advantage to not having one (or vice versa).

Figure 10: Impact on RCA of Carbon Pricing in Southeast Asia on Other Southeast Asian Economies

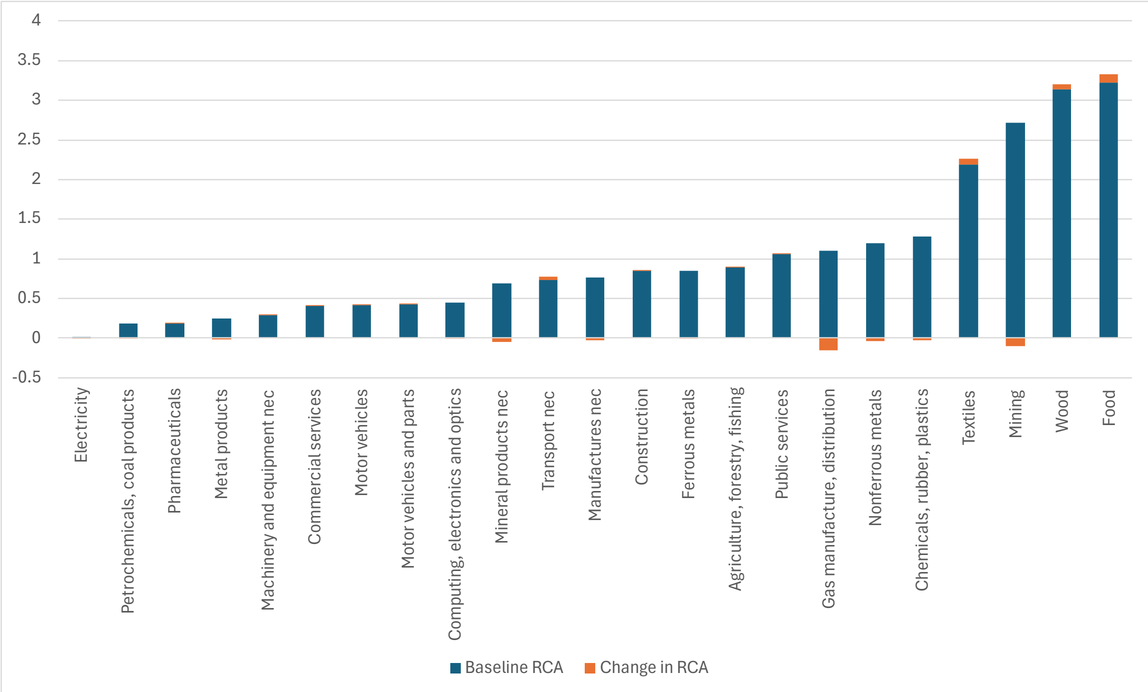


nec = not elsewhere classified, RCA = revealed comparative advantage.
Source: ADB calculations using data from GTAP 11 and International Energy Agency (both accessed November 2023).

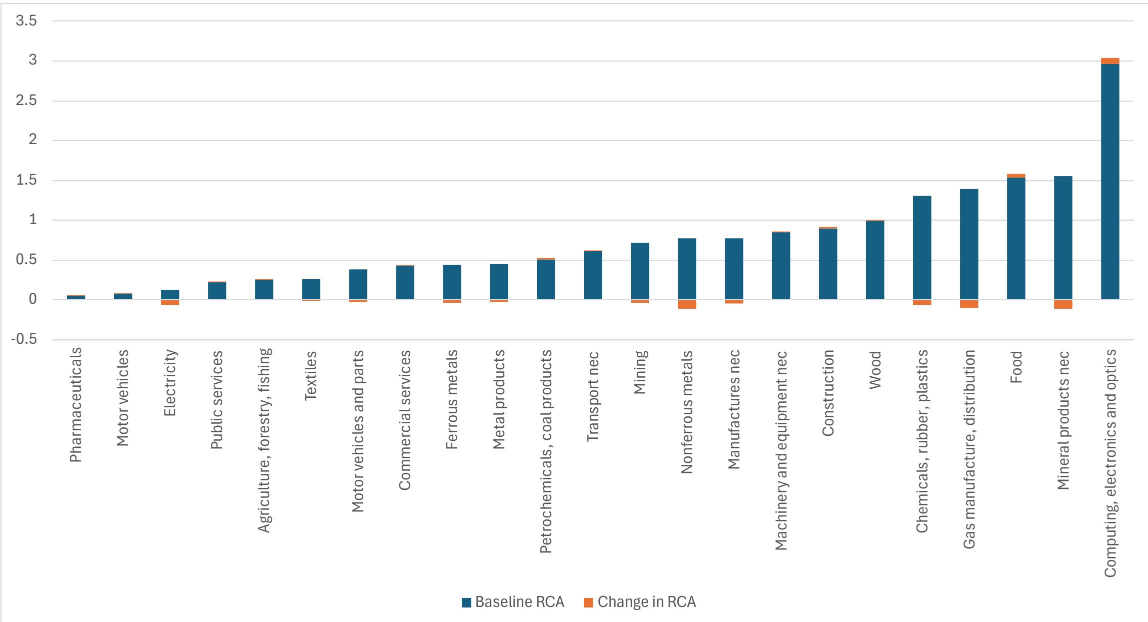
[7] The RCA can be calculated as $RCA_{is} = \frac{Exp_{is} / \sum_{s=1}^{S} Exp_{is}}{Exp_{ks} / \sum_{s=1}^{S} Exp_{ks}}$, where Exp refers to exports, i index economies, s index sectors/products, and k the reference economy (i.e., the world). A value of the RCA index above 1 is considered to represent a situation of comparative advantage.

Figure 11: Impact on RCA of Carbon Pricing in Southeast Asia on Individual Southeast Asian Economies

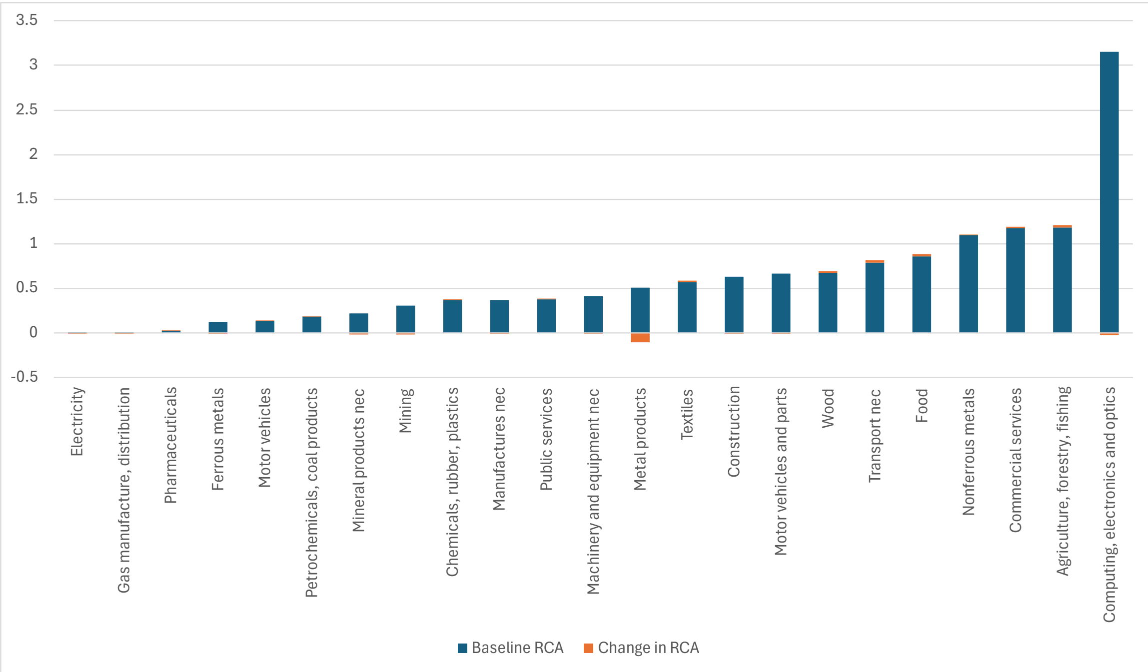
Indonesia



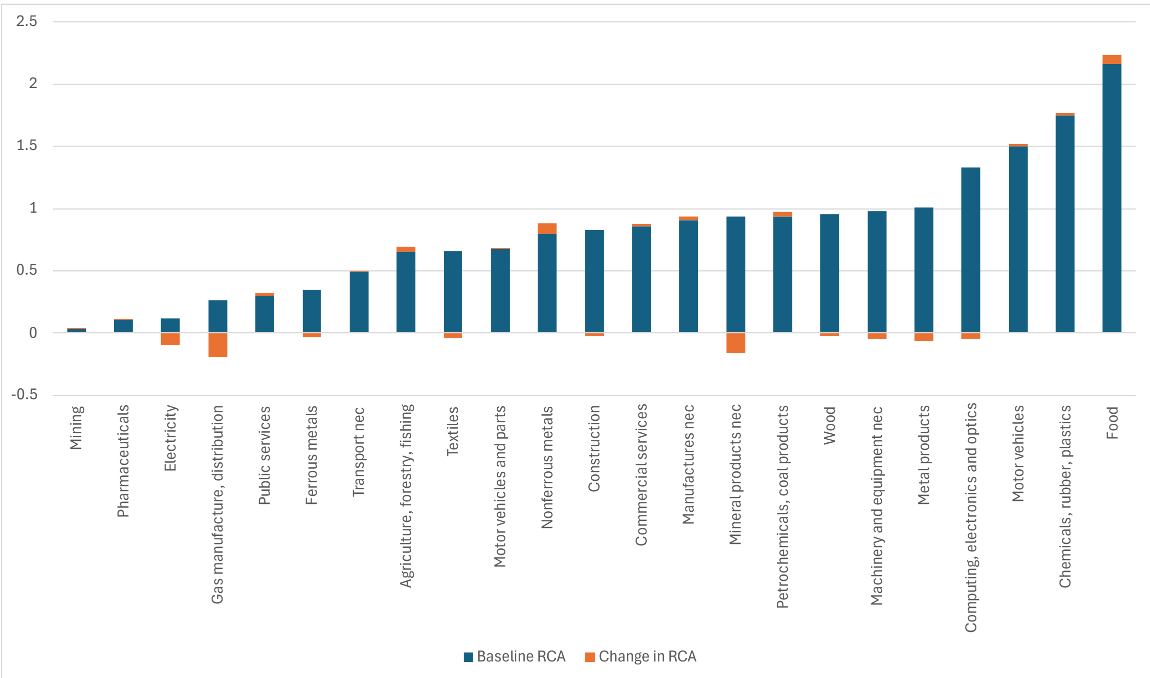
Malaysia



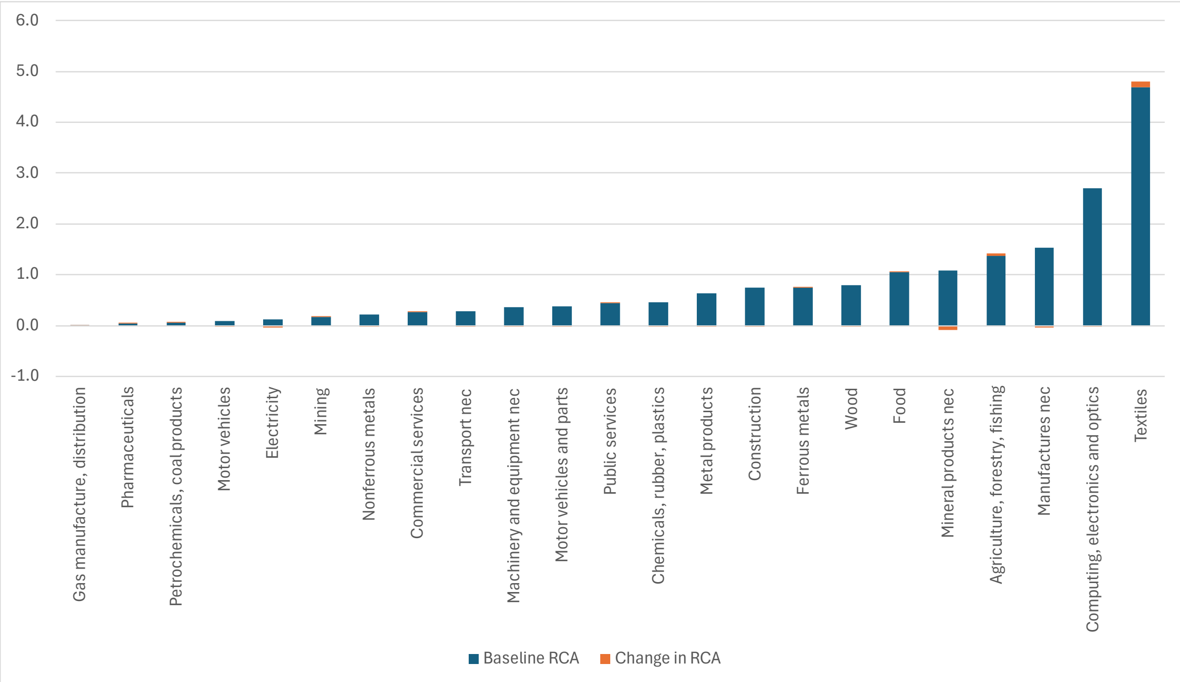
Philippines



Thailand



Viet Nam

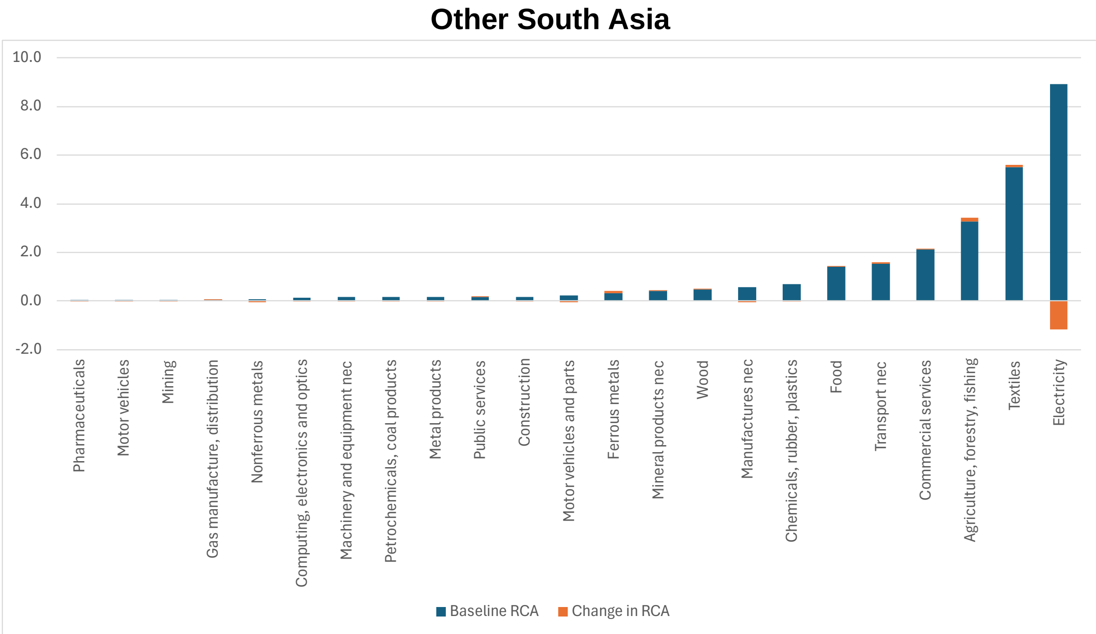


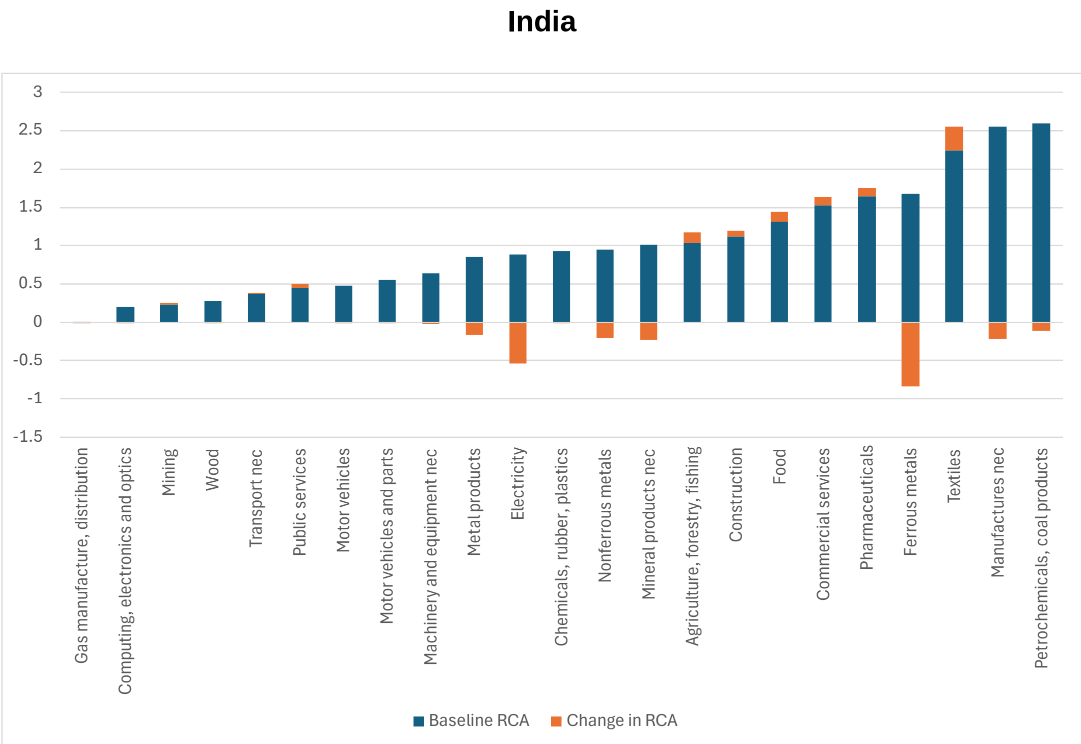
nec = not elsewhere classified, RCA = revealed comparative advantage.
Source: ADB calculations using data from GTAP 11 and International Energy Agency (both accessed November 2023).

There are also few substantial changes in sectoral RCAs in response to carbon pricing in other regions. In the case of South Asia, for example, there is a substantial reduction in the RCA of Electricity for Other South Asian economies but few changes otherwise (

Figure 12). The case of India is somewhat different, with more substantial changes in RCA observed in some sectors. This is especially true for Ferrous metals, where India is estimated to lose its comparative advantage, as well as Electricity, and to a lesser extent Nonferrous metals, Manufacturing nec, and Mineral products nec. The pattern is similar in the case of carbon pricing in East Asia (Figure 13), with few observed changes in Other East Asia but more substantial changes for a subset of sectors in the PRC (Gas manufacture, Ferrous metals, Metal products).

Figure 12: Impact on RCA of Carbon Pricing in South Asia on South Asian Economies

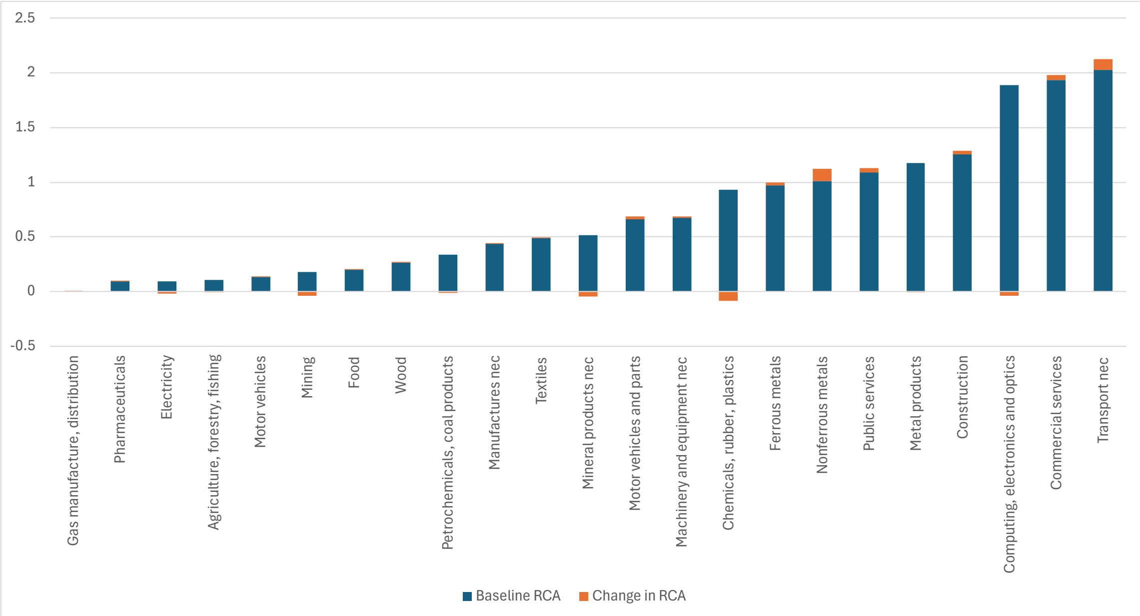




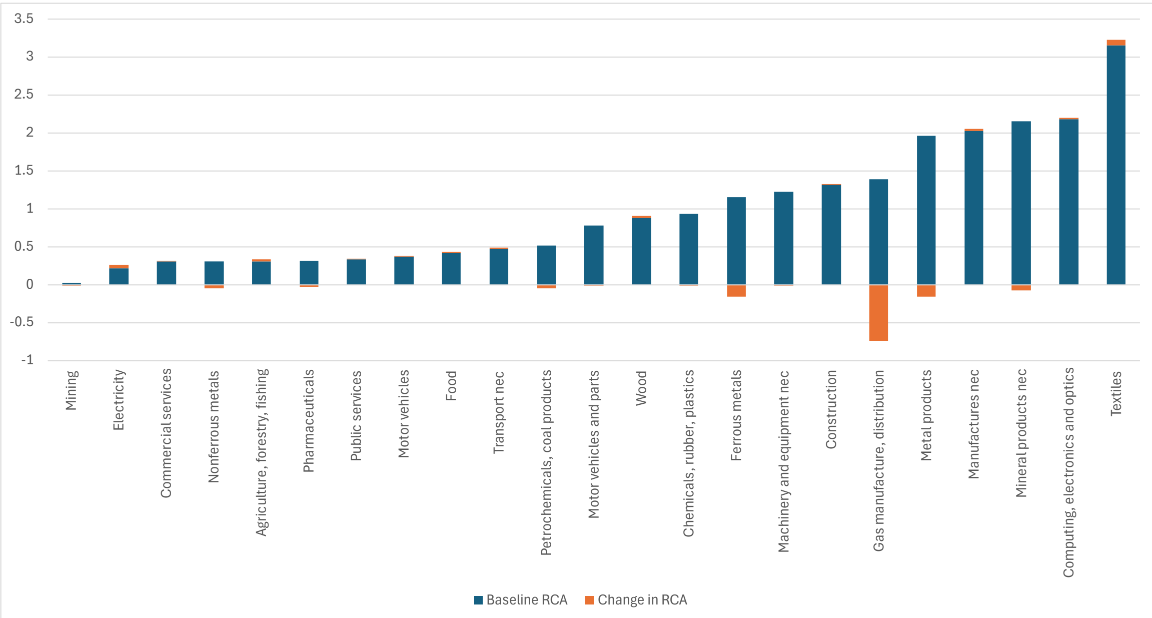
nec= not elsewhere classified, RCA = revealed comparative advantage.
Source: ADB calculations using data from GTAP 11 and International Energy Agency (both accessed November 2023).

Figure 13: Impact on RCA of Carbon Pricing in East Asia and PRC

Other East Asia



PRC



nec = not elsewhere classified, PRC = People's Republic of China, RCA = revealed comparative advantage.
Source: ADB calculations using data from GTAP 11 and International Energy Agency (both accessed November 2023).

Still focusing on sectoral effects, Table 5 reports estimated effects of an ETS and a CBAM imposed across the region (scenario 8) on sectoral output by Asian economy and subregion. The results suggest there will be a reshuffling of production within Asia in response to carbon pricing. LDE South Asia and LDE Southeast Asia are estimated to see gains across a broad range of sectors, reflecting the lower carbon prices in these groups of economies, with LDE

Southeast Asia seeing relatively large increases in Electricity, Gas manufacture, and Ferrous metals, and LDE South Asia relatively large increases in Ferrous metals and Petrochemicals. They also see reductions in some sectors, however, with both seeing reduced Manufactures, LDE Southeast Asia reductions in Mining, Motor vehicles, and Chemicals, and LDE South Asia in Nonferrous metals, Computing, and Machinery. In other economies and subregions, the extent of sectoral negative impacts varies widely. The PRC, Viet Nam, Thailand, and Oceania see reductions in most or sectors, while Other South Asia, Other Southeast Asia, Central and West Asia, and the Philippines see relatively few sectoral declines. Such results confirm the heterogeneous effects of carbon pricing on competitiveness, further highlighting the distributional consequences within economies.

Table 5: Estimated Changes in Sectoral Output in Response to Carbon Pricing in Asia

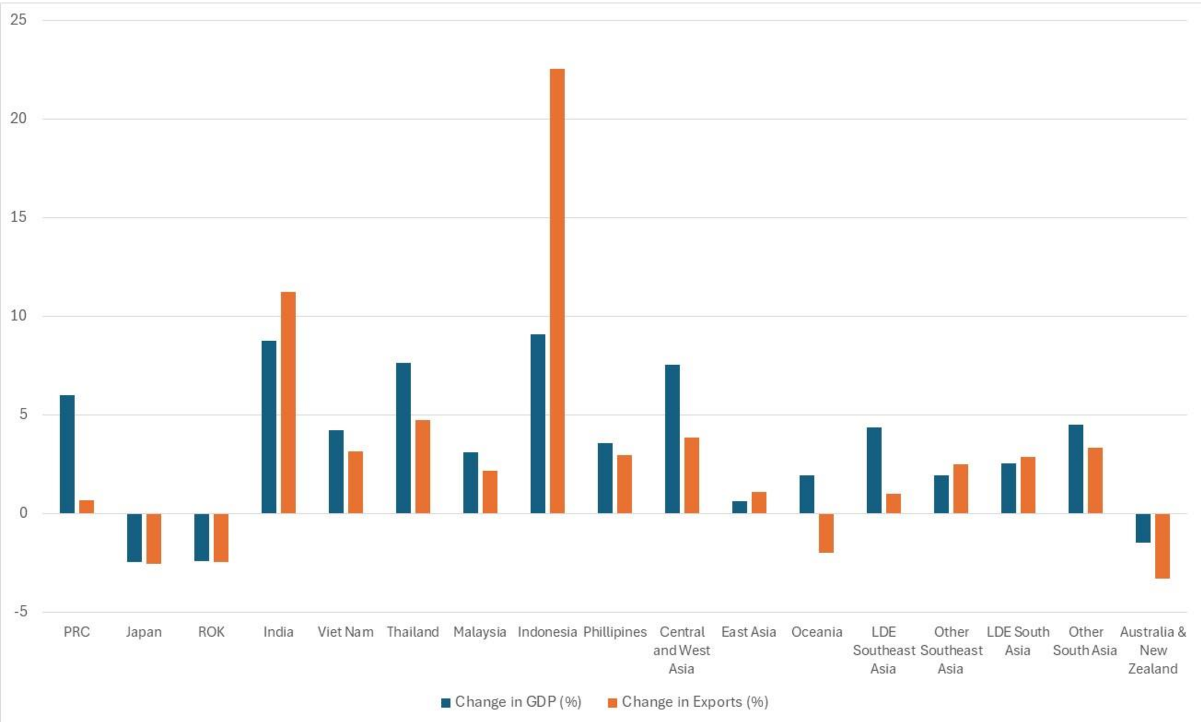
	PRC	Viet Nam	Philippines	Oceania	Indonesia	Malaysia	Thailand	India	Central and West Asia	Other East Asia	Other South Asia	Other Southeast Asia	LDE Southeast Asia	LDE South Asia
Agriculture, forestry, fishing	-0.28	-0.40	0.10	-1.09	0.37	-0.09	-0.09	-0.22	0.53	-0.25	0.14	-0.20	-0.26	0.29
Mining	-5.34	-6.61	-5.99	-7.10	-3.66	-3.00	-5.03	-6.56	-3.44	-4.11	-5.04	-3.86	-8.82	-2.64
Food	-0.65	-1.05	0.66	0.45	0.39	-0.64	-1.26	0.23	0.65	-0.49	0.59	-2.53	0.18	0.38
Textiles	-1.07	0.74	3.60	-9.01	4.01	-7.63	-8.24	1.98	4.13	-1.64	1.94	-7.62	-1.45	0.23
Wood	-1.86	-3.25	0.73	-2.74	2.38	-1.12	-4.15	-5.15	0.59	-1.45	0.89	-5.17	2.12	0.01
Chemicals, rubber, plastics	-2.30	-2.60	2.73	-13.94	1.19	-4.84	-0.66	-5.33	-3.23	-11.96	0.84	0.62	-3.24	-5.15
Pharmaceuticals	-3.43	-0.20	1.03	-5.43	1.66	1.20	-0.85	0.81	-0.37	-1.46	-6.30	4.06	-0.22	-2.16
Ferrous metals	-6.60	2.58	6.01	3.87	24.93	-1.21	-7.34	-36.49	-1.77	-0.42	5.18	-22.22	9.44	8.91
Nonferrous metals	-9.90	-4.54	11.12	-13.19	5.25	-12.12	11.70	-22.13	1.86	6.62	-42.45	-12.55	4.66	-19.05
Metal products	-5.10	-7.26	-12.36	-7.30	1.51	-2.30	-6.20	-8.15	0.86	-2.12	-9.56	1.49	-0.04	1.97
Mineral products nec	-4.10	-5.47	-2.73	-14.31	1.23	-1.35	-9.96	-9.47	0.21	-6.49	0.29	0.47	7.55	4.96
Computing, electronics, and optics	-2.21	-3.24	-1.12	-10.27	2.73	1.17	-5.73	-6.29	-4.61	-5.37	-18.10	0.69	0.04	-16.18
Machinery and equipment nec	-3.71	-4.21	-1.62	-11.72	5.18	1.11	-6.58	-6.68	-4.61	-1.83	-16.19	2.06	-0.78	-6.82
Motor vehicles	-2.88	-3.96	3.75	-7.23	4.86	-1.26	-2.62	-3.94	2.18	0.62	-5.54	-0.81	-0.11	1.85
Motor vehicles and parts	-3.41	-7.16	-0.07	-6.04	5.11	-5.00	-2.74	-4.39	0.35	0.06	-16.63	1.50	-4.86	0.46
Manufactures nec	-1.81	-2.85	0.24	-17.34	-0.83	-4.98	0.41	-10.41	1.32	-0.45	-1.71	-5.72	-3.06	-4.12
Construction	-3.63	-3.00	1.55	-2.54	2.07	-0.99	-3.92	-3.38	1.58	-1.00	0.51	0.78	3.22	2.26
Petrochemicals, coal products	-10.18	-0.90	6.19	-2.12	0.57	2.09	-2.37	-9.95	1.33	-10.10	-0.15	-6.67	4.61	6.29
Electricity	-10.33	-4.94	-4.73	-18.70	-5.18	-13.32	-20.03	-10.63	-5.34	-14.28	-10.95	-13.37	30.47	-2.82
Gas manufacture, distribution	-20.20	-13.73	-12.82	-23.35	-11.86	-14.85	-26.67	-13.42	-7.66	-21.83	-0.89	-18.61	16.96	-3.95
Transport nec	-2.65	-5.99	-0.36	-5.42	1.13	-2.98	-6.66	-4.39	0.24	-0.59	-0.51	-1.15	0.18	1.10
Commercial services	-1.79	-1.41	0.85	-1.38	1.57	-0.79	-2.44	-1.73	1.27	-0.37	0.24	0.05	0.55	1.06
Public services	-0.86	-1.03	1.00	-1.00	0.78	-0.57	-0.33	-0.50	0.88	0.49	0.77	1.11	1.03	1.17

LDE = least developed economies, nec = not elsewhere classified, PRC = People's Republic of China.
Source: ADB calculations using data from GTAP 11 and International Energy Agency (both accessed November 2023).

C. Effects of Emissions Convergence on the Competitiveness of Asian Regions

Moving beyond carbon pricing alone to consider the impact of emissions intensity convergence through some form of technology diffusion, Figure 14 reports estimates of the GDP and export effects of emissions intensity convergence in Asia. The figure reports reductions in GDP and exports in those OECD regions with relatively low emissions intensities, suggesting that improvements in emissions intensity in other parts of Asia can reduce the competitiveness of these economies somewhat. In contrast, in nearly all economies and regions that see emissions convergence, the results indicate an increase in both GDP and exports. In many cases, the increase in these two variables is roughly similar, but there are also notable exceptions. In the PRC and to a lesser extent Thailand, Central and West Asia, and LDE Southeast Asia, the percentage increase in GDP exceeds that of exports. In contrast, for Indonesia the estimated impact on exports far exceeds the estimated increase in GDP. In the former cases, the results suggest the improvements in emissions intensity result in relatively large increases in production for domestic consumption.

Figure 14: Estimates of GDP and Export Effect of Emissions Intensity Convergence in Asia



GDP = gross domestic product, LDE = least developed economy, PRC = People's Republic of China, ROK = Republic of Korea.
Source: ADB calculations using data from GTAP 11 and International Energy Agency (both accessed November 2023).

The results in this figure can also be contrasted with those in Figure 7, which reports results from the scenario where an ETS and a CBAM are imposed in the OECD but without emissions convergence. In addition to positive impacts on competitiveness for non-OECD Asia, the estimated changes in GDP and exports tend to be considerably larger when allowing for emissions convergence. The results thus highlight the important role for innovation and technological diffusion in building the competitiveness of regions. Technology diffusion can have large impacts on GDP and exports, complementing and potentially exceeding the effects that work through the price mechanism (i.e., the imposition of carbon taxes in different regions), with those effects also potentially being more evenly distributed across economies and regions.

D. Carbon Emissions and Carbon Leakage

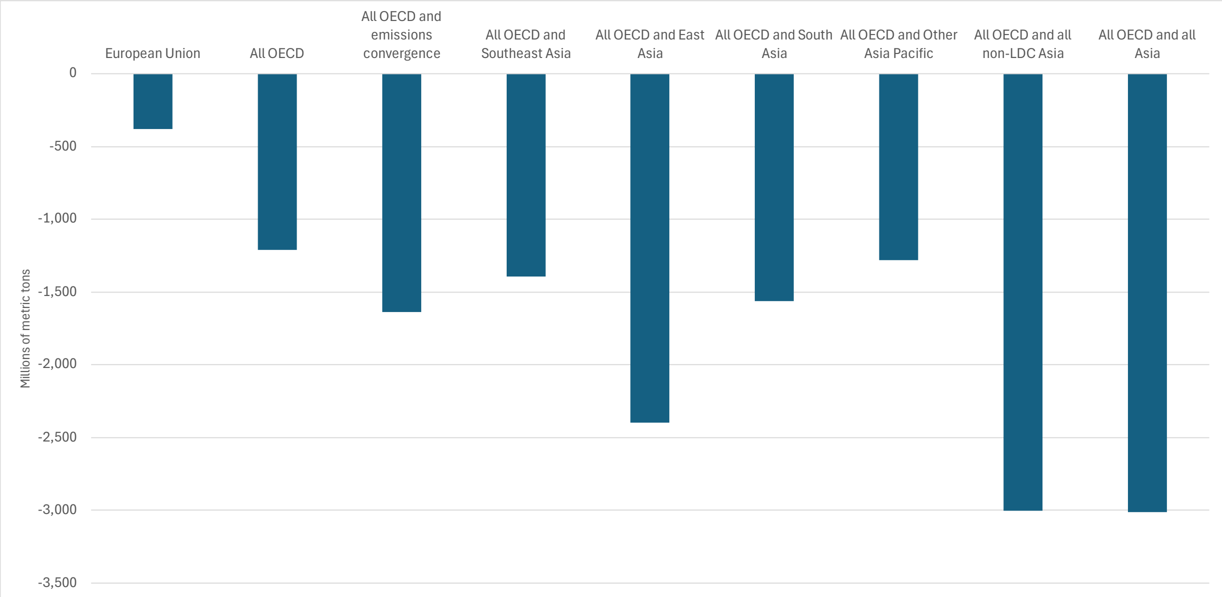
The approach allows us to compute changes in emissions resulting from the estimated set of changes to the level of production, the mix of inputs used in production, and reallocation of resources and activities across sectors. For the present application, we focus on a 2017 benchmark, while modeling adjustments to capital (from investment), to allow for comparison of the actual benchmark year to an alternative version of that year where the policies defined in the different scenarios drive capital stock and production adjustments in the alternative baseline from scenario-driven changes.[8] This modeling of changes in emissions is based on an explicit functional mapping from our emissions data to specific aspects of production and intensity of value-added by sector, which in turn are tied to levels of emissions and resource use.

Considering the impact of the different geographical coverage of ETS and CBAMs, Figure 15 reports the estimated reduction in global CO_2 emissions. A first thing to note is that the higher priced ETS and CBAM in the EU is estimated to have a relatively small effect. This reflects the fact that it covers a relatively small number of countries, with the CBAM covering a relatively small amount of trade. Consistent with this view, as carbon pricing is expanded to the OECD and Asian subregions, the estimated reductions in emissions increase. Adding East Asia to the group of carbon pricing economies is found to have relatively large effects, with expansion to all Asian economies leading to substantial reductions. It is noticeable that the additional effect of imposing carbon pricing in LDE Asia has a minimal effect on global emissions reductions. Figure 15 also highlights the relatively important role of emissions convergence. Compared with an ETS and a CBAM in the OECD, allowing

[8] An alternative is to apply shared socioeconomic pathway (SSP) baseline projections, though the basic pattern of results will convey the same message. In that case, benchmark data are then updated alongside core economic baseline projections, with projections (and with some technical progress included for baseline GHG volumes) based on the Intergovernmental Panel on Climate Change SSP baselines (usually SSP2) and the technology coefficients of the CGE model (O’Neill et al. 2017; Riahi et al. 2017; Samir and Lutz 2017; Bekkers et al. 2023).

for partial emissions convergence in non-OECD Asia reduces global emissions by an additional 35%—more than in expanding carbon pricing to South Asia or Southeast Asia.

Figure 15: Estimated Impact of ETS and CBAM on CO_2 Emissions

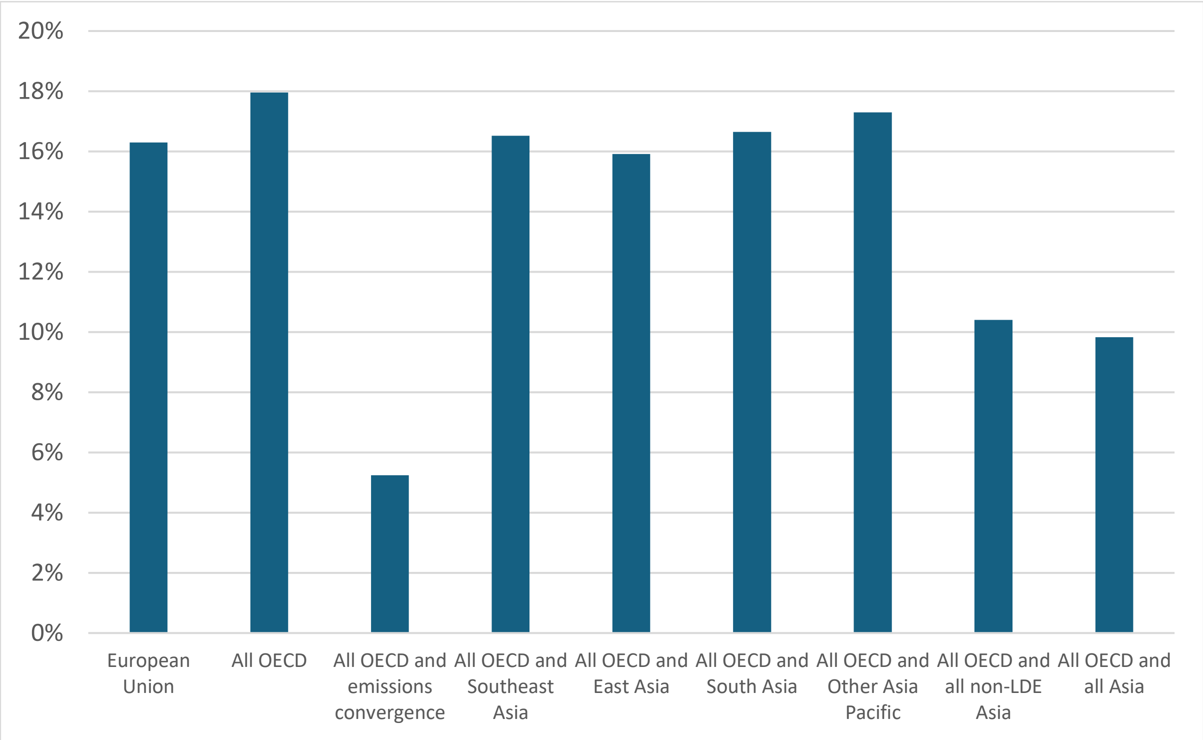


CBAM = carbon border adjustment mechanism, CO_2 = carbon dioxide, ETS = emissions trading scheme, LDE = least developed economy, OECD = Organisation for Economic Co-operation and Development.
Source: ADB calculations using data from GTAP 11 and International Energy Agency (both accessed November 2023.

These estimated changes can be partly explained by the potential for carbon leakage. In the case of an ETS and a CBAM imposed on a relatively small number of economies, the potential for carbon leakage is large, meaning that the reductions in emissions will be more limited. Figure 16 reports the estimates of carbon leakage for the different scenarios and indicates that this link between coverage and carbon leakage is likely non-linear. Carbon leakage rates are relatively high when only the EU implements an ETS and a CBAM, consistent with the view that carbon leakage will be high if geographical coverage is limited. Leakage rates increase when expanding to the OECD, however. This is likely because there is now the opportunity for a larger share of (relatively clean) production being shifted to other economies, economies that are generally less emissions efficient than the OECD. Expanding carbon pricing to Asian economies then tends to reduce carbon leakage, but generally not substantially. This, again, likely reflects the idea that, while other Asian economies are not covered by carbon pricing, there is always the possibility of production being shifted to other parts of Asia that, in many cases, may be less emissions efficient than the previous source of production. It is noticeable, therefore, that, when expanding the ETS and CBAM to the whole of Asia, there is a substantial reduction in carbon leakage rates. In this scenario, the opportunities for carbon leakage have been substantially reduced, resulting in substantial emissions reductions.

A final notable feature of the results is the low carbon leakage rate when allowing for emissions convergence in non-OECD Asia alongside an ETS and a CBAM in the OECD. While emissions convergence will lead to an increase in output and exports in non-OECD Asia, partially at the expense of OECD economies, this is not associated with substantial carbon leakage, since the redirected output is being produced using more emissions-efficient production techniques than without emissions convergence. In this sense, the results highlight the potentially crucial role that revenue from carbon pricing schemes can play if devoted to improving the efficiency of production, for example by greening the energy grid.

Figure 16: Estimated Impact of ETS and CBAM on Carbon Leakage Rates



LDE = least developed economies, OECD = Organisation for Economic Co-operation and Development.
Source: ADB calculations using data from GTAP 11 and International Energy Agency (both accessed November 2023.

VI. CONCLUSION

Carbon pricing is considered to represent a major means of mitigating climate change, encouraging economies to shift to more sustainable production and consumption systems. Yet the risk to competitiveness and the potential for carbon leakage can encourage hesitancy in adopting carbon pricing unilaterally and has led to the adoption of border carbon adjustments by the EU.

This paper estimates the impact on competitiveness and carbon leakage of carbon pricing in Asia—the region that contributes the most to annual global CO_2 emissions. Adopting a CGE model, the paper shows there are potential losses to competitiveness from imposing carbon pricing unilaterally across Asian subregions. Output in subregions imposing an ETS and a CBAM are estimated to suffer relatively strong reductions in output, with other Asian economies and subregions benefiting. Despite this, there is little evidence to indicate that economies are likely to lose comparative advantage in the sectors in which they currently enjoy it from the introduction of carbon pricing.

One way of alleviating the competitiveness impacts of carbon pricing in the region would be to coordinate carbon pricing across the region. While leading to relatively large reductions in CO_2 emissions, a coordinated approach encourages carbon leakage to non-Asian regions. It further creates winners and losers within Asia, which has implications for a coordinated approach and for the potential to develop compensation mechanisms to compensate the losers and increase their incentives to join a coordinated response to carbon pricing.

A further important factor that could increase the extent of emissions reductions, minimize anti-competitive effects in Asia, and potentially ensure more equity is to introduce mechanisms for technology-sharing that allow emissions intensities in Asian economies to converge with those in the most efficient economies. While carbon pricing can help reduce global emissions, without a concerted effort to enhance the emissions efficiency of production its effects will be limited. Here, the revenue generated from carbon pricing schemes can play an important role in shifting economies to more sustainable means of production.

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