6 THEME CHAPTER Decarbonizing Global Value Chains

Introduction

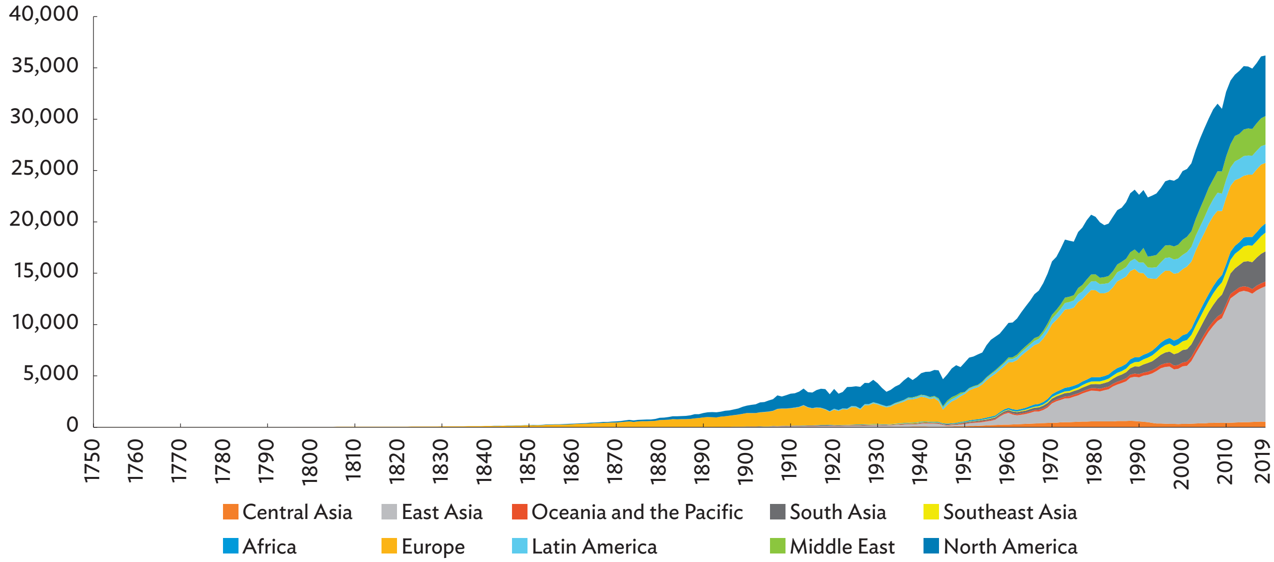
Anthropogenic (human-induced) climate change is dramatically affecting the world's natural environment, its economies, and societies. The complex nature of the earth's climate system means that the overall impact of climate change remains uncertain. Yet it has myriad effects, such as higher temperatures, increased drought, water scarcity, severe fires, melting polar ice, rising sea levels, ocean warming, ocean acidification, flooding, storms, and declining biodiversity, among others. They will likely have dramatic consequences for life on earth. The direct impacts on humans include the effect on health, ability to grow food, access to fresh water and to ocean food chains, productivity, and the destruction of critical infrastructure. In turn, these effects will likely displace communities and force migration. Climate change holds the potential to weaken political, economic, and social systems, exacerbating the risk of conflict within and across nations.

Climate change and global warming have been driven by the production system developed since the First Industrial Revolution; a system based on the burning of fossil fuels for energy. This increased the concentration of heat-trapping greenhouse gases (GHGs)—particularly carbon dioxide (CO_2) and methane (CH_4)—in the earth's atmosphere. It has raised the average surface temperature of the earth, with global average temperatures in 2020 estimated to be 1.1°C above pre-industrial levels (ADB 2023a). Deforestation and land clearance both add carbon to the atmosphere and remove the earth's natural means to absorb atmospheric carbon. Significantly reducing carbon emissions will require a fundamental change in the way humans produce and consume—particularly energy production and consumption—to rapidly move toward net zero CO_2 emissions (IPCC 2022a). Ultimately, success depends upon the speed at which production can be decarbonized.

Despite a drop in the rate of growth, GHG emissions continue to increase rapidly. According to a recent Intergovernmental Panel on Climate Change (IPCC) Assessment Report (IPCC 2022a), annual average GHG emissions during 2010–2019 were higher than in any previous decade. While the growth rate of emissions during the decade was less than the previous 10 years, the increase in the level of emissions was the highest on record. Since 1990, the largest growth in absolute emissions was in CO_2 from fossil fuels and industry, followed by CH_4, with most anthropogenic CO_2 emissions occurring in the past few decades. The PRIMAP-hist dataset indicates that half have occurred since 1990, with 85% being emitted since 1950 (Figure 6.1).

Asian economies, in particular developing economies, are highly exposed to the effects of climate change. Climate change impacts will likely fall disproportionately on developing economies, which have limited resources to mitigate and adapt to the consequences of climate change. Globally, developing Asia's population is most vulnerable to climate change (ADB 2023a), partly due to its geography and socioeconomic conditions—broad exposure to natural hazards and other climate-related risks—and partly by lower levels of economic development that limits the ability to cope with and adapt to the effects of climate change. According to the Global

Figure 6.1: Global Annual Emissions of Carbon Dioxide (million metric tons)



Note: Data exclude carbon dioxide emissions associated with land use, land-use change, and forestry. The regional grouping adopted is a combination of ADB and World Bank regional groupings.

Source: Gütschow (2016); and Gütschow, Günther, and Pflüger (2021).

Climate Risk Index 2021 (Ekstein, Kuenzel, and Schaefer 2021), some Asian economies (such as Bangladesh, Nepal, Pakistan, the Philippines, and Thailand) are among the top 10 economies exposed to long-term climate risk (1990–2019), while Asia accounted for more than half of all multi-hazard global average annual losses for 2000–2022 (UNESCAP 2022).

Sectoral impacts of climate change will disproportionately affect developing Asian economies. Climate change will have large negative impacts on certain sectors of the economy, including agriculture, forestry, fishing, and tourism, which many developing Asian economies depend on. Increased temperatures and drought will reduce crop yields while rising flood levels threaten food supply. Climate change alters where different crops can be grown, with severe consequences for farmers in badly affected regions. Similar effects are expected in fishing, with warmer water temperatures affecting the abundance, migratory patterns, and mortality rates of global fish stocks. The economies of fishing communities may also be affected by rising sea levels and more extreme weather events. The increased prevalence of invasive species and insect outbreaks, along with wildfires and storms, affects the health of forests and forestry in many economies. Extreme temperatures also impact tourism. For example, poorer water quality associated with temperature rises increase toxic algae blooms, preventing recreational water activities and freshwater fishing. Rising sea levels may submerge small islands and coastal areas, with deforestation and loss of biodiversity making other tourist destinations less attractive. Climate change adds infrastructure risk, including housing and business, but also roads, railways, ports, airports, energy infrastructure, and communication systems. This adds to the large infrastructure investments needed across developing Asia to maintain growth and tackle poverty (ADB 2017).

Developing Asian economies play an increasing role as a source of emissions. Asia and the Pacific account for an increasing share of CO_2 emissions production (see Figure 6.1). Throughout the 18th and much of the 19th century, CO_2 emissions were dominated by Europe, given its leading role in the First Industrial Revolution and highlighting the role technology and structural change play in rising GHG emissions. Toward the end of the 19th century, North America began to contribute an increasing share of annual CO_2 emissions and by the mid-1920s accounted for half of all CO_2 emissions. Later in the 20th century, Asia emerged as a leading source of emissions production. By 2019, Asia accounted for 52% of global CO_2 emissions production, with East Asia (36%), South Asia (8.1%), and Southeast Asia (5.1%) accounting for the bulk of this share.[38] These changes in regional contributions to CO_2 emissions reflect a variety of factors, including changes in the structure of global production associated with falling trade costs and the rise of global value chains (GVCs), along with population and technology dynamics.

Climate Change and Global Value Chains

While international trade can alter global production patterns in ways that increase GHG emissions, it can also be an important part of the solution to climate change. Trade can be a source of low-emission goods and services, a source of green technology diffusion and, through competition, enhance production efficiency and reduce GHG emissions (WTO 2022b). To do this, however, trade policies must encourage the flow of low-emission goods, services, and knowledge, while subsidies that distort markets through carbon-intensive production or limit the adoption of green technologies or inhibit innovation should be removed (ADB 2023b). Currently, trade remains a major contributor to GHG emissions, with the rise of GVCs increasing GHG emissions as the scale of production and distance goods travel also increases. Trade has incentivized firms to move the "dirty" parts of production to economies with weak regulations, limiting how economies regulate emissions through existing domestic policies and mechanisms.

GVCs provide an opportunity for developing economies to join the global economy. GVCs split up what is needed to produce a good or service with different segments undertaken by different economies. Driven by differences in factor costs across economies, reduced transport costs and improvements in information and communication technology that help coordinate production across geographically distant locations, GVC production increased rapidly since the late 1990s and early 2000s. Expansion has come mainly through the drive for greater efficiency, particularly in multinational firms based in developed economies. This resulted in a broader global division of labor in line with comparative advantage. These changes have created opportunities for developing economies by making it easier for them to industrialize (Baldwin 2011), with some considering GVCs as a new development paradigm (Taglioni and Winkler 2016). CO_2 emissions and the GVC carbon footprint have not received much attention until recently. However, as concerns grow over the risks of climate change, the carbon content of trade facilitated by GVCs has come under increased scrutiny.

The rapid expansion of GVCs over the last few decades has led to a complex relationship between trade and GHG emissions. While GVCs contribute to development, their relationship with climate change is multidimensional and bidirectional (Box 6.1). They decouple consumption from production, with production taking place in economies and regions different from those where the final product is consumed. From an environmental perspective, one concern with this decoupling is the risk that firms in developed economies may shift production activities to developing economies where environmental regulations are weaker—the so-called pollution haven hypothesis—and where emissions efficiency may be lower. This results in higher GHG emissions for a given level of production. Driven by improved productivity, the greater

[38] These data represent the flow of CO_2 emissions into the atmosphere. There is some debate as to how long emissions remain in the atmosphere (e.g., Inman 2008), creating some uncertainty as to the stock of CO_2 emissions in the atmosphere and the relative contribution of different regions to these stocks. Estimating the stock of CO_2 emissions using the CO_2 flow data from PRIMAP-hist and the Perpetual Inventory Method, Asia was estimated to account for 30.1% of CO_2 emissions in the atmosphere in 2019 under the assumption that CO_2 emissions remain in the atmosphere for 300 years and for 32.2% of CO_2 stocks if emissions remain in the atmosphere for 10,000 years. The corresponding estimates for East Asia are 20.8% and 22.1%, respectively.

scale of production within GVCs can also increase CO_2 emissions, with emission-intensive production of manufactured goods likely to be relocated to developing economies. Developing Asia, as an important GVC producer, accounts for a large and growing share of GVC emissions. Moreover, as developing Asian economies are projected to account for most global economic activity over the next several decades (Leimbach et al. 2017), their share in GVC-related emissions will doubtless continue to rise.

GVCs can weaken the efforts of policymakers to limit GHG emissions. Policymakers are increasingly interested in GVCs and the emissions embodied in GVC production. This is partly due to concerns over the carbon footprint of GVCs, but also around competitiveness and the protection of domestic industries in advanced economies that generally have more stringent environmental protections. One specific concern is that the effectiveness of efforts to reduce GHG emissions—for example,

Box 6.1: Understanding the Complex Relationship between Global Value Chains and Climate Change

The relationship between global value chains (GVCs) and greenhouse gas (GHG) emissions—and its resulting impact on climate change—is complex and multidirectional. GVC activity can be a significant source of carbon dioxide (CO_2) and other GHG emissions. But it can also involve more efficient production techniques and help diffuse new knowledge and technologies that reduce emissions. Conversely, climate change can impact GVCs and how they function, highlighting the costs of not adjusting climate change policies for international trade and for GVCs specifically.

Existing literature (e.g., ADB 2023b) identifies three main channels through which GVCs can affect an economy's GHG emissions: a scale effect; a structural effect; and a technological effect (ADB 2023b).

- Scale Effect: GVCs enhance productivity, which for a given technology and industry structure should increase production and emissions (Antweiler, Copeland, and Taylor 2001). This scale effect need not be linear, however. For a given technology level, increases in the level of production in an economy can potentially lead to more efficient resource use that, to some extent, can decouple the production of goods and services from the production of GHG emissions. If these economies of scale are higher in GVCs than in domestic production, the resulting emissions from production within GVCs may be less than the emissions produced if the same level of production had taken place outside of GVCs.
- Structural Effect: GVC integration can lead to changes in the economic structure of an economy, which can affect the level or intensity of its GHG emissions. Traditionally, the structural effect would be considered at the sectoral level, with some sectors considered more emission intensive than others for a given level of technology and production. Given the distributed nature of production within GVCs, however, the contributions of individual economies to CO_2 emissions through GVC production will further depend on their specialized GVC tasks and activities, with their position in GVCs likely an important factor. Beyond tasks and activities, by shifting production toward more efficient firms, GVCs can also help reduce CO_2 emissions. Firms that trade internationally tend to be more efficient than non-trading firms. GVCs, by shifting production toward more efficient firms, can help reduce emissions if the shift also results in less emissions-intensive production (Copeland, Shapiro, and Taylor 2021).
- Technology Effect: Historically (over the past 150 years or so), a great deal of technological change resulted in higher emissions intensity, with a production structure using energy from carbon-based sources the major contributor to rising levels of CO_2 emissions. More recently, however, technological change has led to new production methods and new renewable sources of energy. As these technologies become cheaper and diffuse both within and across economies, emissions intensities may decline for a given level of production and an unchanged industrial structure. GVCs have been an important source of technological diffusion (Delera and Foster-McGregor 2023). To the extent GVCs involve the production and exchange of green products and provide access to cleaner technologies, GVCs can help reduce emissions. By creating new global markets for low carbon products, GVCs can also lower emissions by encouraging innovation in green products and technology. By promoting global competition, GVCs can also be a source of innovation, potentially opening green windows of opportunity (UNCTAD 2023). Multinational enterprises and their affiliates—that tend to be major drivers of GVCs—may also improve the environment by improving technology and management practices as well as a shift toward cleaner products (Delera 2021).

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Box 6.1: continued

Although the three effects focus on the potential impact of GVC integration on emissions within economies, globally, impacts may differ. GVCs help reallocate production across economies, which either increases or decreases global emissions, depending on whether production is reallocated toward more emissions-efficient economies or not. In the case of the structural effect, for example, while an increase in production within GVCs may lead to a shift in production toward more efficient sectors, activities, or firms, resulting in lower emissions, if the increased GVC-related production in this economy is at the expense of production in more emission-efficient economies, global emissions could rise. While this holds for a given level of technology, in a dynamic sense, different global production structures as a result of GVCs can lead to different outcomes in terms of the production and diffusion of green technologies.

Conversely, GHG emissions and resulting climate change can have important effects on how GVCs function. Climate change policies should guarantee that GVCs can boost development in developing economies. The rise of GVCs is generally considered to have been driven by three main factors:

(i) reductions in the costs of trade through improvements in transport technology (e.g., containerization, refrigeration) and reductions in man-made trade barriers;

(ii) improvements in information and communication technologies that help coordinate globally organized production activities within GVCs; and

(iii) differences in factor endowments and factor costs that allow activities within the value chain to be divided through careful exploitation of global comparative advantage.

Climate change risks affect these different drivers, potentially altering the extent, structure, and dynamics of production within GVCs.

By impacting transport infrastructure and costs, climate change may change the incentives for global production. Climate change is expected to impact different transport modes within transport networks. According to the Intergovernmental Panel on Climate Change (IPCC) (2022a), rising sea levels and melting ice caps will likely lead to significant damage and disruption to ports, more generally exacerbating the societal impact on coastal communities (IPCC 2022a). These concerns are not just limited to maritime transport, however, with evidence suggesting that a significant component of road and railway infrastructure is exposed to extreme flooding events (Koks et al. 2019). These potentially disrupt production, and with maritime shipping accounting for transporting up to 90% of goods and commodities (IMO 2015), there can be large economic consequences. The effects on GVC production will likely be amplified further, given the strong interdependencies between infrastructure systems in economies linked through GVCs.

Beyond the impact on natural trade costs, climate change may encourage higher man-made trade barriers. Climate change will likely reduce the availability of key natural resources, including water and food. And the transition to renewable and clean energy also relies on important yet scarce resources. This scarcity raises the possibility of rising protectionism as economies attempt to secure access. Moreover, efforts to mitigate the effects of climate change can further broaden trade barriers, with mechanisms that put a price on imported carbon resulting in higher effective average tariffs. By raising trade costs, these policy measures will likely influence the extent and geographic structure of GVC production.

The hyper-specialization that GVCs encourage can exacerbate climate change disruptions, making GVC coordination more difficult. GVCs offer the possibility of extreme specialization (Antràs 2020), with certain goods becoming highly concentrated within a few economies (Challinor, Adger, and Benton 2017). Extreme weather events linked to climate change that affect economies or regions can create bottlenecks and spill over to other regions through GVCs. The flow of goods and services may be disrupted by distant climate change events, affecting the level and volatility of production activities through supply chain disruptions in regions not directly affected by these weather events (e.g., Haraguchi and Lall 2015). This is particularly true for GVCs that rely on specialized commodities and key infrastructure (IPCC 2022a). Conversely, GVCs can also create resilience to climate change, leaving firms less reliant on domestic or regional suppliers (Lim-Camacho et al. 2017; Willner, Otto, and Levermann 2018).

An economy's comparative advantage will likely change as economies shift from fossil fuels to renewable energy sources and toward low-carbon-intensive production (IPCC 2022a). In response to climate change, certain factors—notably fossil fuels—will likely become less relevant, reducing the role economies endowed with these resources play in GVCs. Conversely, other endowments—such as those needed for clean energy production—will be more in demand, creating more GVC opportunities. Other value chains are heavily reliant on climate-sensitive inputs (e.g., food processing), with climate change potentially affecting the level and distribution of their activity. These effects will likely impact developing economies to a greater extent than advanced economies, with existing evidence suggesting that imports into the United States from developing economies are reduced by temperature

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Box 6.1: continued

rises, particularly imports of agricultural products and light manufacturing (Jones and Olken 2010). This negative effect of climate change on exports from developing economies may further increase the price of goods imported by developed economies, with negative welfare effects of climate change in climate vulnerable regions being transmitted to non-vulnerable regions (Constant and Davin 2019). Over the longer term, climate change can affect the level and quality of factor endowments, shifting an economy's comparative advantage and production structure (IPCC 2022a). Extreme weather events—such as floods, drought, and extreme heat—are associated with land quality degradation, changes in the hydrological cycle and loss of land, among other impacts. Extreme weather events can also degrade physical capital, both physical infrastructure such as railways and roads as well as machinery through overheating, faster rates of depreciation and the need for longer cooling periods (IPCC 2022a). Extreme temperatures also impact workers' ability to undertake both physical and cognitive tasks (Kjellstrom, Holmer, and Lemke 2009; Somanathan et al. 2021; UNDP 2016).

Beyond these three main drivers of GVCs, climate change can further affect the level and structure of global demand, with consequences for GVC production. The demand structure is likely affected by climate change, with changes in temperature and rainfall leading to changes in human needs. In addition to the structure of demand, levels of demand may be affected, especially in climate-vulnerable economies, which in turn can impact trade for economies strongly integrated with them (Schenker 2013; Schenker and Stephan 2014). Beyond the direct impact of climate change on demand, public awareness and concern over climate change can alter demand toward greener goods, potentially encouraging adoption of more stringent climate policies (Magnani 2000; Nordström and Vaughan 1999).

Sources: ADB using ADB (2023b); Antràs (2020); Antweiler, Copeland, and Taylor (2001); Challinor, Adger, and Benton et al. (2017); Constant and Davin (2019); Copeland, Shapiro, and Taylor (2021); Delera (2021); Delera and Foster-McGregor (2023); Haraguchi and Lall (2015); IMO (2015); IPCC (2022a); Jones and Olken (2010); Kjellstrom, Holmer, and Lemke (2009); Koks et al. (2019); Lim-Camacho et al. (2017); Magnani (2000); Nordström and Vaughan (1999); Schenker (2013); Schenker and Stephan (2014); Somanathan et al. (2021); UNCTAD (2023); UNDP (2016); and Willner, Otto, and Levermann (2018).

through domestic carbon pricing schemes—may be limited by carbon leakage through GVCs, with production activities shifting to economies where carbon pricing schemes are either weaker or nonexistent. The risk of carbon leakage and difficulty of regulating GHG emissions within GVCs—along with evidence that GVCs hold an increasing share of GHG emissions—highlight the significant challenge of GVCs in moving toward net zero emissions. These concerns are reflected in recent policy discussions, notably the development of the European Union's (EU) Carbon Border Adjustment Mechanism (CBAM), a major rationale being to prevent carbon leakage within GVCs. While evidence in favor of carbon leakage is currently limited (for example, Verde 2020), as the prevalence of carbon pricing increases and carbon prices begin to rise, then the potential for carbon leakage increases. Beyond these external pressures on developing economies, there is also self-interest involved. With climate change potentially leading to fundamental changes in production and disrupting GVCs (Box 6.1), developing economies have an incentive to decarbonize GVC activity to both use GVCs as a development tool and to position themselves better in green GVC segments.

An important challenge is how to reconcile the changes needed in the global production system to mitigate climate change with the GVC development model. Climate change mitigation requires a fundamental transition in the global production system, shifting away from a carbon-based economy toward more resource-efficient production. These changes add risk to the GVC development model, which contributes to climate change through increased energy consumption and CO_2 emissions in GVC-related transportation (Box 6.2) and production, and has shifted GHG emissions production to economies and regions with less stringent environmental policies associated with excessive waste production (Forti et al. 2020; Kaza et al. 2018). At the same time, GVCs can help reduce emissions, helping to both mitigate and adapt to climate change (Le Moigne and Ossa 2021). As the world responds to the climate challenge, there is a need to understand how government policy changes will affect GVCs, how much they can be a positive force for climate change mitigation, and how they affect the risks and vulnerabilities of the GVC model to climate change and their responses. Ultimately, the answers to these questions will depend on the extent to which GVCs contribute to CO_2 emissions, the relationship between GVC activity and CO_2 emissions, and how policy interventions to mitigate climate change will likely impact the breadth and structure of GVCs.

Box 6.2: The Role and Impact of Transportation in Carbon Dioxide Emissions

Significant amounts of greenhouse gas emissions are associated with transportation. According to the Intergovernmental Panel on Climate Change (IPCC) (2022a), transportation accounted for 15% of total net anthropogenic greenhouse gas (GHG) emissions in 2019. And unlike other sectors, there is little evidence its growth rate dropped over the previous decade. More than half the carbon dioxide (CO_2) emissions linked to transportation are due to passenger travel (Ritchie 2020). Still, transportation linked to international trade remains a significant source of emissions, with road freight accounting for 29.4% of CO_2 transportation emissions, and shipping 10.6% (Ritchie 2020). The rise of global value chains (GVCs) has been an important contributor to these rising transport-related emissions. Indeed, evidence suggests that international transport accounts for about a third of world trade-related emissions (Cristea et al. 2013). It is higher in many developed economies with substantial differences across sectors.[a] In 2015, international transport accounted for 1.14 gigatons of CO_2 emissions, accounting for 16% of value chain emissions (Wang, Wang, and Chen 2022).

GVCs increase shipping per unit of final output, increasing the average distance goods travel. One implication of GVC development is that intermediate inputs cross borders multiple times during production of final goods (Klotz and Sharma 2023). The overall distance traveled by components of a final good is thus higher than without GVCs. Much of this increase comes from maritime shipping, with the International Maritime Organization estimating that up to 90% of goods and commodities trade is through maritime shipping (IMO 2015). Recent evidence shows that, after accounting for economic growth, real transport use per unit of final consumption more than doubled from 1965 to 2020 (Ganapati and Wong 2023).

Driven by falling transportation costs, GVCs are the main factor explaining the increased distances goods travel. Despite recent price increases due to the coronavirus disease (COVID-19) pandemic, transportation costs have fallen substantially over time, with evidence suggesting that global transportation costs have declined by 33%–39% by weight and 48%-62% by value over the past half century (Ganapati and Wong 2023). The role of GVCs in increasing distances traveled by final goods is evidenced by the observation that all of the increase in global transport use by weight since 1990 can be accounted for entirely by the People's Republic of China (PRC), with trade over longer distances (more than 5,000 kilometers) accounting for most of the increase (Ganapati and Wong 2023).

Although distances traveled by goods have increased with GVCs, the impact on overall emissions is less clear. The effect of GVCs on emissions is twofold (Cristea et al. 2013). First, it leads to a reallocation of production, which can either raise or lower emissions, depending on whether production is reallocated to economies with relatively low or high emissions intensity. Second, it increases the distance traveled by goods, which raises GHG emissions. The overall effect is thus ambiguous in theory. However, evidence suggests that relative to autarky, a minority (31%) of trade flows lead to overall reduced emissions—with production in trade shifted to economies with relatively low emissions intensity, and with international transportation emissions being small relative to the differences in emissions intensities (Cristea et al. 2013).[b] Conversely, the remaining trade flows are associated with higher aggregate emissions—aggregate trade leads to higher emissions.

While GVCs may impact climate change through GHG emissions in transportation, climate change can have feedback effects on GVCs through transport as well. Climate change may change the structure of international transportation, with positive and negative consequences. One potential response could be a shift in mode of transportation (IPCC 2022a). Currently, maritime shipping is the main source of transporting goods and commodities, accounting for around 90% of world trade (IMO 2015), with other modes such as air transport being used for specific types of trade, such as time-sensitive products. As water levels in lakes and rivers drop and with the greater impact of rising sea levels and extreme weather events on port efficiency, climate change may lead to a shift to alternative modes of transportation (Koetse and Rietveld 2009; Du, Kim, and Zheng 2017). Recent concerns over the lack of rainfall at the Gatún Lake that feeds the Panama Canal, for example, resulted in a substantial fall in tonnage traveling through the canal (Arslanalp et al. 2023). Given that different forms of transport have different impacts on CO_2 emissions—with air transport the most emissions intensive, followed by road transport—a shift in transportation mode can significantly affect CO_2 emissions related to transportation. Certain changes related to climate change may also bring economic benefits and further encourage GVC development, with the melting of polar ice sheets potentially opening shorter and more profitable trade routes (Melia, Haines, and Hawkins 2016; Pizzolato et al. 2016; Ng et al. 2018; Mudryk et al. 2021). The opening of a northwest passage because of ice cap loss, for example, has been estimated to reduce maritime

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Box 6.2: continued

shipping times and distances between Asia and Europe by up to 40% (Bekkers, Francois, Rojas-Romagosa 2018). Ultimately, the relationship between GVCs, transportation, and climate change are highly complex, with uncertainty over the net effect of GVC transportation on overall emissions and with strong feedback loops between transportation and climate change. As the IPCC (2022a) highlighted, however, the challenges of reducing emissions in transportation are large, with scenario modeling suggesting that the sector will not reach zero emissions by 2100. This is despite possible mitigation measures including the electrification of more transport services and the use of sustainable biofuels and low-emissions hydrogen.

[a] According to the United States (US) Environmental Protection Agency (EPA), transportation accounts for about 29% of GHG emissions in the US (EPA). According to the work of Cristea et al. (2013), for example, 80% of trade-related emissions in machinery exports are from international transportation.

[b] Case study evidence on trade in cut roses shows that those produced in Kenya and shipped by air to the United Kingdom (UK) results in a reduction of emissions compared to roses produced in the UK (Williams 2007).

Sources: ADB using Arslanalp et al. (2023); Bekkers, Francois, and Rojas-Romagosa (2018); Cristea et al. (2013); Du, Kim, and Zheng (2017); Ganapati and Wong (2023); IMO (2015); IPCC (2022a); Koetse and Rietveld (2009); Klotz and Sharma (2023); Melia, Haines, and Hawkins (2016); Mudryk et al. (2021) ; Ng et al. (2018); Pizzolato et al. (2016); Ritchie (2020); and Wang, Wang, and Chen (2022).

The Contribution of Global Value Chains to Carbon Dioxide Emissions

From 1995 to 2018, global CO_2 emissions from all production sources rose by around 2% per year. A decomposition of CO_2 emissions embodied in an economy's production activities (plus direct emissions by households) shows the recent trend in global CO_2 emissions along with a decomposition of these emissions between different sources activity (Box 6.3).[39] The average compound annual growth rate of emissions from 1995 to 2018 was 2.1%, with the growth rate somewhat lower after 2010 (1.8%) than before (2.2%). This is consistent with the conclusion of the IPCC (2022a) that while anthropogenic carbon emissions during 2010–2019 were larger than in any other time period, the growth rate of emissions was lower than during the previous decade. According to the IPCC scenarios, efforts to limit temperature rises to 1.5°C will require peak GHG emissions to be reached by 2025 and GHG emissions to be reduced by 43% by 2030. Despite the slowdown in the growth of CO_2 emissions in the most recent period, emissions continued to rise year-on-year during 1995–2019[40]—with the brief exception of the global financial crisis, indicating what is needed to achieve the goal of limiting warming to 1.5°C.

GVCs play a relatively small but increasing role in CO_2 emissions production. Emissions associated with domestic production for domestic consumption are by far the largest contributor to overall emissions, accounting for 64% in 2018 (Figure 6.2). Combined, traditional trade and GVCs accounted for 22% of CO_2 emissions in 2018, with GVCs accounting for 14% and traditional trade 8%. The average growth rate of production-based CO_2 emissions during 1995–2019 was smallest for household emissions (0.9% per year), compared to production for domestic consumption (2.1%), traditional trade (2.4%), and GVC trade (2.9%). Thus, the growth rate of emissions was higher for GVC production activities than for other sources of CO_2 emissions. Although there is some evidence of a declining growth rate of CO_2 emissions in GVCs, with an average annual growth rate of 3.3% for 1995–2009 and 2.3% over 2010–2018, the average

39 While commonly used in recent studies, the data used for this kind of analysis are subject to various constraints and rely on certain strong assumptions (see Box 6.2). Most notably, the approach assumes that in any given year the CO_2 intensity (i.e., the ratio of CO_2 emissions to gross output) is constant within a sector, irrespective of whether production occurs within GVCs or by domestic firms.

40 The Organisation for Economic Co-operation and Development (OECD) data on CO_2 emissions are currently not available beyond 2018, meaning that it is not possible using that data source to consider emissions during and after the COVID-19 pandemic. Data from alternative sources, however, suggest that emissions dropped substantially in 2020, with Bhanumati, de Haan, and Tebrake (2022) reporting a drop of 4.6% in 2020, although this was more than offset by the increase of 6.4% in 2021.

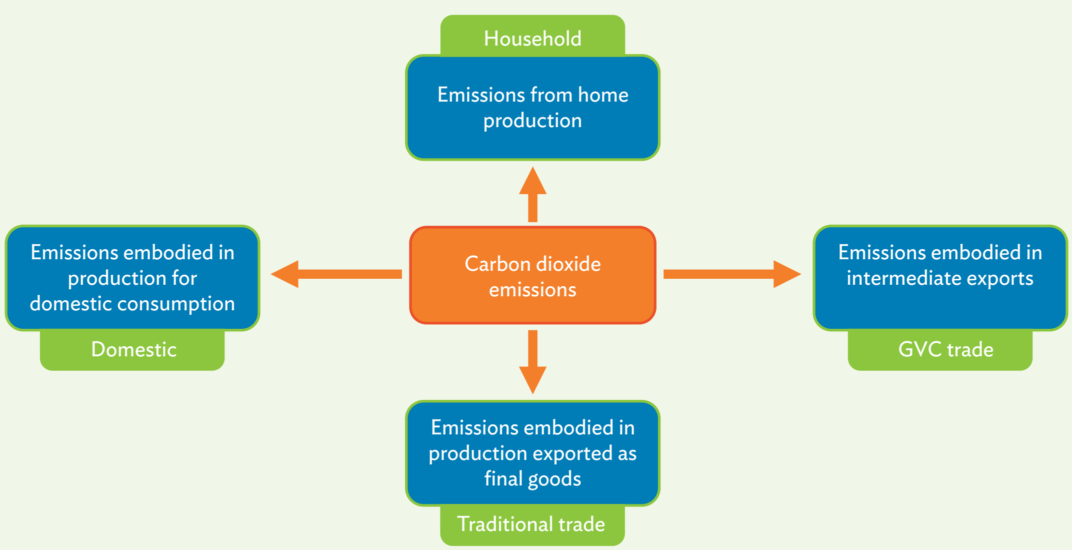
Box 6.3: Methodology for Measuring Emissions in Global Value Chains

The approach adopted to measure carbon dioxide (CO_2) emissions that occur within global value chains (GVCs) extends the decomposition of value-added proposed by Wang et al. (2017) to CO_2 emissions. They proposed decomposing an economy's value-added into a component that serves domestic demand, a component associated with traditional trade (e.g., the exchange of final goods) and a component associated with GVC trade. This GVC trade component was further split into two categories capturing simple and complex GVC integration, with simple GVCs involving the movement of value-added embodied in intermediate goods to an economy that uses it to produce final goods consumed in that economy, and complex GVCs involving the movement of value-added embodied in intermediate products to an economy that uses them to produce final or intermediate goods that are subsequently shipped to third economies. This approach was extended and applied to a decomposition of CO_2 emissions by, among others, Meng et al. (2018).

Under a similar decomposition, CO_2 emissions in production activities are split into three categories: (i) emissions related to domestic production for domestic consumption; (ii) emissions related to traditional trade; and (iii) emissions related to GVC trade. One further component is added to the decomposition, which is emissions that are released directly by domestic households (non-production activities such as using fuel in automobiles, heating, etc.). Box figure 1 describes the different sources into which overall emissions are decomposed.

When considering production components of the decomposition, two different perspectives are considered. The primary focus is on emissions that a sector in a particular economy produces in production activities that are then used in downstream production, either domestically or abroad. This is the standard definition of production-based CO_2 emissions from a territorial perspective, considering emissions produced within the borders of the economy. A second dimension, however, is emissions embodied in intermediate goods and services that are then used by a sector within an economy in its production activities serving either domestic demand or foreign demand through either traditional or GVC trade. This approach traces CO_2 emissions embodied in the flow of intermediate goods and services to the final product, and thus reflects a final production or use perspective, with emissions potentially being sourced both domestically and from abroad. The use perspective thus reflects CO_2 emissions received by a sector through backward linkages, while the production perspective reflects CO_2 emissions produced in a sector and supplied to other sectors and economies through forward linkages (box figure 2).

1: Decomposing Carbon Dioxide Emissions



GVC = global value chain.

Source: ADB.

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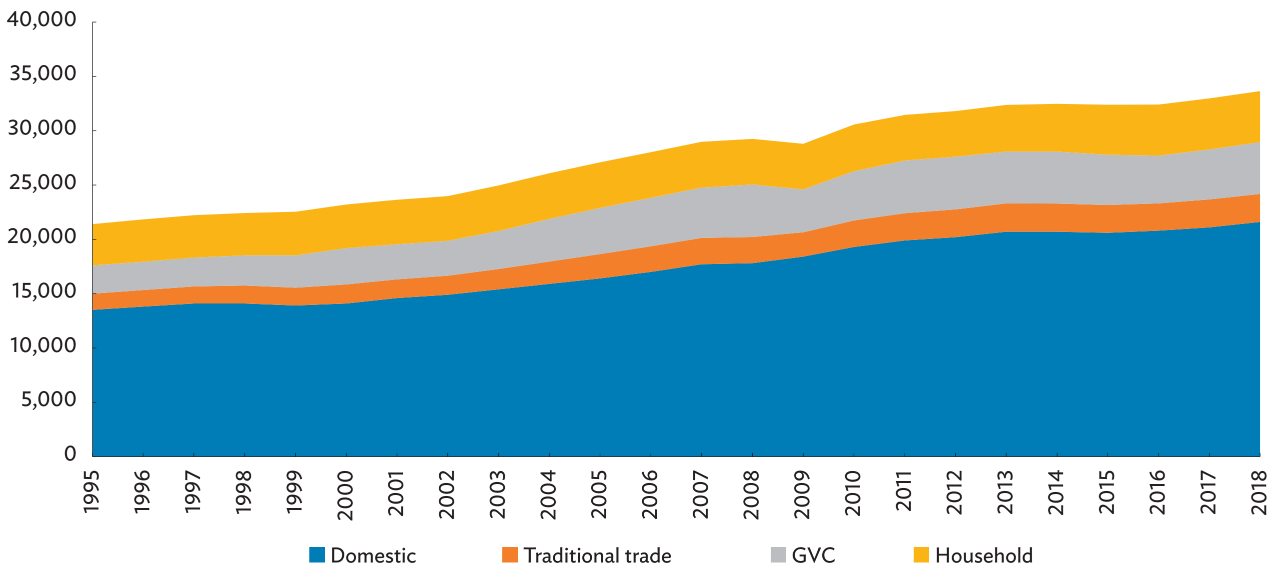
Box 6.3: continued

2: The Production and Use of Carbon Dioxide Emissions in Global Value Chains

Source: ADB.

Sources: ADB using Wang et al. (2017); and Meng et al (2018).

Figure 6.2: Decomposition of Carbon Dioxide Emissions Production (million metric tons)



GVC = global value chain.

Note: Data on emissions are limited to carbon dioxide and include carbon dioxide emissions from the combustion of fossil fuels, but exclude emissions due to land use, land-use change, and forestry and other non-energy related industrial processes.

Sources: ADB calculations using data from Organisation for Economic Co-operation and Development (OECD). Inter-Country Input-Output Tables. https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm; OECD. Carbon dioxide emissions embodied in international trade (TECO$_2$) data set. https://www.oecd.org/sti/ind/carbondioxideemissionsembodiedininternationaltrade.htm (both accessed November 2023).

growth rates of CO_2 emissions in GVCs in the latter period remain above those for the other sources of emissions (1.8% for domestic production, 1.5% for traditional trade, and 1.3% for household production). These differences in growth rates are also reflected in the changes in shares of emissions of the different sources. Combined, the two trade terms (traditional trade and GVCs) saw their share rise from 19% to 22% of total CO_2 emissions between 1995 and 2018, with the share for GVCs increasing from 12% to 14%.

Developing Asia accounts for an increasing share of GVC emissions production. Developing Asia's share in CO_2 emissions embodied in GVC production rose between 1995 and 2018 (Figure 6.3).[41] In 1995, developing Asia accounted for around 23% of overall GVC-related emissions, rising to 42% in 2018. By contrast, shares for all other regions declined. The share for developed Asia declined from 5.2% to 4.9%, and shares dropped from 23% to 15% in the EU and the United Kingdom (UK), 16% to 11% in North America, and 33% to 27% in the rest

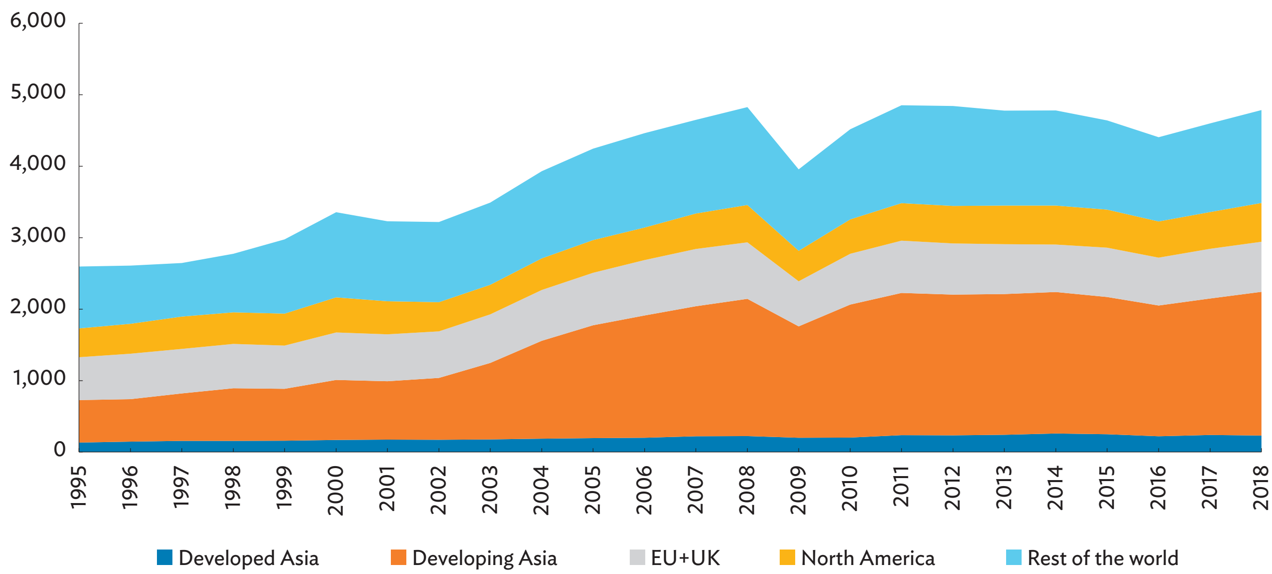
[41] Developing Asian economies included in the OECD databases include Brunei Darussalam; Cambodia; the PRC; Hong Kong, China; India; Indonesia; Kazakhstan; the Republic of Korea; the Lao People's Democratic Republic (Lao PDR); Malaysia; the Philippines; Singapore; Taipei,China; Thailand; and Viet Nam. Sectoral emissions data are not available for the Lao PDR in all years.

of the world.[42] These changes reflect the much higher growth rate of CO_2 emissions production in GVCs in developing Asia, with emissions growing by 238%, driven partly by inward foreign direct investment (Box 6.4). In comparison, the growth rate was 73% in developed Asia, 50% in the rest of the world, 34% in North America, and 17% in the EU and the UK.

While population growth in developing Asia accounts for part of its rising share of aggregate CO_2 emissions production, CO_2 emissions per capita are increasing while falling in other regions. In 1995, aggregate production-based CO_2 emissions per capita were lowest in developing Asia at 2.0 metric tons per capita (Figure 6.4), with emissions per capita substantially higher in North America (15.2 metric tons), the EU and the UK (8.3 metric tons), and developed Asia (7.5 metric tons). Between 1995 and 2018, emissions per capita dropped significantly in North America (to 12.3 tons per capita) along with the EU and the UK (6.8 metric tons). Conversely, developing Asia was the only region to see an increase in emissions per capita, with emissions per capita increasing from 2.0 metric tons per capita in 1995 to 4.4 metric tons in 2018.

GVCs account for the rising share of CO_2 emissions production per capita in most regions. While the share of CO_2 emissions production per capita for domestic consumption dropped in more developed regions—with shares falling by 10.7 percentage points in the EU and the UK, 6.0 percentage points in developed Asia, and 1.9 percentage points in North America—it increased by 2.2 percentage points in developing Asia. Combined with developing Asia's relatively rapid population growth, much of the increase in aggregate production-based emissions in the region was absorbed by domestic consumption. At the same time, the share of emissions per capita due to GVCs increased in the region by 1.6 percentage points between 1995 and 2018, with even larger increases elsewhere, with increases of 5.7 percentage points in developed Asia, 5.3 percentage points in the EU and the UK, and 2.2 percentage points in North America.

Figure 6.3: Carbon Dioxide Emissions Production for Global Value Chain Trade by Region (million metric tons)



EU = European Union (27 members), UK = United Kingdom.

Note: Data on emissions are limited to carbon dioxide (CO_2) and include CO_2 emissions from the combustion of fossil fuels, but exclude emissions due to land use, land-use change, and forestry and other non-energy related industrial processes.

Sources: ADB calculations using data from Organisation for Economic Co-operation and Development (OECD). Inter-Country Input-Output Tables. https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm; OECD. Carbon dioxide emissions embodied in international trade (TECO$_2$) data set. https://www.oecd.org/sti/ind/carbondioxideemissionsembodiedininternationaltrade.htm (both accessed November 2023).

42 Developed Asia refers to Australia, Japan, and New Zealand. The rest of the world includes Argentina, Brazil, Switzerland, Chile, Colombia, Costa Rica, Iceland, Israel, Morocco, Norway, Peru, the Russian Federation, Saudi Arabia, Tunisia, Türkiye, and South Africa, as well as an aggregate rest of the world included in OECD databases.

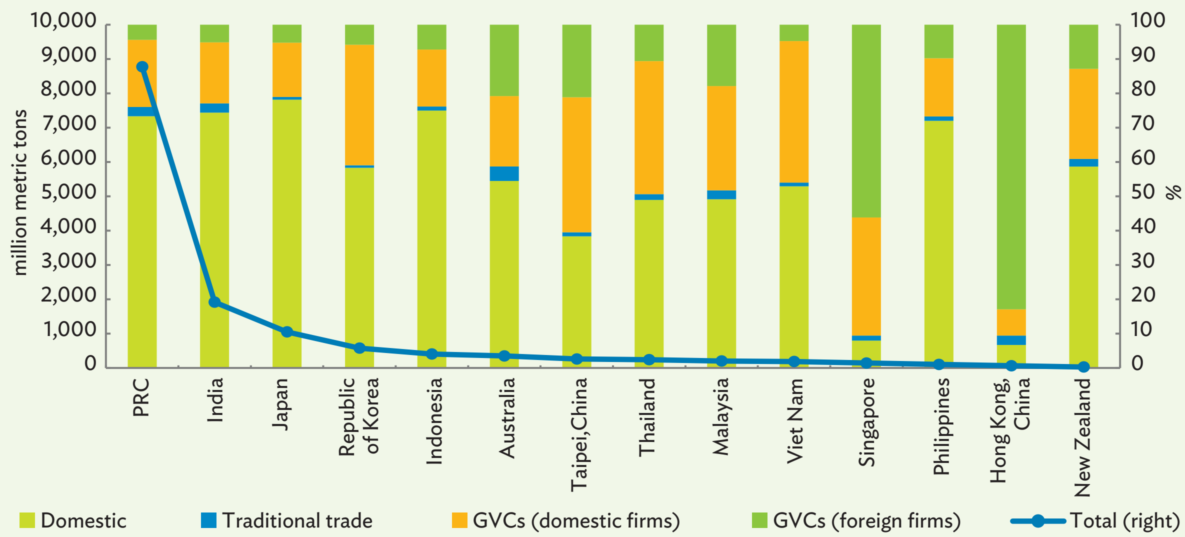
Box 6.4: The Contribution of Multinational Enterprises to Carbon Dioxide Emissions in Global Value Chains

Multinational enterprises (MNEs) play a major role within global value chains (GVCs) and contribute significantly to GVC carbon dioxide (CO_2) emissions. They enter host economies through foreign direct investment (FDI), combining domestic endowments (e.g., labor and resources) with foreign endowments (e.g., capital, technology, and management). They play a primary role in coordinating international trade and GVC activity. MNEs and their network of foreign affiliates account for almost two-thirds of world exports, with foreign affiliates accounting for 30% of global exports (Miroudot and Rigo 2022). Through their role in coordinating GVCs, MNEs are crucial in shaping global production patterns by allocating activities based on the host economy's resource endowments, with implications for the levels of CO_2 emissions of the economies hosting foreign affiliates. Historical evidence suggests that nearly two-thirds of industrial CO_2 and methane (CH_4) emissions from 1751 to 2010 can be attributed to 90 firms producing cement and energy (Heede 2014). A better understanding of the nexus between MNE activity and carbon emissions in GVCs can thus be critical in establishing effective cross-regional carbon governance (Wei et al. 2023; Wang, Wang, and Chen 2022).

Given their major role in GVCs, MNEs can help decarbonize GVCs. They can impose sustainability standards and encourage the transfer of green technologies within GVCs (Thorlakson, de Zegher, and Lambin 2018). They can further use low emission-intensive suppliers and more environmentally friendly distributors within their value chains. In addition, they can also be an important source of finance for sustainable development through FDI (Steenbergen and Saurav 2023). A significant portion of overall MNE emissions transcends the boundaries of the firm and borders of their point of origin. Thus, MNEs are a major driver of an unequal exchange, with emissions production shifting from the developed to developing world, raising emissions and their associated effects on health in developing economies.

Using data from the Organisation for Economic Co-operation and Development (OECD) Activity of Multinational Enterprise (AMNE) database—which splits production activities of domestic firms and foreign affiliates—and following the approach of Li et al. (2022), the extent to which the activities of MNEs and their affiliates contribute to an economy's CO_2 emissions can be examined.[a] Including MNE activities in GVC-related emissions results in a higher share of emissions considered to be GVC-related than when using a territorial-based approach to capture GVC emissions. Using this approach, the share of emissions due to GVCs in Asia was 25.5% in 2016, with the share for all economies 26.2%.[b] The

1: Carbon Dioxide Emissions by Production Type in Asian Economies, 2016



GVC = global value chain, PRC = People's Republic of China.

Note: Data on emissions are limited to carbon dioxide (CO_2) and include CO_2 emissions from the combustion of fossil fuels, but exclude emissions due to land use, land-use change, and forestry and other non-energy related industrial processes.

Sources: ADB calculations using data from Organisation for Economic Co-operation and Development (OECD). Analytical Activities of Multinational Enterprise. https://www.oecd.org/fr/sti/ind/analytical-amne-database.htm; OECD. Carbon dioxide emissions embodied in international trade ($TECO_2$) data set. https://www.oecd.org/sti/ind/carbondioxideemissionsembodiedininternationaltrade.htm (both accessed November 2023).

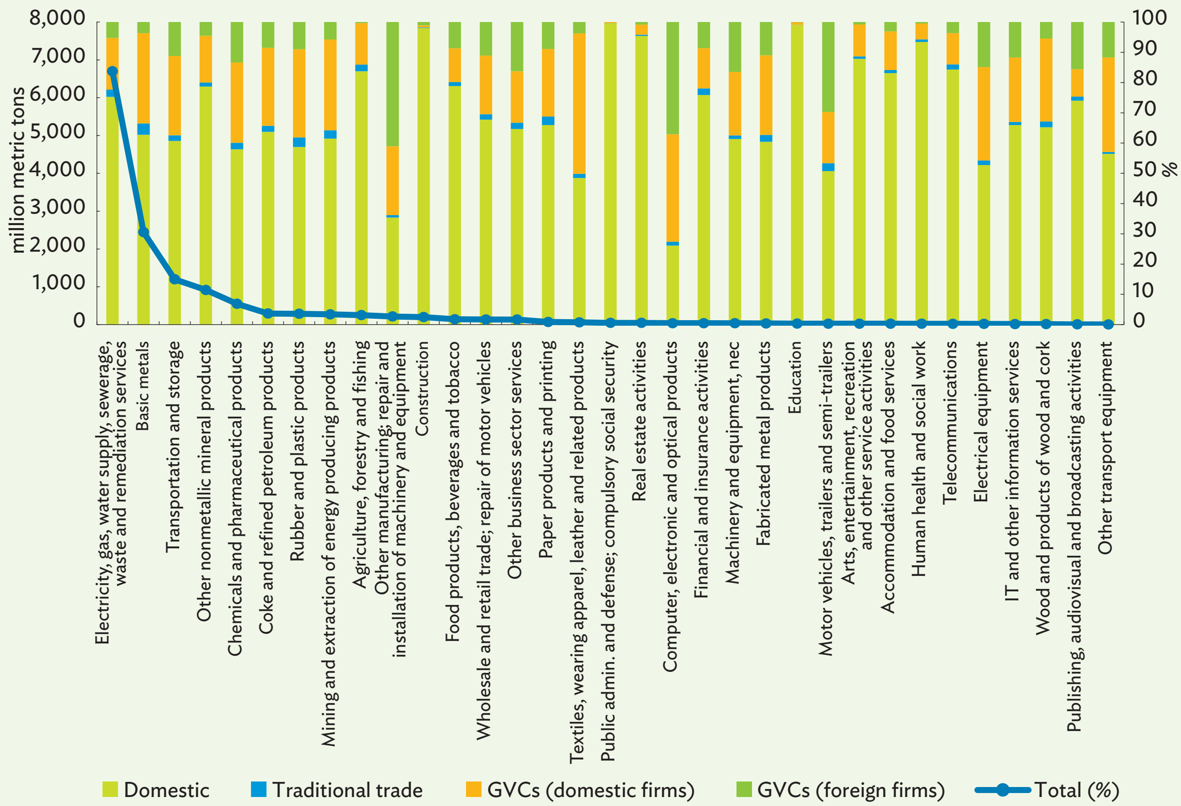
continued on next page

Box 6.4: continued

relative importance of MNE activity to these emissions is found to vary substantially across Asian economies. While domestic production serving domestic consumption tends to dominate in the larger economies with the highest levels of emissions, in other economies GVC activity is a major contributor to overall emissions (box figure 1). Emissions due to MNE activities within GVCs are found to be relatively important in many economies, accounting for more than 50% of GVC related emissions in Singapore; Hong Kong, China; and Australia, and for more than 30% of emissions in Indonesia; Taipei,China; Malaysia; the Philippines; and New Zealand. Conversely, the share of emissions in GVCs due to MNEs is relatively low in Viet Nam (10.4%), the Republic of Korea (14.2%), and the People's Republic of China (18%).

The contributions of GVCs and MNEs to emissions vary greatly across sectors. In Asia, GVC shares of total emissions are relatively high in typical GVC sectors like other transport equipment, electrical equipment, motor vehicles, textiles, other manufacturing, and computer and electronic products (box figure 2). Of these, other manufacturing, motor vehicles, and computer and electronic products have a higher share of emissions in GVCs due to foreign firms than to domestic firms (also for construction and publishing). For both Asian and non-Asian economies, many of the sectors with the highest share of emissions due to GVCs also have a higher share of foreign firm emissions than domestic firms. This is especially true for typical GVC sectors, highlighting the role MNEs play.

2: Sectoral Contributions to Carbon Dioxide Emissions in Asian Economies, 2016



GVC = global value chain, IT = information technology, nec = not elsewhere classified.

Note: Data on emissions are limited to carbon dioxide (CO_2) and include CO_2 emissions from the combustion of fossil fuels, but exclude emissions due to land use, land-use change, and forestry and other non-energy related industrial processes.

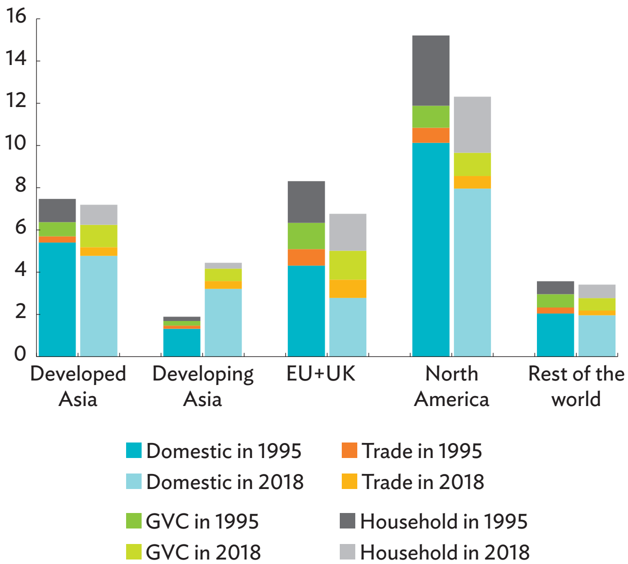
Sources: ADB calculations using data from Organisation for Economic Co-operation and Development (OECD). Analytical Activities of Multinational Enterprise. https://www.oecd.org/fr/sti/ind/analytical-amne-database.htm; OECD. Carbon dioxide emissions embodied in international trade (TECO$_2$) data set. https://www.oecd.org/sti/ind/carbondioxideemissionsembodiedininternationaltrade.htm (both accessed November 2023).

[a] The approach relies on similarly strong assumptions to those for estimating emissions due to GVC activity. While foreign and domestic firms are usually considered to differ in production technologies and structure due to various ownership advantages (Dunning 1988), for example, there is no separate data on CO_2 intensities for domestic and foreign firms, meaning that the same intensity is used for both domestic and foreign firms. FDI emissions intensity may also vary by type of entry or entry mode, which similarly is not captured in the data.

[b] By comparison, the share of emissions due to GVCs in 2016 using the territorial approach is estimated at 13.6%.

Source: ADB using Li et al. (2022); Heede (2014); Miroudot and Rigo (2022); Steenbergen and Saurav (2023); Thorlakson, de Zegher, and Lambin (2018); Wei et al. (2023); and Wang, Wang, and Chen (2022).

Figure 6.4: Production Emissions per Capita by Source and Region (metric tons per capita)



EU = European Union (27 members), GVC = global value chain, UK = United Kingdom.

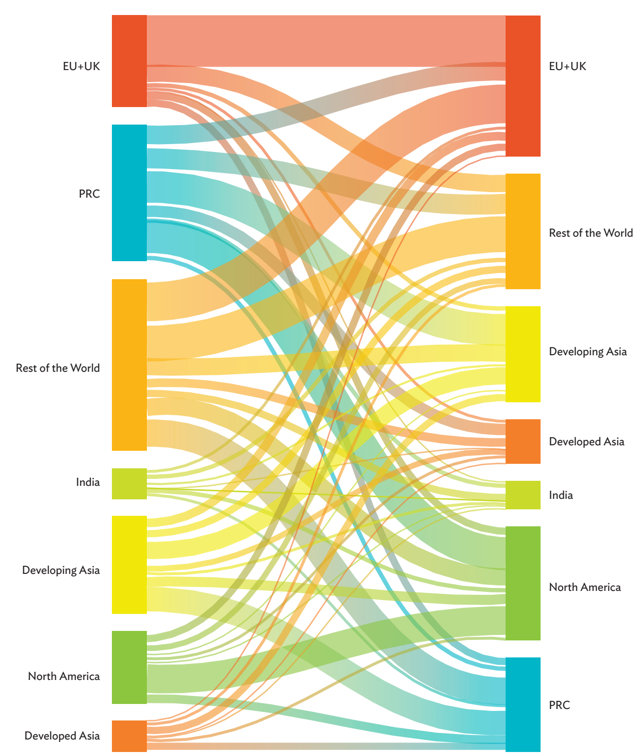
Note: Data on emissions are limited to carbon dioxide (CO_2) and include CO_2 emissions from the combustion of fossil fuels, but exclude emissions due to land use, land-use change, and forestry and other non-energy related industrial processes.

Sources: ADB calculations using data from Organisation for Economic Co-operation and Development (OECD). Inter-Country Input-Output Tables. https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm; OECD. Carbon dioxide emissions embodied in international trade (TECO$_2$) data set. https://www.oecd.org/sti/ind/carbondioxideemissionsembodied ininternationaltrade.htm; and World Bank. World Development Indicators. https://databank.worldbank.org/source/world-development-indicators (all accessed November 2023).

The Production and Use of Embodied Carbon Dioxide Emissions in Global Value Chains

Developing Asia is a net supplier of CO_2 emissions in GVCs. Different production stages in GVCs are often done in different economies, with different economies becoming net suppliers or net recipients of emissions due to their GVC production activity. The extent to which an economy is a supplier or recipient of CO_2 emissions in GVC production depends on several factors, including its position in GVCs. An economy engaged in upstream and often energy-intensive production will likely be a net supplier of emissions, while an economy situated further downstream engaged in assembly and other activities will likely be a net recipient of the emissions embodied in imported intermediate inputs. Previous figures reported CO_2 emissions embodied in production activities, capturing emissions in GVCs due to forward linkages or upstream production. Figure 6.5 introduces backward linkages or downstream production, reporting information on a region's emissions production in GVCs (left-hand side) and the embodied CO_2 emissions it receives through imported intermediates (right-hand side) for 2018. It shows the PRC, other developing Asia, and the rest of the world are net suppliers of GVC emissions, meaning their exports of domestically produced CO_2 embodied in intermediates exceed foreign-produced CO_2 emissions embodied in their intermediate purchases.

Figure 6.5: Regional Carbon Dioxide Emissions Production and Regional Carbon Dioxide Emissions Destinations in Global Value Chains, 2018



EU = European Union (27 members), PRC = People's Republic of China, UK = United Kingdom.

Note: Data on emissions are limited to carbon dioxide (CO_2) and include CO_2 emissions from the combustion of fossil fuels, but exclude emissions due to land use, land-use change, and forestry and other non-energy related industrial processes.

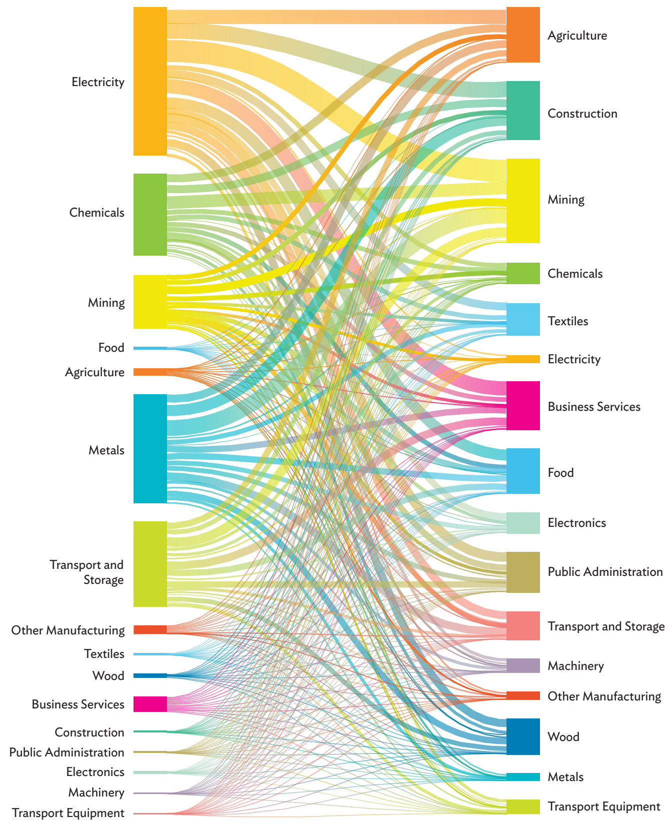
Sources: ADB calculations using data from Organisation for Economic Co-operation and Development (OECD). Inter-Country Input-Output Tables. https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm; OECD. Carbon dioxide emissions embodied in international trade (TECO$_2$) data set. https://www.oecd.org/sti/ind/arbondioxideemissionsembodiedininternationaltrade.htm (both accessed November 2023).

Conversely, developed Asia, the EU and the UK, and North America receive more embodied CO_2 emissions in imported intermediate purchases within GVCs than intermediate exports. This highlights the potential challenges of GVCs for policymakers, with CO_2 emissions embodied in imported intermediate inputs—potentially not subject to a region's carbon policies—contributing substantially to CO_2 emissions embodied in a region's downstream GVC production.

Sectoral Contributions to the Production and Use of Embodied Carbon Dioxide Emissions in Global Value Chains

The production of CO_2 emissions in GVCs is concentrated in a handful of sectors, though these emissions are used across a broad range of downstream sectors. Figure 6.6 illustrates the extent of CO_2 emissions production in GVCs by sector (left-hand side) and the use of the emissions (embodied in intermediate input purchases) in GVCs (right-hand side). It underscores the strong concentration of CO_2 emissions production in a small number of sectors—electricity, chemicals, metals, mining, and transport and storage. These emissions—or the intermediates embodying these emissions—are used in downstream GVC production across a broader range of sectors, with mining, construction, agriculture, business services, and public administration accounting for higher shares. There are two dimensions to consider when looking at emissions in GVCs—the primary source of CO_2 emissions and which sectors use them. Efforts to reduce CO_2 emissions can thus focus on these two dimensions; reducing emissions in sectors where primary emissions are produced and increasing the efficiency of those that use embodied emissions in production. That the production of emissions tends to be concentrated in a small number of sectors suggests that it may be better for policymakers to pursue policies focused on production rather than use of (embodied) CO_2 emissions.

Figure 6.6: Production and Use of Carbon Dioxide Emissions in Global Value Chains by Sector, 2018



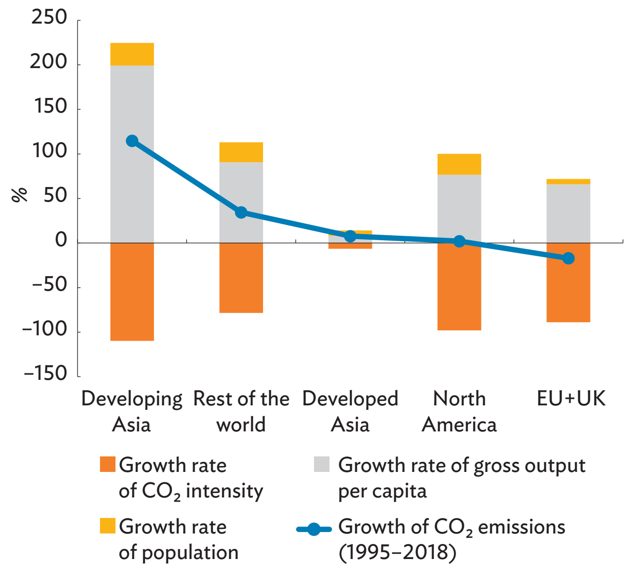
Note: Data on emissions are limited to carbon dioxide (CO_2) and include CO_2 emissions from the combustion of fossil fuels, but exclude emissions due to land use, land-use change, and forestry and other non-energy related industrial processes.

Sources: ADB calculations using data from Organisation for Economic Co-operation and Development (OECD). Inter-Country Input-Output Tables. https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm; OECD. Carbon dioxide emissions embodied in international trade (TECO$_2$) data set. https://www.oecd.org/sti/ind/arbondioxideemissionsembodiedininternationaltrade.htm (both accessed November 2023).

The Relationship between Global Value Chain Activity and Carbon Dioxide Emissions

The growth rate of CO_2 emissions in developing Asia has been relatively rapid, despite a substantial drop in the emissions intensity of production. The level of CO_2 emissions in production can be decomposed into two components—one capturing CO_2 emissions intensity (e.g., the ratio of CO_2 emissions to gross output) and the other a scale effect (e.g., the level of gross output).[43] Identifying the relative importance of the two in driving aggregate emissions and of the role GVCs play in these two dimensions is crucial to understanding the impact of GVCs on CO_2 emissions. This decomposition can be used to consider the contributions of these different components to the growth rate of aggregate CO_2 emissions production. For 1995–2018, the growth rate of CO_2 emissions in developing Asia was 114% (Figure 6.7). This growth rate was substantially higher than in other regions—with the growth rate in the rest of the world 34%, developed Asia 7.7%, and North America 2.1%. Within the EU and the UK, CO_2 emissions fell by 17% over the period. The rapid growth in emissions in developing Asia was driven by the rapid growth in gross output per capita, which increased by nearly 200%, with population growth associated with a 25% increase in CO_2 emissions. These increases were partially offset by a 110% reduction in CO_2 intensity. The reduction in CO_2 intensity occurred across all regions, with the rate being largest for developing Asia. Thus, while technological and structural change have reduced CO_2 intensity in developing Asia's production, the increase in gross output per capita to satisfy both domestic and foreign demand far outweighed the reductions in CO_2 intensity, resulting in a substantial increase in emissions.[44]

Figure 6.7: Growth Rate and Decomposition of the Growth of Carbon Dioxide Emissions in Production, 1995–2018 (%)



CO_2 = carbon dioxide, EU = European Union (27 members), UK = United Kingdom.

Notes: The figure decomposes the growth rate of carbon dioxide (CO_2) emissions using $\Delta \ln CO_2 = \Delta \ln\left(\frac{CO_2}{GO}\right) + \Delta \ln\left(\frac{GO}{POP}\right) + \Delta \ln POP$, where GO and POP refer to gross output and population. In is natural logarithm, and Δ refers to the change between two time periods.

Sources: ADB calculations using data from Organisation for Economic Co-operation and Development (OECD). Inter-Country Input-Output Tables. https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm; OECD. Carbon dioxide emissions embodied in international trade ($TECO_2$) data set. https://www.oecd.org/sti/ind/carbondioxideemissionsembodiedininternationaltrade.htm (both accessed November 2023).

Relative to their value-added contribution, GVCs account for a high share of CO_2 emissions in production. The data indicate that while there is a positive association between the share of GVCs in value-added and the share of GVCs in CO_2 emissions production, the shares of GVCs in total CO_2 emissions tend to be larger than those in value-added (Figure 6.8). As such, the sectoral structure of production in GVCs tends to be relatively emissions intensive. This confirms previous results that show international trade is tilted toward dirty goods and sectors (Le Moigne and Ossa 2021). For GVCs, this further reflects the strong association of GVCs with manufacturing, which tends to be more emissions intensive than non-manufacturing sectors.[45]

A higher scale in GVC production does not appear to result in increased efficiency in CO_2 emissions production. While a higher level of GVC production would generally be associated with more CO_2 emissions produced in an economy, the size of the increase is theoretically

[43] The scale effect can further be split into a component due to the level of population and a component capturing the level of gross output per capita by writing CO_2 emissions in production as $CO_2 = \frac{CO_2}{GO} \times \frac{GO}{POP} \times POP$, with GO being gross output and POP being population. Expressing this in logs and taking the difference between two time periods, the approximate growth rate of CO_2 emissions can be decomposed into an effect due to changing CO_2 intensity and the two scale terms. This can be written as $\Delta \ln CO_2 = \Delta \ln\left(\frac{CO_2}{GO}\right) + \Delta \ln\left(\frac{GO}{POP}\right) + \Delta \ln POP$, where ln is the natural logarithm and Δ refers to the change between the two time periods.

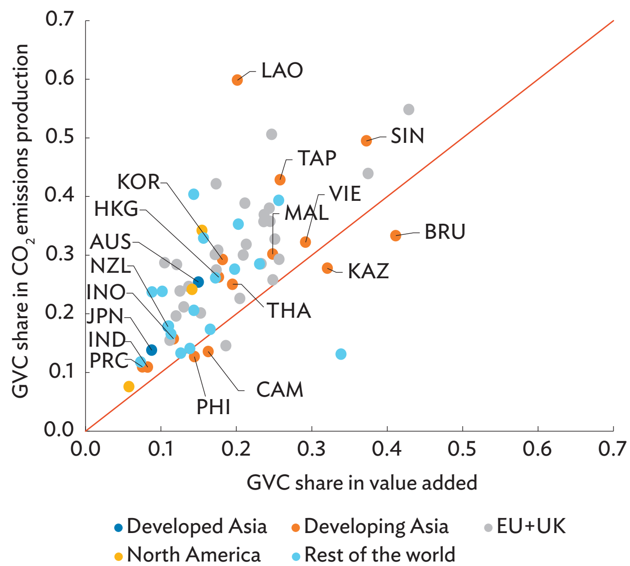
[44] While most of the gross output per capita serves domestic demand—its share increasing from 75% to 77% during the period—the share serving GVCs remained roughly constant at around 12.5%.

[45] Since the data only report overall sectoral CO_2 intensity of production, it must be the case that it is differences in sectoral structures of GVC production relative to other forms of production that drive the differences.

ambiguous. If increases in the scale of GVC production are associated with better emissions efficiency, then a 1% higher level of GVC production would be associated with a less than 1% higher level of aggregate CO_2 emissions. Conversely, if an increase in the scale of GVC production is associated with lower emissions efficiency, then a 1% higher level of GVC production would be associated with a more than 1% increase in CO_2 emissions. Considering the cross-section of economies covered by OECD databases and the data for 2018, emissions appear to scale roughly linearly with GVC production, such that a 1% higher level of GVC production is associated with a roughly 1% higher level of CO_2 emissions.[46] So the efficiency of emissions production in GVCs does not appear to be influenced by the scale of production.

Differences in the scaling relationship exist between developed and developing economies, with a given level of GVC production associated with higher emissions in developing economies. One version of the pollution haven hypothesis is that developed economies offshore some of their emissions-intensive activities to developing economies, making those economies even more emissions-intensive in production. Thus, it may be expected that the response of CO_2 emissions to increases in GVC production may be stronger in developing economies, which increasingly rely on less emissions-efficient firms. Data for 2018 provide some limited evidence in favor of this hypothesis (Figure 6.9). While the scaling relationship for developed economies suggests constant returns to scale in emissions production due to GVC production—with a 1% increase in GVC production associated with a 1% increase in aggregate CO_2 emissions—for developing economies the relationship is above 1, such that a 1% increase in GVC production is associated with a 1.15% increase in CO_2 production.[47] Moreover, for a given level of GVC production, aggregate CO_2 emissions tend to be higher in developing economies than developed economies. This suggests that GVC production in developing economies is more emissions-intensive than in developed economies—driven by a combination of differences in production technology and the sectoral structure of GVCs between developed and developing economies.

Figure 6.8: Scatterplot of Global Value Chain Shares in Value-Added and in Carbon Dioxide Emissions Production, 2018



AUS = Australia; BRU = Brunei Darussalam; CAM = Cambodia; CO_2 = carbon dioxide; EU = European Union (27 members); GVC = global value chain; HKG = Hong Kong, China; IND = India; INO = Indonesia; JPN = Japan; KAZ = Kazakhstan; KOR = Republic of Korea; LAO = Lao People's Democratic Republic, MAL = Malaysia; NZL = New Zealand; PHI = Philippines; PRC = People's Republic of China; SIN = Singapore; TAP = Taipei,China; THA = Thailand; UK = United Kingdom; VIE = Viet Nam.

Note: Developed economies are defined as high-income economies according to the classification of the World Bank, while developing economies refer to all other economies. GVC shares in CO_2 emissions are calculated excluding direct household emissions to make them comparable with the production data.

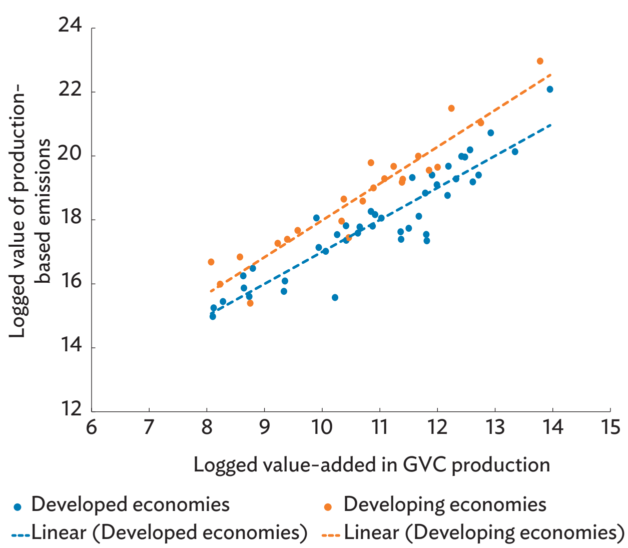
Sources: ADB calculations using data from Organisation for Economic Co-operation and Development (OECD). Inter-Country Input-Output Tables. https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm; OECD. Carbon dioxide emissions embodied in international trade (TECO2) data set. https://www.oecd.org/sti/ind/arbondioxideemissionsembodiedininternationaltrade.htm (both accessed November 2023).

[46] The scaling coefficients are obtained from a regression of the log of GVC-related production-based emissions on the log of GVC-related value-added. A coefficient of 1 on the log of value-added due to GVC production indicates a proportional increase in GVC-related emissions in response to an increase in GVC-related value-added, while a value above (below) one indicates super-linear (sub-linear) scaling such that a 1% increase in GVC-related value-added is associated with a greater (less) than 1% increase in GVC-related emissions. The coefficient for GVC production is 1.02, while for domestic production it is estimated at 0.998, and for traditional trade 0.926. The coefficients are never significantly different from one, suggesting little difference in the scaling relationship between domestic production, traditional trade, and GVC trade.

[47] The statistical association is not significantly different from one in the case of developed economies but is significantly different from one for developing economies (albeit only at the 10% level).

Being more upstream in GVCs is associated with a higher level of CO_2 emissions. Existing evidence suggests that positioning in GVCs can affect the extent of GVC emissions.[48] Specifically, positions further upstream in the value chain—having relatively strong forward linkages—are associated with higher emissions than positions further down the chain. Evidence for 62 economies supports this hypothesis, with a moderate negative association between positioning in GVCs (measured as the relative importance of backward linkages in GVCs—from the use perspective) and their CO_2 emissions (Figure 6.10). The structure and positioning of an economy's GVC activity are thus relevant dimensions for its contributions to CO_2 emissions through GVCs, with those positioned further upstream and with relatively high forward linkages having a higher level of GVC-related emissions.

Figure 6.9: Association between Global Value Chain Production and Carbon Dioxide Emissions Production, 2018

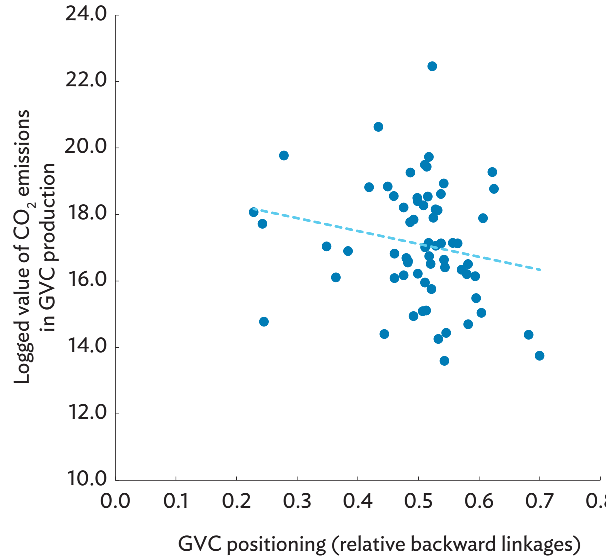


GVC = global value chain.

Note: Production-based emissions refer to those related to sectoral production activities and exclude direct emissions from households.

Sources: ADB calculations using data from Organisation for Economic Co-operation and Development (OECD). Inter-Country Input-Output Tables. https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm; OECD. Carbon dioxide emissions embodied in international trade (TECO$_2$) data set. https://www.oecd.org/sti/ind/carbondioxideemissionsembodiedininternationaltrade.htm (both accessed November 2023).

Figure 6.10: Association between Global Value Chain Positioning and Carbon Dioxide Emissions in Global Value Chains, 2018



CO_2 = carbon dioxide, GVC = global value chain.

Notes: GVC positioning is calculated as the ratio of GVC activity from a use perspective to the sum of GVC activity from a production and use perspective. As such, the indicator captures the importance of backward relative to forward linkages in GVCs.

Sources: ADB calculations using data from Organisation for Economic Co-operation and Development (OECD). Inter-Country Input-Output Tables. https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm; OECD. Carbon dioxide emissions embodied in international trade (TECO$_2$) data set. https://www.oecd.org/sti/ind/carbondioxideemissionsembodiedininternationaltrade.htm (both accessed November 2023).

CO_2 emissions intensity in value-added varies widely across economies, with emerging economies tending to have higher intensities. CO_2 intensities are particularly high in Asian economies such as Kazakhstan, the Lao PDR, Viet Nam, India, and the PRC (Figure 6.11). Based on OECD data, 6 of the top-10 economies by aggregate CO_2 intensity are in developing Asia. Many economies with high CO_2 emissions intensities—including the Russian Federation, South Africa, Saudi Arabia, and Brunei Darussalam—are heavily involved in resource extraction, highlighting again the importance of sectoral structure. Conversely, western European economies—Luxembourg, Switzerland, Sweden, France, Ireland, Austria, the UK—along with New Zealand and Costa Rica have relatively low CO_2 emissions intensities. In most economies, the CO_2 intensity associated with

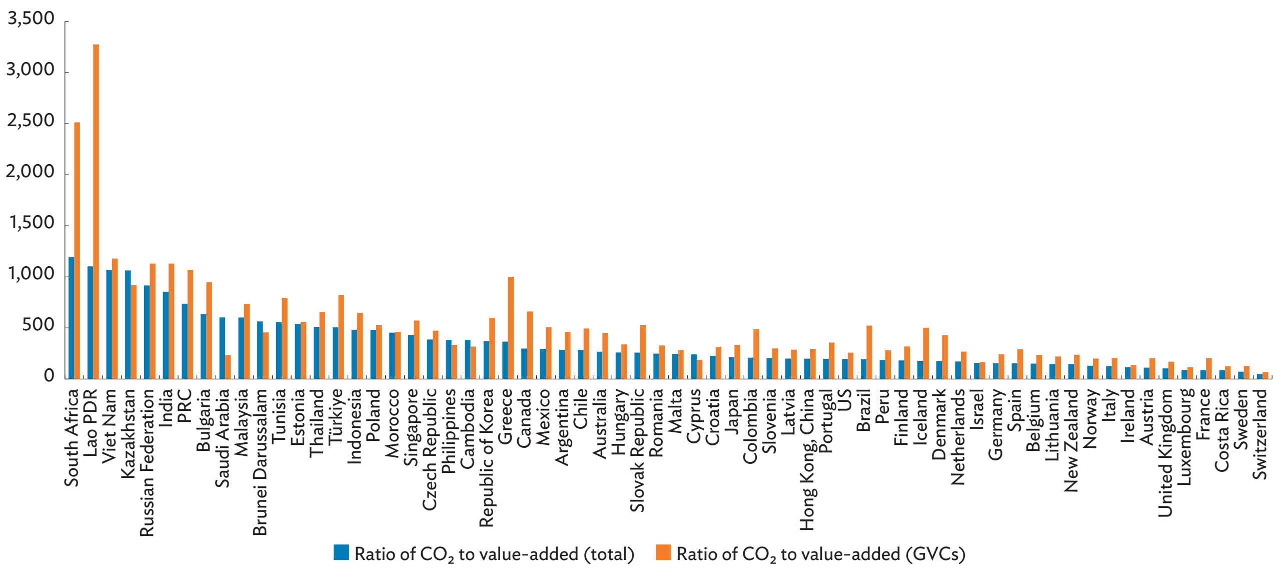
[48] See, for example, Huang and Zhang (2023).

GVC production in 2018 exceeds overall CO_2 intensity, the main exceptions being Saudi Arabia, Brunei Darussalam, and Kazakhstan—economies that export raw materials used in energy production elsewhere.[49]

CO_2 emissions intensities in production vary widely across sectors. The aggregate CO_2 emissions intensity of an economy depends on its sectoral structure and sectoral CO_2 emissions intensity (CO_2 emissions per unit of value-added). This represents an inverse measure of the CO_2 efficiency of production. There are wide differences in the average (across economies) CO_2 emissions intensity by sector. Electricity, water and air transport, basic metals, and nonmetallic minerals have the highest intensities with various services (such as real estate, health, publishing, and finance) showing relatively low intensities (Figure 6.12). In 2018, the CO_2 emissions intensity in electricity was 74 times that of the median sector—water transport was 44 times as large, basic metals 32 times, and air transport 26 times the median intensity.

Across many sectors, there have been substantial reductions in CO_2 emissions intensities. Between 1995 and 2018, CO_2 emissions intensities fell across nearly all sectors (except post and warehousing), with a 44% (unweighted) average decline over the period (Figure 6.12). The evidence strongly supports the view that technological change, better efficiency, and the reallocation of production through GVCs can substantially reduce the CO_2 intensity of production. Still, the drop in CO_2 intensity has not been enough to offset the increased emissions associated with the greater scale of production (see Figure 6.10). Reductions in CO_2 intensities have tended to be stronger in sectors that had initially relatively low CO_2 emissions intensities, suggesting greater challenges in bringing down emissions intensities in sectors with initially high intensities. For example, the average reduction in CO_2 emissions intensities from 1995 to 2018 for the 10 sectors with the highest initial emissions intensities was 38.6%, while the 10 with the lowest initial emissions intensities fell 50%.

Figure 6.11: Ratio of Carbon Dioxide Production to Total Value-Added, and Carbon Dioxide Production in Global Value Chains to Value-Added due to Global Value Chains, 2018



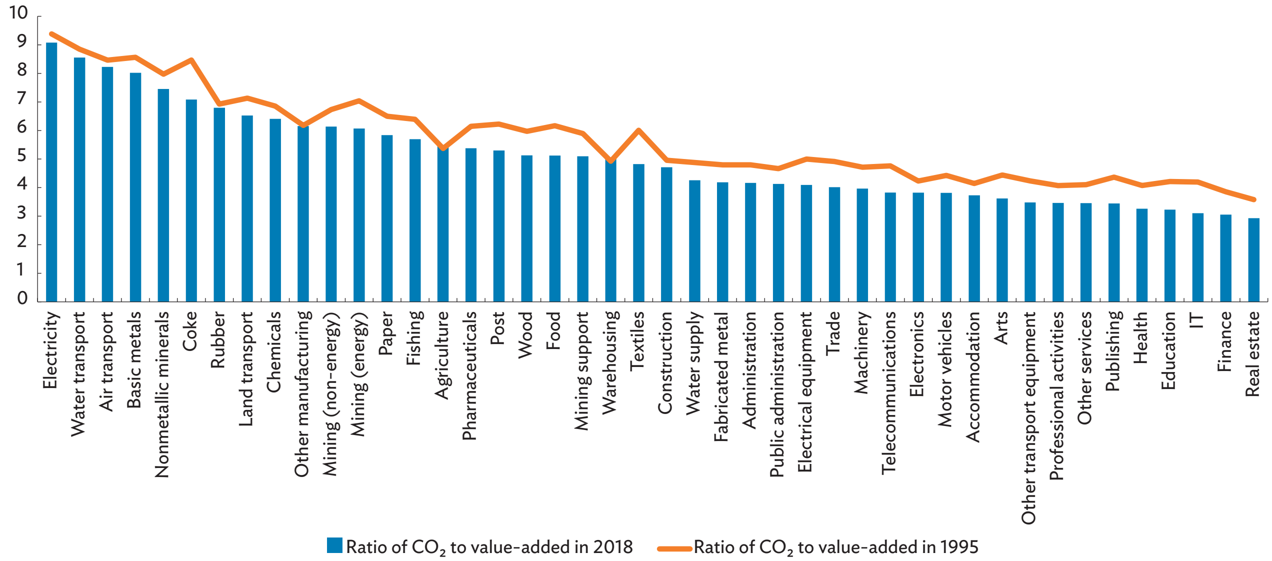
CO_2 = carbon dioxide, GVC = global value chain, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China, US = United States.

Note: CO_2 emissions intensity is measured as the ratio of aggregated carbon dioxide emissions (in total or due to GVC production) to aggregated value-added (in total or due to GVC production), with value-added deflated using the gross domestic product deflator.

Sources: ADB calculations using data from Organisation for Economic Co-operation and Development (OECD). Inter-Country Input-Output Tables. https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm; OECD. Carbon dioxide emissions embodied in international trade ($TECO_2$) data set. https://www.oecd.org/sti/ind/carbondioxideemissionsembodiedininternationaltrade.htm (both accessed November 2023).

[49] Data on sectoral CO_2 intensities by production type are not available, meaning that differences in CO_2 intensity between aggregate production and GVC production are due to differences in their sectoral structure. The OECD dataset excludes other economies heavily reliant on energy-related raw material exports such as Azerbaijan and Turkmenistan.

Figure 6.12: Log Ratio of Carbon Dioxide Emissions to Value-Added by Sector



CO_2 = carbon dioxide, IT = information technology.

Note: CO_2 emissions intensity is measured as the ratio of sectoral CO_2 emissions (in production) to sectoral value-added (all aggregated across economies), with value-added deflated using the gross domestic product deflator. Data are reported in metric tons per $ million and in logs in the figure.

Sources: ADB calculations using data from Organisation for Economic Co-operation and Development (OECD). Inter-Country Input-Output Tables. https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm; OECD. Carbon dioxide emissions embodied in international trade (TECO$_2$) data set. https://www.oecd.org/sti/ind/carbondioxideemissionsembodiedininternationaltrade.htm (both accessed November 2023).

Higher shares of GVC production in value-added are associated with a higher CO_2 emissions intensity in developing Asia and the rest of the world. A 10% increase in the share of value-added due to GVCs in an economy is associated with an increase in CO_2 emissions intensity of 5.7% (Figure 6.13).[50] The strength of this association differs by region, however, and is only statistically significant in developing Asia and the rest of the world. For developing Asia, a 10% increase in value-added due to GVCs is associated with a 7.0% increase in CO_2 emissions intensity, with a similar increase associated with a 5.7% increase in CO_2 emissions intensity in the rest of the world. The international division of labor is thus an important source of differences in emissions intensities across economies, with those regions specialized in certain manufacturing sectors and in upstream GVC production having a strong positive association between GVC production shares and emissions intensities.

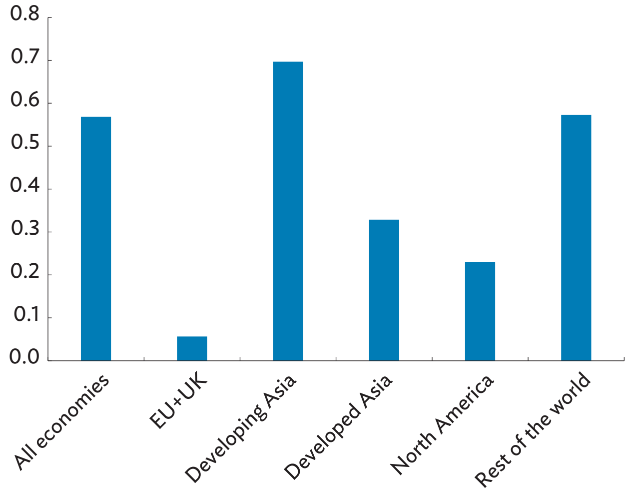
Structural change has played a limited role in reducing CO_2 emissions intensities within GVCs in developing Asia. CO_2 emissions intensities associated with GVC activity have dropped significantly across Asia, falling by 18% in developed Asia and by 89% in developing Asia from 1995 to 2018. These reductions have been driven entirely by reductions in CO_2 emissions intensities within sectors.[51] There was no shift in production activities within GVCs toward less emissions-intensive sectors in developing Asia (Figure 6.14).[52] Despite this, structural

[50] Replacing the GVC share in value-added with the traditional trade share gives similar results, suggesting there are few differences between different ways of providing foreign markets when considering the relationship between trade and CO_2 emissions intensities. Conversely, the coefficient when using the domestic production share is negative, significant, and large in absolute value, suggesting strong differences in the relationship between CO_2 emissions intensity and production for domestic versus foreign consumers.

[51] While the observed changes in CO_2 intensities were due to effects within sectors, they could still be related to external factors that lower sectoral emissions intensities. In GVCs, for example, these may include the diffusion of green technologies to the sector. They may also refer to the outsourcing of more emissions-intensive activities within the sector to other economies, though the declining intensities across all sectors and most economies suggest that in aggregate this is unlikely.

[52] The Lao PDR is excluded from the figure due to the lack of sectoral data until 2000.

Figure 6.13: Association Between the Share of Value-Added Due to Global Value Chain Production and Carbon Dioxide Emissions Intensities, 1995–2018



EU = European Union (27 members), UK = United Kingdom.

Notes: The figure reports the estimated coefficients on the log of the share of value-added due to global value chain (GVC) production from a regression with the log of the ratio of carbon dioxide (CO_2) emissions to value-added as dependent variable and the log of gross domestic product (GDP) per capita (and its square), the log of the share of manufacturing in value-added, the log of the urban population share, and economy, and time fixed effects. The regression model is estimated at the level of the economy, with annual data over the period 1995-2018. Since both dependent and the main explanatory variables are expressed in logs, the coefficients can be interpreted as elasticities, providing an estimate of the percentage change in the ratio of CO_2 emissions to value-added in response to a 1% change in the share of value-added due to GVC production.

Sources: ADB calculations using data from Organisation for Economic Co-operation and Development (OECD). Inter-Country Input-Output Tables. https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm; OECD. Carbon dioxide emissions embodied in international trade ($TECO_2$) data set. https://www.oecd.org/sti/ind/carbondioxideemissionsembodiedininternationaltrade.htm; and World Bank. World Development Indicators. https://databank.worldbank.org/source/world-development-indicators (all accessed November 2023).

change has contributed to reductions in emissions intensities within GVCs for individual economies.[53] Structural change accounted for between 12% and 20% of reduced emissions intensities in India, the Republic of Korea, and Singapore, for example, and for 35% in the Philippines. In Cambodia and Hong Kong, China, structural change also helped offset some of the rise in within sector CO_2 emissions intensities.

Global Value Chains and Policies to Decarbonize Production

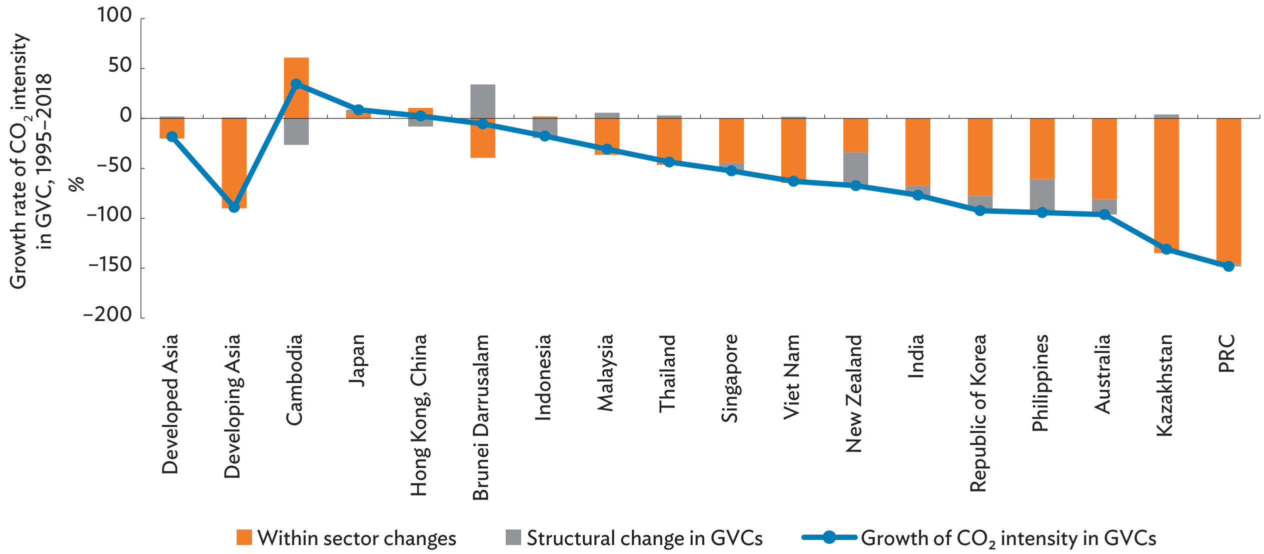
The Challenge of Global Cooperation for Climate Change Mitigation

Enhanced international cooperation is essential for climate change mitigation and adaptation. Despite efforts at national and subnational levels to implement carbon pricing policies, confronting the climate change crisis is a global public good. The increased interdependence of economies ultimately requires increased global coordination in dealing with the threats of climate change. GVCs, for example, deepen the interdependent links between economies and increase the potential for policies in one economy to have spillover effects on others, affecting emissions production and economic activity in other economies. As the World Trade Report 2022 (WTO 2022b) highlights, enhanced global cooperation can help deal with climate change in a variety of ways. International cooperation can create a more coherent and predictable policy environment, helping signal a commitment to decarbonization. It can increase transparency that in turn facilitates better review and monitoring of decarbonization efforts. And it can mobilize financial and technical resources to overcome capacity constraints and encourage the diffusion of green technologies across borders. Cooperation between developed and developing economies—by way of technical assistance, capacity building and knowledge exchange—can also help the spread of low-carbon technologies to developing and emerging economies.

Despite the Kyoto Protocol and Paris Agreement, for example, global coordination on climate mitigation remains weak. Recent literature examines what a global carbon pricing scheme could look like (ADB 2023a; Böhringer, Schneider, and Asane-Otoo 2021; Nordhaus 2015a; Stiglitz 2019). Proposals involve extending carbon taxes and emissions trading system (ETS) globally. A global

[53] The calculations are based on a shift-share decomposition, which involves splitting the change in CO_2 emissions intensities in GVCs into two components: (i) a within-sector change in emissions intensity holding the structure of production in GVCs constant; and (ii) a between-sector or structural change effect that accounts for changes in the structure of production in GVCs while holding the sectoral CO_2 emissions intensity constant.

Figure 6.14: Rate of Change of Carbon Dioxide Emissions Intensities within Global Value Chains and the Contributions of Structural Change and Intra-Sectoral Emissions Intensities *(%)*



CO_2 = carbon dioxide, GVC = global value chain, PRC = People's Republic of China.

Note: CO_2 emissions intensity in GVCs is measured as the ratio of (production-based) CO_2 emissions due to GVC production to value-added associated with GVC production. Value-added data are deflated using the gross domestic product deflator. The contributions of structural change and intra-sectoral changes in emissions intensities are calculated using shift-share analysis.

Sources: ADB calculations using data from Organisation for Economic Co-operation and Development (OECD). Inter-Country Input-Output Tables. https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm; OECD. Carbon dioxide emissions embodied in international trade ($TECO_2$) data set. https://www.oecd.org/sti/ind/carbondioxideemissionsembodiedininternationaltrade.htm (both accessed November 2023).

ETS would give economies GHG emission reduction targets and enable economies to then buy and sell surplus and deficit emission rights on the world market. A global carbon tax would involve economies applying a tax on emissions, leading to a similar reduction in emissions (Cramton et al. 2017; Nordhaus 2015b). Despite these proposals, efforts to bolster global cooperation have remained generally weak and limited. Of those that have taken place, the pledge and review mechanism of the Paris Agreement has been criticized for having limited impact on emission reduction targets (Barrett and Dannenberg 2016). Those that involve developed economies offering financial assistance to help developing economies decarbonize generally lack credibility, given the failure to meet past financial commitments (Subramanian 2022). Article 6 of the Paris Agreement provides the basis for trading GHG emission reductions, but COP28 failed to reach agreement on how to operationalize trading mechanisms.

The major challenges to coordinating carbon pricing globally stem from free-riding and fairness issues. The possibility of free riding makes carbon pricing coordination challenging, with economies and regions having an incentive not to join. This is because the benefits in setting a carbon price are shared by all economies, while the costs in terms of higher costs and lower production are incurred only by those imposing a carbon price. The issue of fairness arises as some economies—currently developed economies—have historically contributed more to global emissions than developing and industrializing economies. These differences are accounted for through the principle of common but differentiated responsibilities (CBDR), formalized during the 1992 Rio Earth Summit, which said that all jurisdictions have a responsibility to help mitigate climate change, but that they are not equally responsible.[54] A common global carbon price, therefore, may contravene the CBDR principle, while carbon

[54] Principle 7 of the Rio Declaration at the first Rio Earth Summit in 1992 states, "In view of the different contributions to global environmental degradation, States have common but differentiated responsibilities. The developed economies acknowledge the responsibility that they bear in the international pursuit of sustainable development in view of the pressures their societies place on the global environment and of the technologies and financial resources they command."

pricing more generally may impact certain economies disproportionately—particularly developing economies and energy producers. One solution proposed is to have different minimum international carbon prices based on an economy's development level (Parry, Black, and Roaf 2021).

Regional cooperation and related initiatives are increasingly considered alternatives to multilateral progress on decarbonization. There were past successful multilateral efforts—such as the Montreal Protocol on Substances that Deplete the Ozone Layer—that largely succeeded in phasing out

Box 6.5: Climate Clubs as Global Cooperation

In a fragmenting world with narrowing opportunities for global cooperation, climate clubs may provide a way for like-minded nations to cooperate. Reducing carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions, and their associated impact on climate change, are examples of a global public good. Nordhaus (2015a, 2020) notes that international coordination and agreement on global public goods is difficult because individual economies have an incentive to defect, engaging in beggar-thy-neighbor policies. Economies thus have an incentive to free ride on others that are reducing emissions. By failing to properly acknowledge that by its very nature, climate change is a global public good with a potential for free-riding, Nordhaus argues that existing frameworks (like the Paris Accord and the earlier Kyoto Protocol) are voluntary agreements that encourage free-riding. A proposed solution is a climate club, which is based upon two main foundations: (i) members voluntarily agree to share the burden of emissions reductions; and (ii) nonmembership of the club carries certain penalties. The Carbon Border Adjustment Mechanism being implemented by the European Union is considered to hold many characteristics of a climate club.

Simple carbon club targets are needed to minimize the risk of conflict and to allow flexibility in meeting the targets. Members can agree on burden-sharing principles by undertaking harmonized emissions reductions with the aim of meeting a particular objective (e.g., keeping temperature rises below 2°C) and joining efforts to agree on a target international carbon price (and how it should rise over time) (Nordhaus 2020). This may be preferred to negotiating individual member emissions allocations—with a carbon price being simpler to work out (essentially reducing negotiations to a single price)—given the limited likelihood of success in negotiating economy level allocations. A further advantage of a carbon price target is that it leaves economies with a degree of flexibility on how they achieve the target price (e.g., either through carbon taxes or through cap-and-trade schemes).

A tariff on imports can be the most effective way of enforcing the behavior of trade partners. For the club and its related agreements to be sustainable, there needs to be some kind of sanction against nonmembers (Nordhaus 2020). This can induce economies to join the club and/or abide by club agreements. The obvious penalty would be a tariff on imports from nonparticipants, which should encourage them to enter the club and/or undertake the necessary emissions reductions (e.g., by implementing their own carbon policies). According to Nordhaus (2020), choosing a tariff is better than the alternatives, such as countervailing import duties on carbon content. There are at least two reasons for this. First, a great deal of carbon is emitted in producing non-traded goods—like electricity—which can reduce the effectiveness of the club in "correcting" behavior. Second, it is very difficult to accurately calculate the (indirect) carbon content of imports. Instead, therefore, Nordhaus argues for a uniform tariff on all imports from nonmembers.

The concept of climate clubs may also move beyond burden sharing and penalties to allow for cooperation on other ways to mitigate climate change. For example, given the potential of technology in mitigating climate change, Jakob et al. (2022) argue that climate clubs could go beyond imposing border adjustment mechanisms on nonmembers and consider broader forms of cooperation. Specifically, they argue that a club or clubs could implement common green industrial policies, including low-carbon requirements for climate-intensive globally traded basic materials—such as iron, steel, aluminum, cement, and fertilizers. The clubs could further provide support for research, development, and the diffusion of technologies and infrastructure. These mechanisms can be an incentive for joining the club, since members would gain access to markets for environmental goods.

Sources: ADB using Nordhaus (2015a, 2020) and Jakob et al. (2022).

ozone-depleting substances. Some argue that their governance and design was important for success, and that climate change efforts can learn a great deal from their experience (Sabel and Victor 2022). But in today's world, increasing geopolitical rivalry and limited progress in international fora such as the World Trade Organization increase the challenges for global cooperation on climate, with the result that global ambitions are set to accommodate the least ambitious partner (Sabel and Victor 2022). With the possibility of broad multilateral cooperation on climate change mitigation thus limited, regional cooperation is increasingly seen as a way forward. One approach uses the power of regional blocs to place conditions on trading partners, with the EU's CBAM a prime example. Another is using environmental provisions in preferential trade agreements (PTAs) to agree on a common set of standards for trade between partners. Irrespective of whether action is domestic, regional, or global, there is need for reliable and trustworthy data on CO_2 emissions and well-functioning institutions for decarbonization efforts to be effective and credible (Rosenbloom et al. 2020).

Carbon Pricing, Border Carbon Adjustment Mechanisms, and Decarbonizing Global Value Chains

There is widespread acknowledgment that carbon pricing holds the key to mitigating climate change. CO_2 emissions during production—and GHGs more generally—represent a classic negative externality, with the broader costs to society of CO_2 emissions not being internalized by those producing them. Many consider carbon pricing the most efficient way of correcting this market failure, forcing firms to pay the full (social) costs of their emissions, encouraging a reduction in emissions and a shift to cleaner forms of production. A carbon price is a market-based instrument that sets a price per metric ton (MT) of CO_2 emissions to reflect the additional costs to society. Carbon pricing generally takes two forms, a carbon tax or an ETS (or "cap and trade" system). By forcing firms to pay for their CO_2 production, producers are encouraged to reduce their carbon intensity—by innovating or switching to alternative means of production, for example. The potentially universal nature of carbon pricing that encompasses all production and transportation can be an important force in decarbonizing GVCs and production more broadly.

While many worry over economies' slow and narrow response to the climate crisis, a wide range of carbon pricing policies are in place across a range of jurisdictions. There have been several efforts across different jurisdictions to create a carbon price through carbon taxes or ETS. 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 jurisdictions, although only 23% of carbon emissions are covered.[55] However, only 4% of emissions are covered by carbon pricing 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 CO_2 (Carbon Pricing Leadership Coalition 2019). As currently implemented, carbon pricing efforts also have the considerable drawback that they tend to cover relatively narrow jurisdictions (e.g., cities, states, individual economies), with the EU's ETS the major exception covering multiple economies.

The fragmented nature of carbon pricing globally leads to the risk of carbon leakage. According to the IPCC (2022a), carbon leakage can occur through three main channels (see also Dröge 2009): (i) competitiveness, (ii) the energy market, and (iii) income. Competitiveness is affected when carbon pricing in one jurisdiction pushes up production costs for firms in the jurisdiction, leading them to lose market share. The extent of the carbon leakage will depend on the extent of differences in emissions intensity between firms in the jurisdiction and trade partners, and the trade exposure of goods and services (Böhringer et al. 2022). The energy market can further play a role in carbon leakage if carbon pricing in one jurisdiction leads to lower energy demand from firms covered, which in turn lowers global demand for energy, lowering energy prices

55 World Bank. Carbon Pricing Dashboard. https://carbonpricingdashboard.worldbank.org/ (accessed November 2023).

and increasing energy consumption in jurisdictions not subject to carbon pricing (IPCC 2022a). Finally, the income effect occurs when carbon policies lead to changes in the terms-of-trade, which then affects the global distribution of income, consumption, and emissions (Cosbey et al. 2019). While the number of ETS and carbon tax policies has increased, this does not significantly mitigate the risk of carbon leakage. In addition to the incomplete coverage of carbon pricing policies globally, the carbon prices associated with existing schemes vary widely, creating greater opportunities for carbon leakage (Figure 6.15).

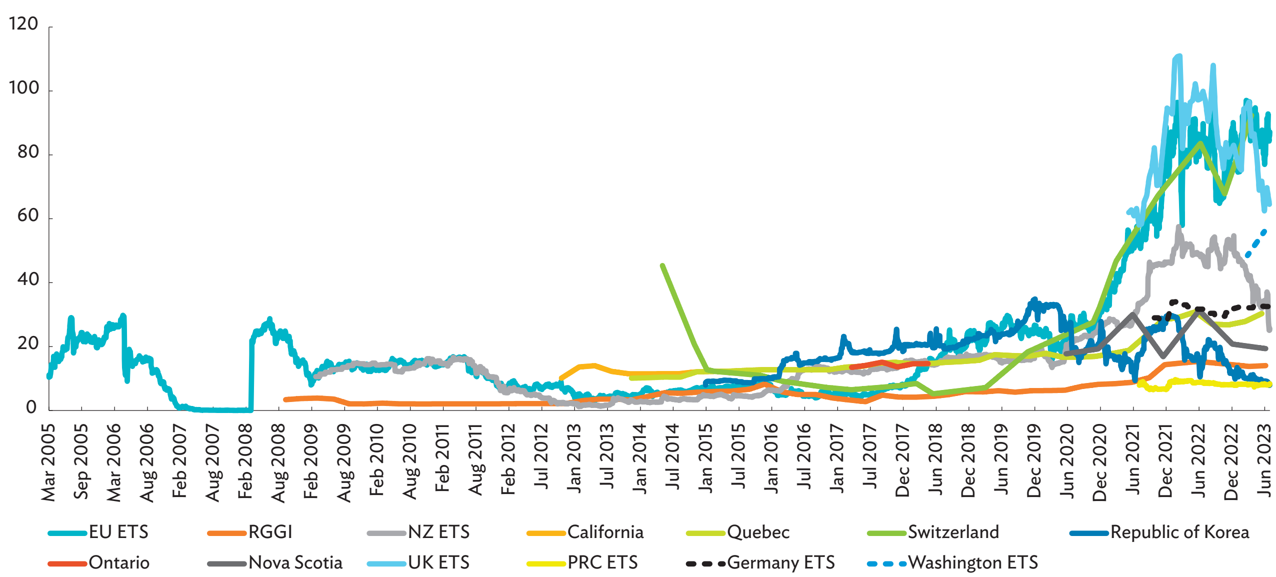
Border Carbon Adjustment Mechanisms

The lack of a globally coordinated response to climate change, combined with different rates of progress on climate action, can help encourage regions to implement border carbon adjustments. Without a globally coordinated response to climate change, economies and regions with ambitious climate targets have incentives to adopt border carbon adjustment (BCA) policies to reduce the risk of carbon leakage.

BCAs can level the playing field, ensuring that foreign producers face the same effective carbon price in export markets as domestic producers. They do this by applying fees on imported goods based on their emissions content, and possibly by exempting local firms exporting to economies with weaker domestic climate policies. BCAs align the price an importer pays with the domestic carbon price, thus removing a major incentive for production to shift to regions with a lower price and potentially reducing carbon leakage (Bellora and Fontagné 2023; Böhringer, Balistreri, and Rutherford; Branger and Quirion 2014).

While evidence of carbon leakage is limited, including that due to the EU's ETS, it could increase significantly as carbon prices begin to rise. Even though the primary aim of the EU's CBAM is to reduce the risk of carbon leakage, existing evidence suggests that carbon leakage due to the EU's ETS and other schemes has been limited (European Parliament 2020; Verde 2020; Cherniwchan and Taylor 2022). According to the World Trade Report 2022 (WTO 2022b), the lack of evidence is likely because emissions abatement costs are only a small part of a firm's total operating costs—with other costs related to capital, labor, and market proximity more important

Figure 6.15: Developments in Carbon Price under Various Carbon Pricing Initiatives ($ per metric ton)



ETS = emissions trading system, EU = European Union (27 members), NZ = New Zealand, PRC = People's Republic of China, RGGI = Regional Greenhouse Gas Initiative, UK = United Kingdom.

Source: International Carbon Action Partnership Database. https://icapcarbonaction.com/en (accessed November 2023).

determinants of where a firm locates. At the same time, there is some evidence that broader carbon policies can lead to carbon leakage (European Parliament 2020), that the current lack of evidence on carbon leakage possibly due to the shielding of certain sectors is incompatible with longer-term decarbonization goals (Grubb et al. 2022), and that carbon leakage rates can be significant particularly for small open economies (Misch and Wingender 2021). Moreover, increased climate change policy ambitions will inevitably lead to rising carbon prices, which may encourage significant future carbon leakage.

While reducing carbon leakage is a major reason for implementing BCA policies, they also serve other political economy motives. BCAs can serve the dual purpose of lowering domestic opposition to carbon pricing and encouraging other economies and regions to adopt more ambitious measures. By ensuring that foreign firms pay the same price for carbon as domestic firms, BCAs can help reduce opposition by domestic firms to domestic carbon pricing and ease concerns over the potential loss of competitiveness and market share that stringent climate change policies may create. To avoid paying tariffs under BCAs, other economies are thus encouraged to increase their own ambitions in developing carbon pricing mechanisms. According to the European Parliament (2022), CBAM is intended to "incentivize non-EU economies to increase their climate ambition and ensure that the EU and global climate efforts are not undermined by production being relocated from the EU to economies with less ambitious policies."

Fairness and equity are at the heart of discussions on the impact of BCA policies. By imposing new tariffs, BCAs may reduce global demand for imported goods, driving down prices and worsening the terms of trade for those exporters covered (Bellora and Fontagné 2023; Böhringer, Fischer, and Rosendahl 2010; UNCTAD 2021). These effects will be most strongly felt by exporters in GVC supplier economies—particularly those supplying energy-intensive products—that tend to be concentrated in Asia and in developing economies (Böhringer et al. 2022). Evidence suggests that the main impact of the EU's CBAM will be on middle- and low-income economies (Beaufils et al. 2023). BCAs can also push against the CBDR principle. Adjustment mechanisms will more likely be imposed by developed economies, partially with the incentive of increasing developing economies' ambition to limit emissions, and with the requirement that firms from all regions pay the same carbon price when selling in markets covered by the mechanism (WTO 2022b). Despite these concerns, given the strong interrelationship between climate change and GVCs, and the potential for climate change to impact how GVCs function, there is an incentive for developing economies to cooperate on climate change mitigation to protect the GVC development model.

Tensions between BCA policies and World Trade Organization rules can potentially lead to trade conflict. Concerns have been raised that BCAs could amount to a form of disguised protectionism, focused more on protecting and enhancing the competitiveness of domestic firms than achieving emissions reductions. Bacchus (2021) identifies several areas for potential conflict in the context of the EU's CBAM, including the possibility that it may violate the most-favored-nation principle of the World Trade Organization (WTO), which can happen if imported products originating in different WTO members were discriminated against based on their carbon content. CBAM may also involve a charge on imports into the EU more than the "ceilings on customs duties and other charges connected with importation that have been agreed by the EU in its WTO schedule of commitments," leading to a further source of tension. Bacchus further identifies possible inconsistency with the EU's national treatment principle, with free emissions allowances to local producers continuing for some time after CBAM implementation. For some economies, it may be best to impose countermeasures to BCAs to limit their negative economic effects (Böhringer, Carbone, and Rutherford 2016). Beyond the WTO, BCAs potentially conflict with Article 3.5 of the United Nations Framework Convention on Climate Change (UNFCCC), which states that climate change mitigation measures should not serve as a "disguised restriction on international trade" or involve "arbitrary and unjustifiable discrimination."

For various legal and other reasons, BCA mechanisms will need to include default emission values that may create unwanted incentives. For CBAM, the EU has published default emissions intensities for CBAM products during the transition period (see European Commission 2023b). These rates are partly based on cross-economy evidence on CO_2 emissions intensities (e.g., Vidovic et al. 2023). A system that focuses on default intensities has drawbacks. It can lead to relatively clean producers being overcharged relative to high-carbon rivals and provides no incentive to reduce carbon intensity below the default rate (Mehling and Ritz 2023). An EU proposal to set default rates at the level of the 10% worst emitting producers is intended to remove this concern. If this were the sole metric used, however, the incentives for firms to improve their emissions efficiency would be severely diminished. Moreover, with domestic firms having to report their actual emissions and imported goods subject to default rates, there would also be the risk of BCAs being discriminatory, contrary to international trade law. On efficiency grounds and to be compatible with trade law, BCAs will therefore need to allow producers a reasonable means of demonstrating that their product's embedded emissions are below the default value. It is the responsibility of implementing jurisdictions to specify acceptable approaches for embedded emissions verification, with the current CBAM approach leaving much uncertainty.

Even with clarity on an acceptable means for emissions verification, BCA mechanisms can be seen as *de facto* discriminatory. Measurement issues within BCAs will likely be substantially more burdensome for some rather than others, with developing economies and small and medium-sized enterprises (SMEs) potentially hardest hit. In the case of CBAM, the EU's own impact assessment acknowledged the burden on SMEs would likely be substantially more than for larger firms, although no estimates of the burden or number of SMEs affected were provided (European Commission 2021b). SMEs usually do not have the resources to professionally certify CO_2 emissions in their production and supply chains, forcing them to accept what is a potentially punitive default rate (Cornago and Lowe 2021). It will be difficult for many developing economies and firms to create appropriate institutions and structures to accurately measure emissions intensities.

BCA mechanisms can provide substantial revenue, which can be used to compensate losers and help the energy transition. CBAM, for example, has been estimated to raise around €14 billion in revenue by 2030 (European Commission 2021b), with most expected to be revenue in the EU's budget (European Commission 2023). CBAM could also rebate all or part of the domestic carbon price paid by exporters to compensate them for the higher carbon price paid domestically, compared with firms in the recipient economy. Because of the border adjustment, final consumers in a jurisdiction would in principle face the same carbon tax rate on domestic and imported goods (Elliott et al. 2013). Some have proposed allocating revenues from CBAM to a carbon fund to mitigate or adapt to climate change in developing economies—to avoid claims of unfairness and to meet CBDR responsibilities (Falcao 2020).

The European Union's Carbon Border Adjustment Mechanism and Its Impact on Developing Asia

The EU's CBAM is the first BCA mechanism and remains in a transitional phase. The EU's CBAM entered into force on 1 October 2023. During the initial transition phase, importers of goods covered by CBAM need only report emissions embedded in their imports (both direct and indirect emissions), without incurring any financial cost or adjustment. Given the challenges in calculating indirect emissions, they will only be included after the transitional phase and only for some sectors (fertilizers and cement), with the methodology to construct these to be developed during the current phase. The transitional phase is thus intended to serve as a pilot and learning opportunity for different stakeholders (importers, producers, and authorities) as well as an opportunity to develop and refine methodologies for collecting information on emissions embedded in products. During the transition phase, a further review of the product scope will assess whether other products covered by the ETS should fall under CBAM. Following the transition phase, EU importers of goods covered will need to obtain CBAM certificates, which will be priced based on ETS allowances. They will then declare the emissions embedded in their imports and surrender the corresponding number of certificates. An important feature is that if an importer can prove a carbon price has already been paid on their imports during production, then the corresponding amount can be deducted.

Concerns over losing competitiveness and market share are important motivations for CBAM. The main argument put forward by the European Commission in favor of CBAM (European Commission 2021b) is that it can address some of the shortcomings of the ETS, particularly the risk of carbon leakage to economies outside the EU where no carbon price exists.[56] Despite these arguments, concerns about losing competitiveness and market share as firms following the EU's strong environmental protection regime are undercut by rivals in regions with less stringent climate policies are also serious, especially given the unease around rising energy costs for industrial competitiveness. While energy prices have been stable for many years, supply has tightened since 2021, leading to large increases in energy prices—in the aftermath of the coronavirus disease (COVID-19) pandemic, the Russian invasion of Ukraine, and ambitious environmental targets.[57] There is now greater concern that sectors heavily reliant on energy, such as iron and steel, could relocate out of the EU, potentially drawing downstream sectors with them.

Estimating the Impact of the Carbon Border Adjustment Mechanism on Emissions, Exports, and Output in Developing Asia

CBAM's impact depends a great deal on the CO_2 intensity of production in products covered. CO_2 intensity is driven by various factors, including the energy mix in production and the production technology in different economies and regions. The wide variations in CO_2 intensities across economies and regions at the aggregate level (see Figure 6.11) can also be seen when looking at specific sectors (Figure 6.16).[58] Considering the sectors covered by CBAM, regions in developing Asia and Eastern Europe often have some of the highest emissions intensities, given different production techniques and heavy reliance on coal as a source of energy across much of developing Asia.[59] Relative to the EU, CO_2 intensity in ferrous metals is found to be high in India, the PRC, and Central and West Asia, for example. These economies and subregions also have relatively high emissions intensities in nonferrous metals, with South and Southeast Asia also high in emissions intensity in this sector. Regions in developing Asia also rank high in terms of emissions intensities in mineral products and chemicals, indicating that in the sectors that are the main CBAM targets, production in developing Asia is relatively dirty, potentially raising the costs of CBAM for these subregions relative to other regions.

High CO_2 intensities imply that implicit taxes on production associated with the implementation of an ETS would be relatively high for developing Asia. Under the assumption of a carbon price of €100 per MT of CO_2, current CO_2 intensities in developing Asia would be the equivalent of a value-added tax of between 3% and 12% when considering the aggregate economy, with the rates being relatively high for India, the PRC, and Central and West Asia (Table 6.1). For individual sectors, these rates can be substantially higher. For ferrous metals, for example, the VAT equivalent rate for India would be 787% and the PRC 86%. For mineral products, VAT equivalent rates would be above 100% for Central and West Asia, South Asia, Southeast Asia, and India.

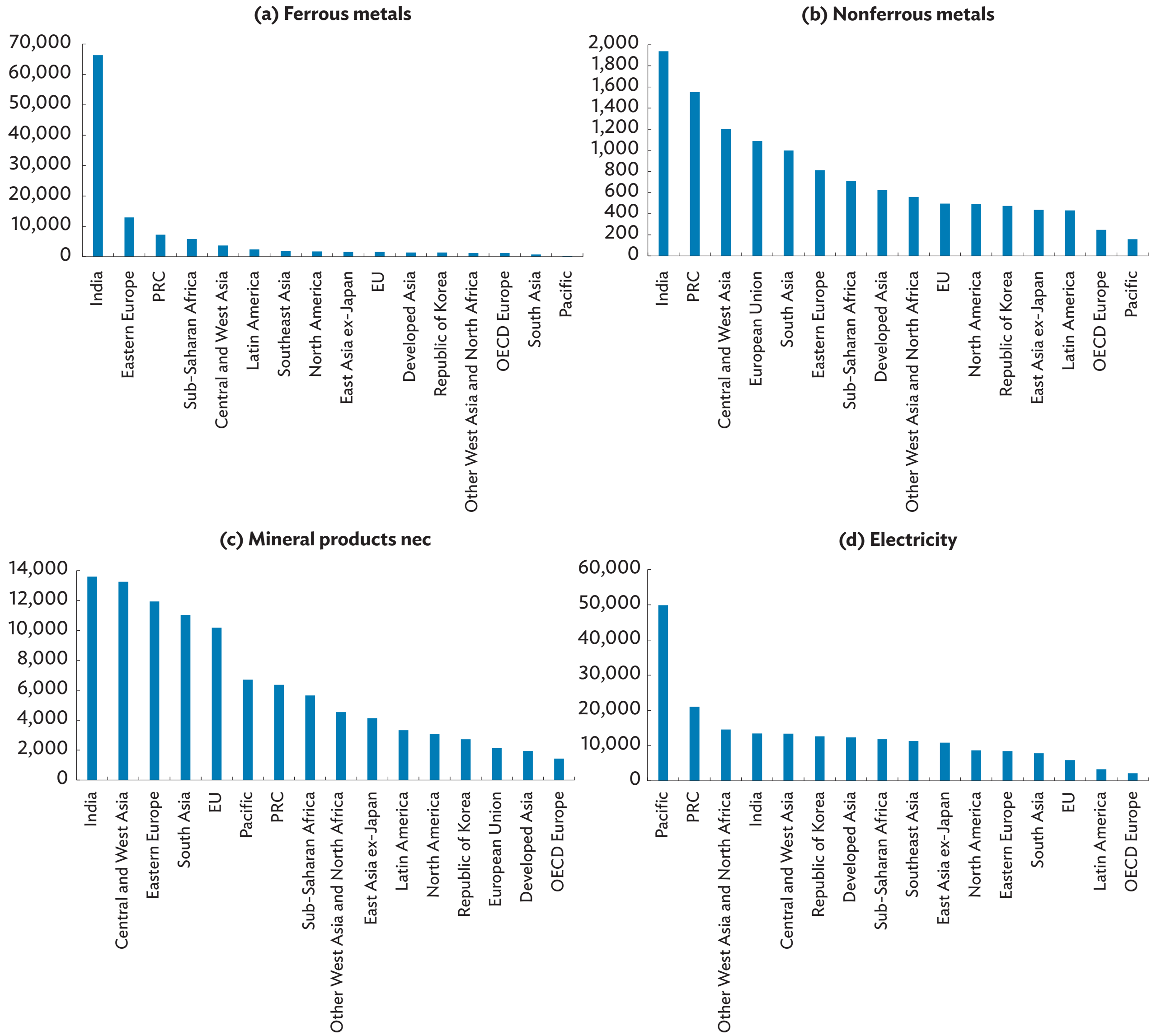
56 Another perceived ETS shortcoming is that the risk of carbon leakage is managed by granting free allowances and compensation for price increases in electricity under state aid rules. Yet, as the European Commission points out (European Commission 2021b), this free allocation "weakens the price signal that the system provides for the installations receiving it compared to full auctioning," thus affecting "the incentives for investment into further abatement of GHG emissions."

57 See, for example, European Council (2023).

58 In the CBAM analysis, some of the larger economies (the PRC, India, Japan, and the Republic of Korea)—and thus the largest emitters—are included individually rather than as a part of any subregion. This is to avoid these economies dominating the results for subregions and because they are expected to be most impacted by CBAM. Results for subregions are thus exclusive of these large economies.

59 The assumption throughout the modeling of CBAM is that other ETS sectors will be added to the current CBAM product list by the end of the transition phase. These include energy-intensive industries such as glass, ceramics, pulp, paper, and acids and bulk organic chemicals. Hence, these products are also considered part of CBAM in the modeling.

Figure 6.16: Carbon Intensity of Production in Selected Sectors by Economy and Region, 2017 (metric tons of carbon dioxide per $ million of value-added)



EU = European Union (27 members), nec = not elsewhere classified, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China.

Source: ADB calculations using data from Global Trade Analysis Project. GTAP 11 Data Base. https://www.gtap.agecon.purdue.edu/databases/; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (both accessed November 2023).

For electricity, which is not strongly traded, the rates are all above 100% except for South Asia. These numbers highlight the potential impact of a carbon price on the competitiveness of developing Asia given its current production technology.

CBAM's impact will also depend on the extent to which developing Asia exports the products covered to the EU. Data from UN Comtrade indicate that exports in CBAM products in 2019 were a small fraction of the region's total exports (Figure 6.17). By value, these account for less than 0.5% of exports in most regions of the world. The major exceptions are in Europe, including

Table 6.1: Value-Added Tax Equivalent of a Carbon Price of €100 per metric ton of CO_2 *(%)*

	Developed Asia	Central and West Asia	East Asia ex-Japan	South Asia	Southeast Asia	Pacific	PRC	India	Republic of Korea
Agriculture, forestry, and fishing	3.16	0.71	1.64	1.00	1.06	2.78	1.40	0.96	1.69
Mining	3.62	6.33	3.91	1.22	3.65	5.12	21.81	9.89	50.34
Food	1.30	1.86	1.60	0.37	1.95	1.02	3.10	1.56	1.65
Textiles	1.42	0.48	1.97	0.20	3.11	4.89	1.52	1.34	1.51
Wood	2.76	5.21	4.08	2.92	5.67	2.03	3.78	5.21	1.03
Chemicals, rubber, plastics	9.16	47.81	17.60	13.67	13.15	10.53	22.03	20.21	4.46
Pharmaceuticals	0.19	4.55	1.50	18.84	1.33	3.86	17.58	0.74	0.46
Ferrous metals	16.29	43.76	18.50	8.82	22.40	2.67	86.16	786.9	16.27
Nonferrous metals	7.39	14.24	5.18	11.84	12.91	1.89	18.41	23.00	5.62
Metal products	0.54	9.11	2.09	7.78	3.82	4.07	1.96	5.17	0.18
Mineral products nec	23.10	157.2	49.08	130.9	120.9	79.64	75.45	161.3	32.27
Computer, electronic, and optic	0.35	10.35	0.29	2.51	0.60	3.14	0.29	0.38	0.24
Machinery and equipment nec	0.22	9.19	0.29	5.79	0.96	3.10	1.32	1.93	0.22
Motor vehicles and parts	0.51	1.95	0.30	0.87	0.56	4.18	0.81	0.26	0.49
Other transport equipment	0.35	2.67	0.45	3.47	0.81	2.73	1.70	0.25	1.83
Manufactures nec	0.15	5.13	2.22	5.19	3.16	12.44	0.98	11.22	0.22
Construction	0.24	1.53	0.42	0.21	0.81	3.76	0.75	0.33	0.33
Petrochemicals, coal products	117.78	19.90	109.6	4.87	47.46	4.76	64.16	29.37	107.6
Electricity	146.01	159.13	128.5	92.75	134.04	592.0	249.0	159.7	150.1
Gas manufacture, distribution	23.27	18.72	85.85	0.03	62.92	158.2	497.6	5.60	609.7
Transport nec	10.99	16.62	20.55	9.37	27.03	48.02	16.02	21.45	22.14
Commercial services	0.17	2.14	0.15	0.14	0.32	0.11	0.46	1.00	0.29
Public services	0.19	1.68	0.35	0.31	0.24	0.07	0.68	0.43	0.24
Economy-wide	3.02	10.21	5.12	3.54	6.80	5.37	11.37	10.50	4.88

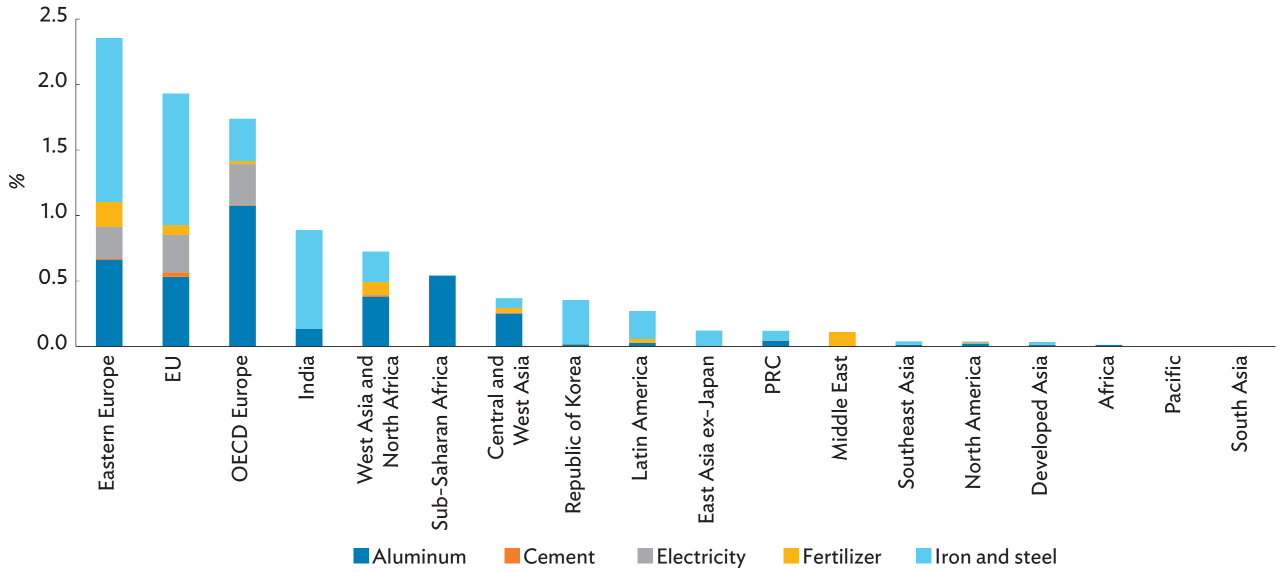
nec = not elsewhere classified, PRC = People's Republic of China.

Source: ADB calculations using data from Global Trade Analysis Project. GTAP 11 Data Base. https://www.gtap.agecon.purdue.edu/databases/; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (both accessed November 2023).

intra-EU trade, where the share in total exports of such products going to the EU is above 1.5%. Within Asia, India, Central and West Asia, and the Republic of Korea have relatively high shares when compared with other Asian regions. While the export shares are small, the exports may still represent a significant share of all exports in sectors for some economies. Moreover, there is an expectation that CBAM's scope will be expanded during the transition phase to cover other ETS sectors and potentially other products.

The EU is generally not the primary market for CBAM products originating from developing Asia, though the tariff equivalents can be large in some cases. In only a couple of cases (India and the Republic of Korea) does the EU account for more than 10% of core CBAM exports from developing Asia, suggesting that CBAM's impact on production in developing Asia may be limited (Table 6.2). Under these trade patterns, and assuming existing carbon intensities and a carbon price of €100 per MT of CO_2, the trade-weighted import tax rate equivalents of border carbon adjustments vary

Figure 6.17: Share of Total Exports of a Region Covered by the European Union's Carbon Border Adjustment Mechanism, 2017 (%)



EU = European Union (27 members), OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China.

Notes: The list of products covered by the Carbon Border Adjustment Mechanism (CBAM) is taken from European Commission (2021a). This reports information on the products covered using the Combined Nomenclature classification, which can be converted to the Harmonized System classification used by United Nations Commodity Trade Database and CEPII's Base pour l'Analyse du Commerce International (BACI) Database by removing the final two digits.

Source: Centre d'Études Prospectives et d'Informations Internationales (CEPII or the French Research Center in the International Economics). BACI Database. http://www.cepii.fr/CEPII/fr/bdd_modele/bdd_modele_item.asp?id=37; and Zignago and Gaulier (2010) (both accessed November 2023).

widely.[60] The simple average tax rate across regions of 8.1% represents a substantial cost. There are wide variations across Asian subregions, however, with the rate being relatively low in East Asia (1.7%), but higher in other regions including Central and West Asia (13.0%), South Asia (12.3%), and India (36.9%). Using the EU CO_2 intensity as the default leads to much lower trade-weighted tariffs, with tariffs less than 3% in all regions except for Central and West Asia and South Asia. The drop in tax equivalent in India to below 3% highlights the large differences in CO_2 intensities across economies and the potential impact of the choice of the default rate when implementing CBAM. When considering other ETS sectors, exports to the EU generally account for a higher share of these exports, with shares to the EU above 10% in East Asia, the PRC, India, and the Republic of Korea. The unweighted average tax rate across regions is lower for other ETS sectors (6.7%), reflecting the lower CO_2 intensities in these other sectors, though exceptions exist, notably in the Pacific and East Asia.

Modeling CBAM's effects under various scenarios allows an examination of its potential impact on Asia. Computable general equilibrium (CGE) models combine economic theory that identifies the structure of an economy and behavioral responses of agents (e.g., firms, households, and governments) with real-world data to model the potential effects of policies on economies (see Box 6.6). The approach involves comparing an initial baseline case with results following some change in policy, such as CBAM. By accounting for interactions between different sectors, agents, and markets, CGE models can consider the wider impact of policy interventions and quantify those effects. CGE models

60 While the CGE model accounts for existing carbon pricing efforts in Asia when calculating the predicted effects of CBAM, the trade-weighted import taxes in Table 6.2 do not adjust for existing carbon prices.

have been extensively used to estimate the effects of climate mitigation policies (Babatunde, Begum, and Said 2017). To model CBAM effects, various scenarios are compared to a baseline of the current ETS and a carbon price of €18 per MT of CO_2.[61] These scenarios include increasing the carbon price within the ETS to €100 per MT of CO_2, introducing a CBAM at a price of €100 per MT of CO_2, and increasing the price to €200 per MT of CO_2 (Table 6.3).[62]

The effects of a more stringent ETS and imposition of CBAM have ambiguous effects on emissions, output, and trade. Understanding and predicting the estimated effects of policy interventions in a CGE model—such as increases in the EU's ETS carbon price or the imposition of CBAM—is complicated by the general equilibrium nature of the model, with the direct effects of policy interventions potentially being reinforced or counteracted by indirect effects that work through changes in relative prices.

The impact of policy interventions on CO_2 emissions, output, and trade will reflect two main effects—a substitution and income effect. The substitution effect will work toward raising emissions, production, and exports of the rest of the world, while lowering these levels in the EU. A higher carbon price in the EU's ETS, for example, would involve the substitution of EU production for production in other regions, with EU firms replacing domestic intermediates with imported ones and potentially shifting downstream production out of the EU to avoid higher carbon prices for intermediates. These substitution effects are likely to be stronger in ETS sectors than in non-ETS sectors. These impacts would be expected to reduce the production of CO_2 emissions in the EU, while increasing emissions in other regions through both upstream and downstream carbon leakage. Countering these substitution effects, however, is an income effect—with the higher carbon price on intermediates for EU firms leading to cost increases for downstream producers in the EU, lowering production levels and income. Lower income levels in the EU may in turn lower the demand for goods, particularly non-ETS goods, from other regions. As such, the income and substitution effects all work toward reducing emissions, output, and exports in the EU. For the rest of the world, however, the substitution and income effects work in opposite directions, meaning that the overall impact of a higher ETS price on CO_2 emissions, production, and exports in the rest of the world is ambiguous. Although ambiguous in theory, estimated impacts are likely to depend upon the extent of carbon leakage. If leakage from the EU to other regions is limited, then the substitution effect would likely be relatively small, with the income effect potentially dominating. Effects are also likely to differ between ETS and non-ETS products.

The effects of CBAM on emissions, output, and trade in the EU and rest of the world will also depend on the relative strengths of the substitution and income effects. With CBAM, the price of intermediates imported into the EU will become relatively higher as they are now subject to a carbon price. This can reduce the substitution effect of the ETS, with EU firms potentially substituting imported intermediates for domestic ones, raising production and emissions in the EU and reducing them in the rest of the world relative to an ETS only. Conversely, the greater cost of downstream production in the EU due to the expansion of carbon pricing to all intermediates—both domestic and foreign—may encourage firms to shift downstream production out of the EU to other regions, thus reducing output and emissions in the EU, but potentially increasing production and final product exports to the EU from other regions. As with the ETS, however, income effects are also at play. The higher carbon price of the EU would reduce output and income levels, with negative consequences for output and exports in all regions. Once again, therefore, the overall impact of CBAM on emissions, production, and trade are ambiguous. With substitution effects for intermediate and downstream production working against one another, it is perhaps more likely that income effects dominate in the case of

[61] The baseline of €18 per MT of CO_2 reflects the approximate price of CO_2 in the reference year of 2017.

[62] The revenue collected from the CBAM is assumed to go into the EU's budget in the model.

CBAM for both the EU and the rest of the world. If so, then an ETS plus CBAM is more likely to result in lower emissions, production, and exports than under an ETS only. However, that outcome would depend on carbon leakage and the extent to which downstream production moves outside the EU.

Table 6.2: Trade and Carbon Border Adjustment Mechanism Rates across Exporters

	Core CBAM Sectors			Other ETS Sectors			Carbon Intensity Relative to the EU	
	Share of Exports to EU	Trade-Weighted Import Tax at Local CO_2 Intensity, €100/MT	Trade-Weighted Import Tax Using EU Rates €100/MT	Share of Exports to EU	Trade-Weighted Import Tax at Local CO_2 Intensity, €100/MT	Trade-Weighted Import Tax Using EU Rates €100/MT	Core CBAM Products	Other ETS Products
Developed Asia	0.053	2.55%	2.10%	0.092	3.14%	2.93%	1.2	1.1
Central and West Asia	0.037	13.03%	4.16%	0.041	7.59%	4.92%	3.1	1.5
East Asia ex-Japan	0.098	1.74%	1.41%	0.121	5.01%	4.68%	1.2	1.1
South Asia	0.006	12.25%	6.02%	0.013	5.98%	4.13%	2.0	1.4
Southeast Asia	0.040	5.67%	1.97%	0.086	6.53%	3.16%	2.9	2.1
Pacific	0.085	0.85%	1.96%	0.088	14.62%	5.75%	0.4	2.5
PRC	0.086	6.52%	1.88%	0.118	5.45%	2.85%	3.5	1.9
India	0.115	36.92%	2.63%	0.163	5.99%	3.16%	14.0	1.9
Republic of Korea	0.109	2.24%	2.09%	0.178	2.89%	2.59%	1.1	1.1
European Union		7.88%	7.88%		4.13%	4.13%	1.0	1.0
OECD Europe	0.091	2.01%	3.43%	0.128	3.17%	3.20%	0.6	1.0
Eastern Europe	0.114	19.19%	4.23%	0.140	7.39%	4.25%	4.5	1.7
North America	0.045	3.54%	2.11%	0.084	6.82%	3.68%	1.7	1.9
Latin America	0.064	4.16%	2.13%	0.085	7.06%	3.86%	2.0	1.8
West Asia and North Africa	0.060	7.53%	2.38%	0.092	10.93%	4.39%	3.2	2.5
Sub-Saharan Africa	0.097	3.99%	1.75%	0.114	11.16%	4.63%	2.3	2.4

CBAM = Carbon Border Adjustment Mechanism, CO_2 = carbon dioxide, EU = European Union (27 members), ETS = emissions trading system, MT = metric ton, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China.

Notes: Values are output tax equivalents, weighted by exports to the EU; EU values are weighted by value of EU production rather than exports.

Source: ADB calculations using data from Global Trade Analysis Project. GTAP 11 Data Base. https://www.gtap.agecon.purdue.edu/databases/; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (both accessed November 2023).

Table 6.3: Modeling Scenarios to Consider the Impact of the European Union's Carbon Border Adjustment Mechanism on Asian Economies

Scenario	Description	Carbon Price
1	European economies impose tighter ETS carbon allocations, with a resulting €100/MT price. There is no CBAM applied at the border.	€100/MT CO_2
2	European economies impose tighter ETS carbon allocations, with a resulting €100/MT price. CBAM taxes are imposed for ETS sectors.	€100/MT CO_2
3	European economies impose tighter ETS carbon allocations, with a resulting €200/MT price. There is no CBAM applied at the border.	€200/MT CO_2
4	European economies impose tighter ETS carbon allocations, with a resulting €200/MT price. CBAM taxes are imposed for ETS sectors.	€200/MT CO_2

CBAM = carbon border adjustment mechanism, CO_2 = carbon dioxide, ETS = emissions trading system, MT = metric ton.

Notes: 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. There is also some discussion on expanded sector coverage. These potential changes to the ETS are not modeled in this analysis. Imposing tighter ETS carbon allocations refers to reducing the supply of carbon certificates as a means of increasing the price of CO_2 emissions.

Source: ADB.

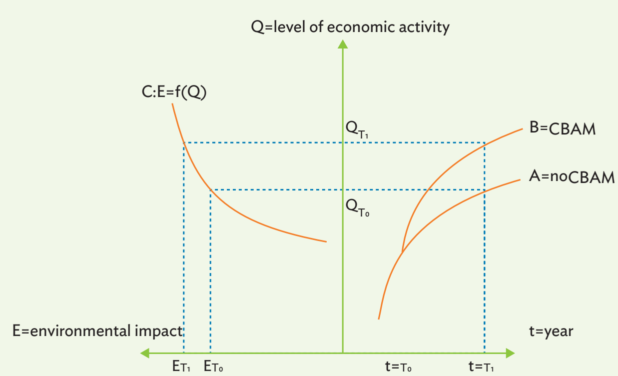
Box 6.6: Modeling the Effects of Carbon Border Adjustment Mechanism Using Computable General Equilibrium Models

A computable general equilibrium (CGE) model of global world production and trade is used to estimate the economic effects of carbon border tax scenarios. The CGE large-scale economic model translates price signals from the taxes modeled into domestic and global economic effects. The estimated effects include detailed information regarding changes in value, quantity, and price for domestic activities and associated trade flows. The general equilibrium nature of these models (meaning that sectors interact through both supply linkages and factor markets) captures complex interactions. In particular, the model simulates under different scenarios the changes in specific economic activities (sectors) that result from relative changes in cost and market access conditions. This is important, as the combined impact of policy changes across sectors will not be the same as if each sector was examined in isolation. The model has a microeconomic theoretical foundation.[a] The model uses a balanced and internally consistent global database (in this case the Global Trade Analysis Project [GTAP] version 11 database) of all trade and production across economies and industries, including trade in intermediate goods.[b]

The model can estimate the changes in GHG emissions due to changes in patterns of production and resource use. The combination of underlying baseline data and exogenous parameters (the various technical parameters in the model) determine the size and scope of these adjustments. To evaluate policy changes, the baseline (business as usual) scenario with no policy changes is compared with the counterfactual scenario that includes the changes in policy under the different scenarios. The effect of the policy change is then quantified as the difference between the two. The effects of different scenarios on CO_2 emissions can then be quantified. Data on GHG emissions and pollutants are used to compute changes in emissions resulting from this set of changes in resource allocation and production.

To illustrate the results of the modeling exercise, the figure below shows how the simulation results (the counterfactual) compare with simulated baseline values. In the right-side panel, curved line *A* represents the baseline trend for economic activity indicator Q (e.g., production of steel in Economy X), while line *B* represents the evolution of that same economic activity following the introduction of carbon taxes under the policy scenarios. The left-side panel provides a mapping from the same economic activity (in this example, production of steel in Economy X) to its environmental impact (for example, CO_2 emissions associated with different levels of steel production), represented by curved line *C*. The modeling results are reported as the numerical difference or percentage change from moving to *B* with respect to the baseline values *A*. In the figure, the full economic effects take time, and so the focus is on a long-run scenario. This means the benchmark economic structure is considered and compared with an alternative economic structure where investment and production patterns have had time to adjust (including longer-run capital stock changes). In this context, with T_1 as the benchmark or reference year, an alternative set of outcomes for period T_1 is examined where the changes in policy (carbon taxes) have had time to work through the economy after implementation in a prior period T_0.

Mapping Economic Effects to Their Impact on Emissions



[a] The model is based on what is known as the Eaton and Kortum model. For technical details on the model beyond the background report, see Bekkers, Francois, and Rojas-Romagosa (2018) and Bekkers et al. (2024). The model and underlying data also cover atmospheric pollution indicators, including both greenhouse gas (GHG) and non-greenhouse gas (NGHG) emissions.

[b] The GTAP database is a global multiregional input-output (GMRIO) database containing extensive and comprehensive economic data for 140 economies/regions and 65 production sectors. It provides disaggregated data for sectoral production, consumption, taxes and subsidies, trade, government finances, labor variables for different skill levels, and data on other production factors. For documentation on the structure of the database see Aguiar et al. (2019).

Source: ADB.

CBAM is predicted to reduce carbon leakage by around half relative to an ETS with a similar carbon price. The estimated impact on CO_2 emissions of the different scenarios suggests that CBAM's direct impact on emissions will likely be limited. A shift from a price of €18 per MT to €100 per MT of CO_2 within the EU's current ETS is predicted to reduce global CO_2 emissions by a fairly modest 1%, or by 358 million MT of CO_2 (Table 6.4). Reductions in CO_2 emissions are confined to two regions, the EU itself and the Organisation for Economic Co-operation and Development (OECD), which includes several economies that are part of the EU's ETS. In the remaining economies and regions, CO_2 emissions will increase by 132.8 million MT of CO_2. The increase can provide a rough estimate of the extent of carbon leakage of the ETS, representing around 27% of the reduction in CO_2 emissions in the EU and OECD Europe.[63] The estimated reduction in emissions in the EU and OECD under CBAM at €100 per MT of CO_2 is similar to that with the ETS only at €100 per MT of CO_2 (480.6 versus 490.9 million MT of CO_2). However, the estimated carbon leakage is more than halved, from 132.8 million MT of CO_2 to 62.4 million MT of CO_2, equal to 13% of the reduction in the EU and OECD Europe under CBAM. That emissions in the EU and OECD Europe drop by a similar amount under ETS alone and ETS with CBAM, while the increase in emissions outside of the EU under CBAM is substantially smaller, suggests that CBAM will have a more negative impact on output levels outside the EU relative to a higher priced ETS only. Increasing the price of carbon to €200 per MT of CO_2 under both an ETS alone and ETS with CBAM scenario results in a further drop in global CO_2 emissions, with the drop estimated at 1.9% for ETS alone and 2.2% with CBAM, with reductions again confined to the EU and OECD Europe. The higher price is associated with somewhat higher carbon leakage rates, however—29.4% in the case of ETS alone and 13.6% in ETS with CBAM.

The estimated reduction in exports to the EU following more stringent EU carbon policies is substantial for some regions. Moving from a price of €18 per MT to €100 per MT of CO_2 within the current ETS is predicted to lead to a decline in the value of exports to the EU from all regions (Figure 6.18). Across developing Asia, the decline in exports to the EU is largest for Central and West Asia (a drop of 7.7%). In most other developing Asian subregions and economies, the estimated effects on exports to the EU are muted, with reductions of 1% or less except for South Asia (where exports drop by 1.2%). The introduction of CBAM at a price of €100 per MT of CO_2 leads to larger drops in exports to the EU for most developing Asian subregions. Estimated declines in exports to the EU are above 2% in all cases except for South Asia (1.2%) and the Republic of Korea (1.9%).[64] Interestingly, the two Asian subregions with the highest effects under the higher-priced ETS—Central and West Asia, and South Asia—do not see a further drop in exports to the EU with CBAM. A higher carbon price of €200 per MT of CO_2 within CBAM is predicted to have substantial effects on exports to the EU for many regions. Within developing Asia, reductions in exports to the EU of 4% or more are predicted for East Asia, Southeast Asia, India, the PRC, and the Republic of Korea, with the predicted decline in Central and West Asia at 14.4%.[65] This highlights the potential for more ambitious climate change targets in the EU and how they impact Asian economies.

A higher carbon price in the EU's ETS impacts upon production and exports of ETS and non-ETS sectors in the rest of the world differently. Increasing the price of carbon from €18 per MT to €100 per MT of CO_2 within the current ETS is estimated to impact on the quantity of exports to the EU differently for ETS and non-ETS sectors (Table 6.5). While exports to the EU from non-EU regions are estimated to increase in the case of ETS sectors, reflecting the substitution of domestic for imported intermediates in the EU, exports to the EU in

[63] As several of the OECD Europe group are part of the EU's ETS, they are combined when calculating the reduction in emissions due to the ETS. The reduction in emissions in the EU and OECD Europe will reflect various general equilibrium effects, including the lower levels of production due to the higher carbon price and shifts of CO_2 intensive production outside the EU.

[64] For developing Asia as a whole, exports to the EU are estimated to fall by 1.3% under an ETS at a price of €100 per MT and by 2.4% with a similar ETS and CBAM, indicating that CBAM is expected to reduce Asian exports to the EU by 1.1% at a price of €100 per MT.

[65] Relative to an ETS at the same price of €200 per MT, CBAM is estimated to reduce developing Asia's exports to the EU by 2.1%.

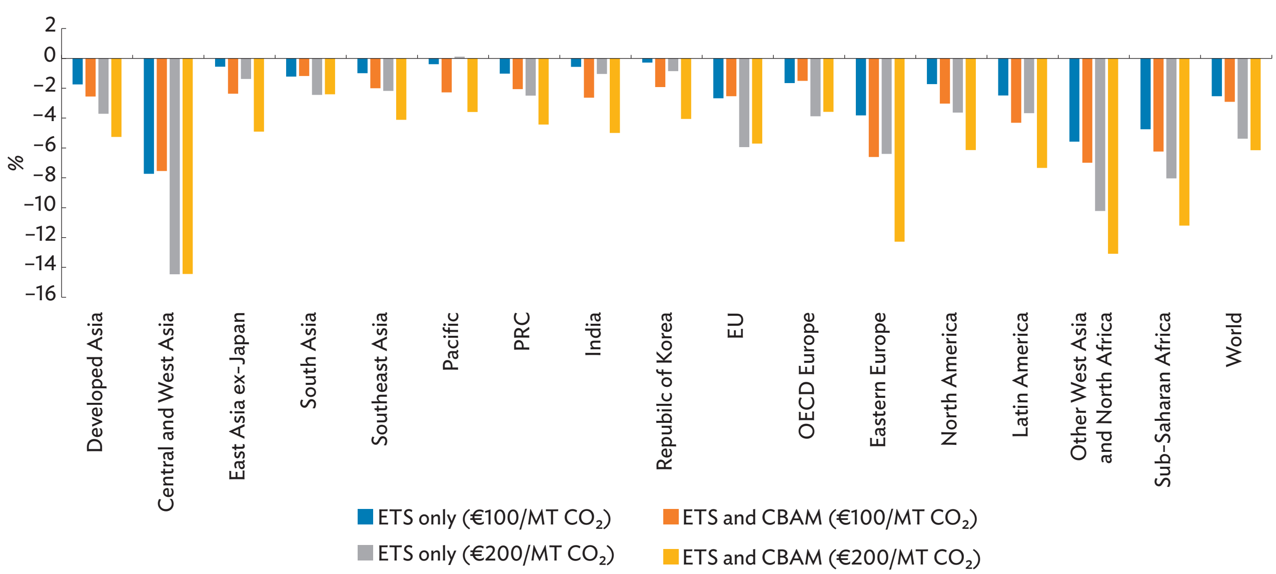
Table 6.4: Change in Carbon Dioxide Emissions under Different European Union Climate Policy Scenarios (million MT of CO_2)

	ETS Only (€100/MT CO_2)	ETS and CBAM (€100/MT CO_2)	ETS Only (€200/MT CO_2)	ETS and CBAM (€200/MT CO_2)
Developed Asia	5.66	5.33	10.69	10.21
Central and West Asia	4.15	2.10	8.18	3.67
East Asia ex-Japan	2.17	1.37	3.94	2.39
South Asia	0.53	0.37	0.98	0.64
Southeast Asia	5.36	2.38	9.88	4.16
Pacific	0.10	0.03	0.20	0.05
PRC	10.70	3.72	18.70	5.46
India	11.61	7.12	23.54	14.58
Republic of Korea	2.54	1.75	4.69	3.17
European Union	-435.77	-425.38	-777.19	-759.58
OECD Europe	-55.12	-55.18	-107.91	-108.04
Eastern Europe	37.34	13.60	79.44	28.68
North America	22.74	14.50	44.01	27.89
Latin America	4.41	1.63	8.55	3.03
Other West Asia and North Africa	18.18	4.61	33.59	6.43
Sub-Saharan Africa	7.29	3.92	14.23	7.47
World	-358.10	-418.15	-624.48	-749.78
World percentage change	-1.08	-1.26	-1.88	-2.25

CBAM = carbon border adjustment mechanism, CO_2 = carbon dioxide, EU = European Union (27 members), ETS = emissions trading system, MT = metric ton, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China.

Sources: ADB calculations using data from Global Trade Analysis Project. GTAP 11 Data Base. https://www.gtap.agecon.purdue.edu/databases/; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (both accessed November 2023).

Figure 6.18: Percentage Change in Export Values to the European Union under Different European Union Carbon Border Adjustment Mechanism Policy Scenarios (%)



CBAM = Carbon Border Adjustment Mechanism, CO_2 = carbon dioxide, ETS = emissions trading system, EU = European Union (27 members), MT = metric ton, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China.

Sources: ADB calculations using data from Global Trade Analysis Project. GTAP 11 Data Base. https://www.gtap.agecon.purdue.edu/databases/; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (both accessed November 2023).

non-ETS sectors are estimated to decline across regions. Negative income effects that fall on non-ETS sectors offset the positive substitution effects in Asian regions, which given the larger share of non-ETS exports in total exports to the EU result in negative overall effects of the higher ETS. A similar pattern exists when the ETS price rises to €200 per MT of CO_2.

The introduction of CBAM in the EU redirects ETS production back toward EU producers but encourages some downstream production to shift out of the EU. Introducing CBAM at a price of €100 per MT of CO_2 is estimated to reduce exports to the EU in ETS products across non-EU regions. This reflects a second substitution effect, with intermediate demand in the EU being reoriented back toward EU suppliers relative to the higher priced ETS. The negative effects of the ETS on exports to the EU of non-ETS products are also diminished relative to the higher priced ETS. This change likely reflects carbon leakage, with downstream producers shifting some of their production outside of the EU to avoid paying the carbon price.

Estimates of reductions in exports to the EU across Asian regions are mirrored by reductions in exports to other regions. The increase in ETS price from €18 to €100 per MT of CO_2 tends to be associated with a reduction in exports from different Asian regions to non-EU regions of between 0.5% and 1.0% (Figure 6.19). For comparison, the estimated global drop in exports to non-EU regions due to the ETS is 0.8%. While higher than that for some Asian regions, this is mainly driven by a relatively large drop in exports from the EU and OECD Europe.[66] With an ETS carbon price of €100 per MT, the imposition

Table 6.5: Percentage Change in Export Quantities of ETS and non-ETS Exports to the European Union under Different European Union Carbon Border Adjustment Mechanism Policy Scenarios (%)

	ETS Only (€100/MT CO_2)		ETS and CBAM (€100/MT CO_2)		ETS Only (€200/MT CO_2)		ETS and CBAM (€200/MT CO_2)	
	ETS Sectors	Non-ETS Sectors	ETS Sectors	Non-ETS Sectors	ETS Sectors	Non-ETS Sectors	ETS Sectors	Non-ETS Sectors
Developed Asia	7.2	-3.0	-3.2	-2.1	14.4	-6.2	-5.3	-4.6
Central and West Asia	13.4	-8.2	-4.2	-6.5	32.0	-16.1	-4.8	-12.8
East Asia ex-Japan	8.3	-2.7	-2.7	-1.9	17.8	-6.1	-3.7	-4.5
South Asia	12.1	-1.5	-4.5	-0.8	27.0	-3.1	-6.5	-1.7
Southeast Asia	7.6	-2.3	-3.0	-1.5	15.5	-4.9	-4.9	-3.3
Pacific	11.4	-2.7	-2.4	-1.9	24.9	-4.8	-2.3	-3.1
PRC	5.8	-2.3	-3.5	-1.4	11.6	-5.0	-6.0	-3.4
India	7.7	-2.7	-3.7	-1.9	16.7	-5.7	-5.3	-4.0
Republic of Korea	6.9	-2.2	-2.6	-1.4	14.5	-5.0	-4.0	-3.3
European Union	-5.7	-2.1	-4.7	-2.5	-11.9	-4.9	-10.1	-5.8
OECD Europe	-1.9	-1.6	-1.1	-1.8	-4.3	-3.9	-2.8	-4.3
Eastern Europe	9.4	-8.8	-5.1	-5.8	21.5	-17.2	-7.5	-11.9
North America	7.4	-3.3	-4.1	-2.5	15.3	-7.0	-6.7	-5.3
Latin America	9.2	-5.4	-2.4	-4.3	19.4	-9.4	-3.3	-7.4
Other West Asia and North Africa	7.0	-8.3	-5.8	-6.6	14.9	-15.7	-9.4	-12.8
Sub-Saharan Africa	10.1	-8.2	-1.7	-6.8	21.2	-15.1	-2.1	-12.4

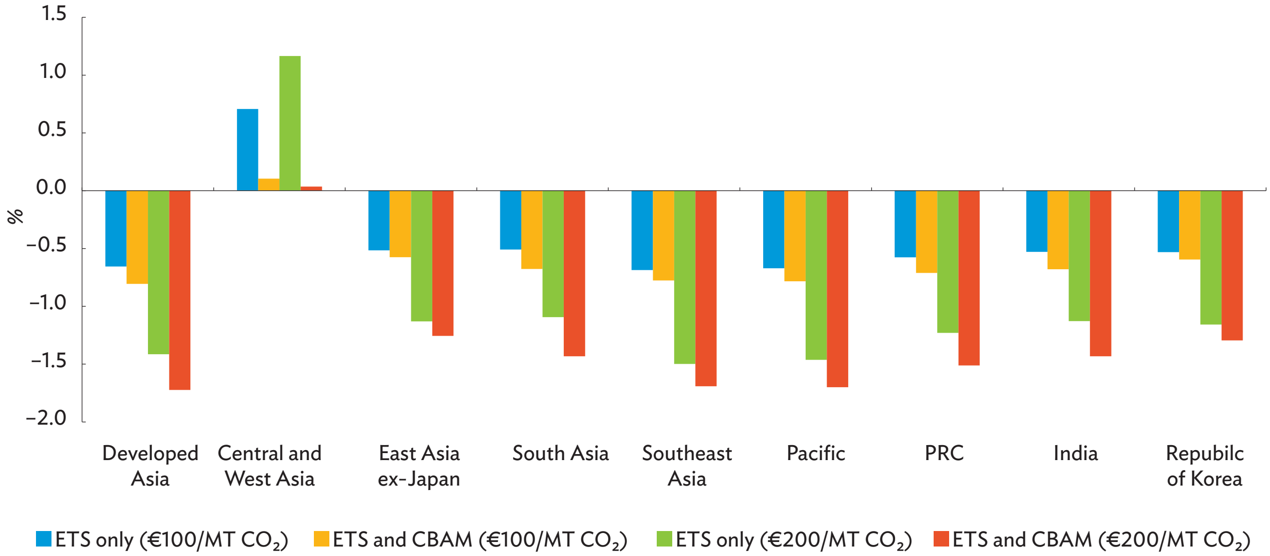
CBAM = carbon border adjustment mechanism, CO_2 = carbon dioxide, EU = European Union (27 members), ETS = emissions trading system, MT = metric ton, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China.

Note: To isolate changes in production and export levels, the table reports estimated percentage changes in export quantities relative to the baseline.

Sources: ADB calculations using data from Global Trade Analysis Project. GTAP 11 Data Base. https://www.gtap.agecon.purdue.edu/databases/; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (both accessed November 2023).

66 Ignoring these two regions, only Latin America has a percentage drop (0.66%) comparable to Asia, with exports to non-EU regions increasing in Eastern Europe, West Asia and North Africa, and sub-Saharan Africa.

Figure 6.19: Percentage Change in Exports to Non-European Union Regions under Different European Union Carbon Border Adjustment Mechanism Policy Scenarios *(%)*



CBAM = carbon border adjustment mechanism, CO_2 = carbon dioxide, ETS = emissions trading system, MT = metric ton, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China.

Sources: ADB calculations using data from Global Trade Analysis Project. GTAP 11 Data Base. https://www.gtap.agecon.purdue.edu/databases/; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (both accessed November 2023).

of CBAM is associated with larger percentage drops in exports to non-EU regions, though still usually in the range of 0.5% to 1%. The exception in both cases is Central and West Asia, which is expected to see an increase of 0.7% in the case of the ETS alone and 0.1% with CBAM. This suggests a partial redirection of exports from the EU to other regions. Globally, the reduction in exports to non-EU regions from a CBAM with a carbon price of €100 per MT is 1.1%. Increasing the carbon price to €200 per MT of CO_2 significantly impacts aggregate exports from Asia. Aggregate exports are estimated to fall between 1.3% and 1.7% across subregions, again except for Central and West Asia, where exports to non-EU regions barely change from the baseline. Globally, exports are estimated to fall by around 2.4%, with the drop again relatively large from the EU, OECD Europe, and Latin America. As such, CBAM can potentially have a significant impact on trade levels, suggesting a potential trade-off between emissions reduction and trade. CBAM thus could indeed present a challenge for some economies to advance development through GVCs.

Other macroeconomic effects of more stringent climate policies in the EU on developing Asian economies are estimated to be relatively small. For instance, the estimated changes in gross domestic product (GDP) in developing Asian economies and subregions under the various scenarios are quite limited (Table 6.6). At a price of €100 per MT of CO_2, reductions in GDP are estimated to be less than 0.2% of GDP, with Central and West Asia, and the Pacific somewhat larger. A carbon price of €200 per MT of CO_2 leads to larger reductions in GDP, but still below 0.5% of GDP in all Asian subregions except Central and West Asia and the Pacific. Levels of labor displacement are also generally small, although they become more substantial as the carbon price increases (Figure 6.20). Labor displacement reflects shifts of employment across sectors and thus captures the extent of structural change in response to the EU's climate policies, possibly due to downstream leakage of production outside of the EU.[67] In comparison to the estimated global rates of labor displacement—0.14% under ETS at €100 per

[67] The CGE model used includes an assumption of full employment, meaning that in equilibrium the sum of labor displaced will sum to zero. The percentage of the workforce displaced is thus used to capture the extent of labor displacement across sectors.

Table 6.6: Percentage Change in Gross Domestic Product under Different European Union Carbon Border Adjustment Mechanism Modeling Scenarios (%)

	ETS Only (€100/MT CO_2)	ETS and CBAM (€100/MT CO_2)	ETS Only (€200/MT CO_2)	ETS and CBAM (€200/MT CO_2)
Developed Asia	-0.104	-0.106	-0.241	-0.246
Central and West Asia	-0.332	-0.386	-0.702	-0.818
East Asia ex-Japan	-0.112	-0.139	-0.265	-0.318
South Asia	-0.183	-0.185	-0.401	-0.408
Southeast Asia	-0.183	-0.208	-0.425	-0.475
Pacific	-0.210	-0.278	-0.420	-0.559
PRC	-0.034	-0.047	-0.097	-0.121
India	-0.029	-0.044	-0.086	-0.112
Republic of Korea	-0.088	-0.091	-0.216	-0.222
European Union	-1.844	-1.907	-4.356	-4.490
OECD Europe	-0.793	-0.853	-1.980	-2.108
Eastern Europe	-0.159	-0.365	-0.295	-0.718
North America	-0.098	-0.101	-0.223	-0.229
Latin America	-0.099	-0.125	-0.218	-0.270
Other West Asia and North Africa	-0.283	-0.390	-0.605	-0.813
Sub-Saharan Africa	-0.138	-0.195	-0.292	-0.406
World percentage change	-0.454	-0.487	-1.070	-1.137

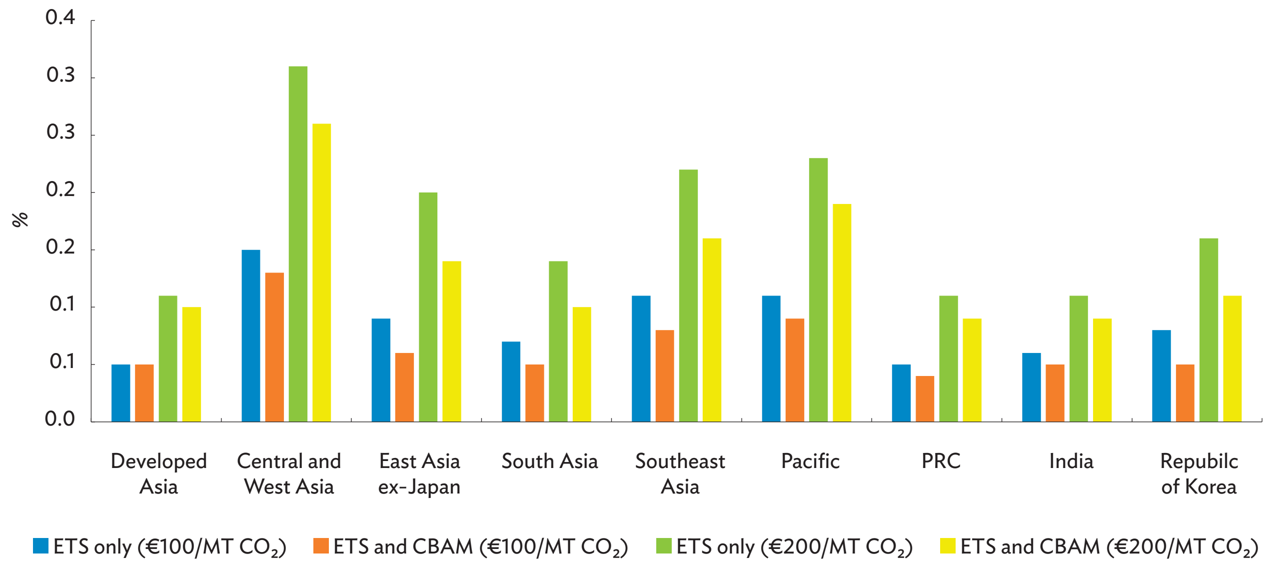
CBAM = carbon border adjustment mechanism, CO_2 = carbon dioxide, ETS = emissions trading system, MT = metric ton, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China.

Sources: ADB calculations using data from Global Trade Analysis Project. GTAP 11 Data Base. https://www.gtap.agecon.purdue.edu/databases/; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (both accessed November 2023).

MT and 0.13% under CBAM at €100 per MT—labor displacement rates in developing Asian regions are relatively low, with only Central and West Asia having displacement rates above the global average. The extent of labor displacement is estimated to increase with increases in the carbon price to €200 per MT, though the extent of labor displacement in Asia is lower than that globally (0.3% with ETS and 0.27% with CBAM).

Reductions in production within the EU in response to CBAM are not confined to the sectors covered. The increase in the carbon price within the ETS from €18 to €100 per MT results in relatively large reductions in production within the EU in CBAM sectors, particularly petrochemicals, electricity, and gas (Table 6.7). Reductions also occur across other sectors, with the increased costs in CBAM sectors raising the cost and price of goods and services produced in other sectors. CBAM at a price of €100 per MT has a dual effect. On one hand, the reduction in production in CBAM sectors is generally lower than in the case of the ETS at a price of €100 per MT only, consistent with the reduction in carbon leakage from these sectors in response to CBAM. On the other hand, the reduction in production in certain downstream sectors such as textiles, pharmaceuticals, computer, electronic and optical equipment, machinery and equipment, and other transport equipment, among others, is larger under CBAM than with the ETS alone. These results are consistent with the idea of greater downstream leakage in response to CBAM, with producers substituting downstream production in the EU for production in other regions including developing Asia, to avoid paying the CBAM tariff on imports of intermediates into the EU.

Figure 6.20: Extent of Labor Displacement under Different European Union Carbon Border Adjustment Mechanism Policy Scenarios (% of workforce displaced)



CBAM = carbon border adjustment mechanism, CO_2 = carbon dioxide, ETS = emissions trading system, MT = metric tons, PRC = People's Republic of China.

Sources: ADB calculations using data from Global Trade Analysis Project. GTAP 11 Data Base. https://www.gtap.agecon.purdue.edu/databases/; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (both accessed November 2023).

Table 6.7: Percentage Change in European Union Production by Sector (%)

	ETS Only (€100/MT CO_2)	ETS and CBAM (€100/MT CO_2)	ETS Only (€200/MT CO_2)	ETS and CBAM (€200/MT CO_2)
Agriculture, forestry, fishing	-0.7	-0.9	-3.2	-3.6
Mining	-3.1	-3.4	-11.2	-12.0
Food	-1.3	-1.5	-4.0	-4.4
Textiles	-1.3	-2.2	-3.5	-5.3
Wood	-3.2	-3.4	-6.9	-7.3
Chemicals, rubber, plastics	-5.8	-5.4	-11.7	-11.0
Pharmaceuticals	-1.1	-1.8	-2.5	-4.0
Ferrous metals	-7.1	-6.1	-15.5	-13.5
Nonferrous metals	-8.3	-7.9	-16.1	-15.3
Metal products	-2.7	-3.3	-5.9	-7.2
Mineral products nec	-5.8	-3.9	-12.0	-8.7
Computer, electronic and optical equipment	-1.8	-2.8	-4.1	-6.2
Machinery and equipment nec	-2.0	-2.7	-4.4	-5.9
Motor vehicles and parts	-2.0	-2.7	-4.6	-5.9
Other transport equipment	-1.4	-2.5	-3.0	-5.1
Manufactures nec	-1.3	-1.9	-2.9	-4.2
Construction	-2.6	-2.7	-6.2	-6.4
Petrochemicals, coal products	-13.2	-10.2	-26.3	-21.2
Electricity	-11.4	-10.4	-21.6	-19.5
Gas manufacture, distribution	-11.8	-9.6	-28.2	-24.1
Transport nec	-5.4	-4.9	-11.4	-10.4
Commercial Services	-1.5	-1.6	-3.7	-4.0
Public Services	-0.7	-0.6	-1.8	-1.7

CBAM = carbon border adjustment mechanism, CO_2 = carbon dioxide, ETS = emissions trading system, MT = metric ton, nec = not elsewhere classified, PRC = People's Republic of China.

Sources: ADB calculations using data from Global Trade Analysis Project. GTAP 11 Data Base. https://www.gtap.agecon.purdue.edu/databases/; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (both accessed November 2023).

Estimating the Impact of the Carbon Border Adjustment Mechanism Expanding into Other Regions

Whether others will follow in implementing BCA policies remains uncertain; but extending them to other regions could have larger effects on CO_2 emissions. Other economies may consider whether they should follow the EU in implementing their own version of CBAM, which would expand the coverage of exports affected. The CGE model used above can examine the impact of extending CBAM to other regions, considering scenarios in which other OECD economies (including those in Asia) implement both an ETS and a CBAM, or other ADB regional members implement both an ETS and CBAM (Table 6.8).

Extending the EU's ETS with CBAM to other OECD economies could triple the reductions in CO_2 emissions relative to a CBAM in the EU only. Extending CBAM to other OECD economies at a price of €100 per MT of CO_2 is estimated to reduce global CO_2 emissions by 1,226 million MT, or 3.7%, nearly three times the 1.3% reduction estimated for an EU CBAM (Table 6.8). Emissions in non-OECD regions are predicted to increase by 217.5 million MT, partly offsetting the 1,443.7 million MT reduced in the OECD. Notably, this implies that the rough estimate of carbon leakage of 15.1% under this scenario is slightly higher than the 13% estimate for an EU CBAM, with just over half of this leakage going to developing Asia. Increasing the carbon price to €200 per MT of CO_2 results in even larger drops in CO_2, by 6.4%, with the extent of carbon leakage also increasing to 16.9%. These results show that extending CBAM coverage and increasing its carbon price may lead to higher carbon leakage, especially in a situation with a relatively large share of global industry remaining outside any CBAM.

Including developing Asia in a CBAM can substantially reduce CO_2 emissions, while further limiting the extent of carbon leakage. Extending CBAM to cover all developing Asia is estimated to reduce global CO_2 emissions by around 8.7% at a carbon price of €100 per MT of CO_2 and by almost 15% at €200 per MT of CO_2 (Table 6.9). Moreover, the extent of carbon leakage is estimated to be much lower—7.1% at €100 per MT of CO_2 and 8.1% at €200 per MT of CO_2. This reflects the fact that as CBAMs expand to cover a predominant share of overall production, opportunities for carbon leakage decline. Compared to extending CBAM to only OECD economies, these results also highlight that the possibility for carbon leakage remains high if Asia is excluded, given the large production capability in the region.

Table 6.8: Scenarios to Consider the Impact of an Extended Carbon Border Adjustment Mechanism on Asian Economies

Scenario	Description	Carbon Price
5	All OECD economies impose tighter ETS carbon allocations, with a resulting €100/MT price. CBAM taxes are imposed for ETS sectors.	€100/MT CO_2
6	All OECD and other ADB regional members impose tighter ETS carbon allocations, with a resulting €100/MT price. CBAM taxes are imposed for ETS sectors.	€100/MT CO_2
7	All OECD economies impose tighter ETS carbon allocations, with a resulting €200/MT price. CBAM taxes are imposed for ETS sectors.	€200/MT CO_2
8	All OECD and other ADB regional members impose tighter ETS carbon allocations, with a resulting €200/MT price. CBAM taxes are imposed for ETS sectors.	€200/MT CO_2

CBAM = Carbon Border Adjustment Mechanism, CO_2 = carbon dioxide, ETS = emissions trading system, MT = metric ton, OECD = Organisation for Economic Co-operation and Development.

Notes: Given that Australia, Japan, New Zealand, and the Republic of Korea are included in the OECD, other ADB regional members refers to the remaining developing members of ADB. Imposing tighter ETS carbon allocations refers to reducing the supply of carbon certificates as a means of increasing the price of CO_2 emissions.

Source: ADB.

While extending the Carbon Border Adjustment Mechanism to other regions can lead to substantial reductions in CO_2 emissions, it can come at the cost of a significant decline in global trade. Extending CBAM to cover other OECD economies is estimated to reduce the (unweighted) average of developing Asian exports by 1.9% at a carbon price of €100 per MT of CO_2 and by 3.7% at €200 per MT of CO_2. Estimated reductions when ADB regional members are included do not have a significant additional impact on exports, with declines of 2.0% at €100 per MT of CO_2 and 3.7% at €200 per MT of CO_2 (Figure 6.21). These estimates are substantially larger than those obtained with only an EU CBAM, highlighting how extending CBAM does present risks to global trade and to the GVCs that economies have recently relied on for development.

The estimated macroeconomic effects of extending CBAM to other regions are distinct to each region. The impact on GDP of expanding ETS and CBAM to OECD and developing Asian economies varies considerably, with GDP increasing in a few developing Asian regions, particularly when considering extending CBAM to other OECD economies (Table 6.10).[68] These effects likely reflect a diversion of production away from OECD economies and toward other regions following the rise in costs within the OECD. The PRC and India are strongly affected by extending CBAM to developing Asia, likely reflecting the costs of an ETS in the context of relatively carbon-intensive production in sectors covered. While the ETS can directly impact other Asian subregions, lowering GDP, the large negative effects in India and the PRC also have negative spillover effects on other Asian subregions

Table 6.9: Change in Carbon Dioxide Emissions under Different European Union Climate Policy Scenarios (million MT of CO_2)

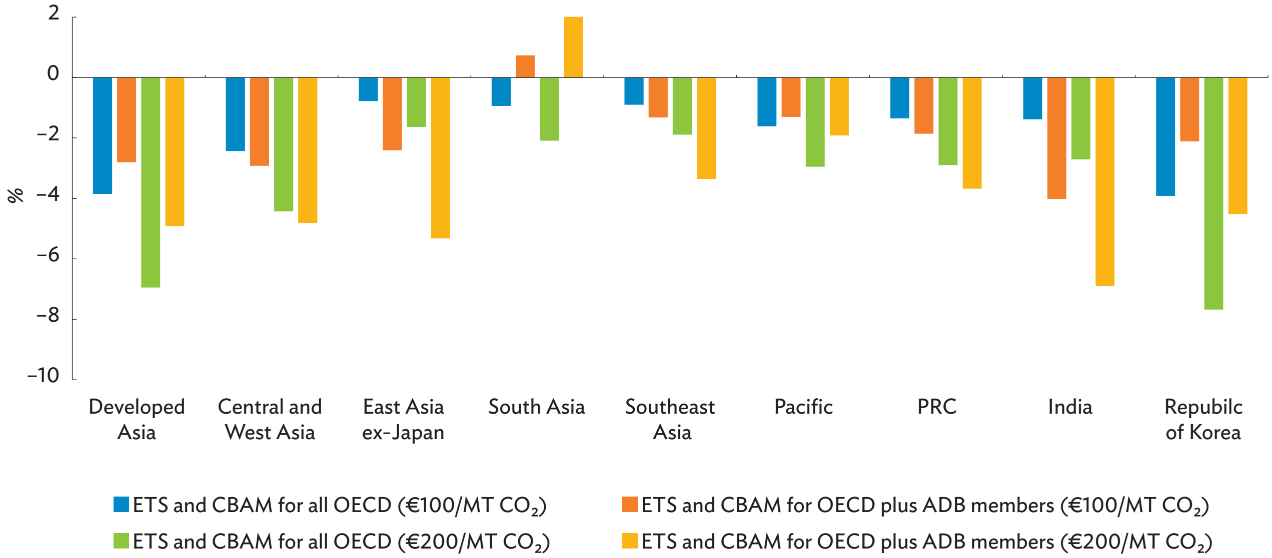
	ETS and CBAM for All OECD (€100/MT CO_2)	**ETS and CBAM for OECD Plus ADB Members** (€100/MT CO_2)	**ETS and CBAM for All OECD** (€200/MT CO_2)	**ETS and CBAM for OECD Plus ADB Members** (€200/MT CO_2)
Developed Asia	-238.13	-192.24	-410.70	-327.63
Central and West Asia	11.21	-50.97	24.02	-108.61
East Asia ex-Japan	6.34	-66.23	12.40	-116.38
South Asia	3.07	-10.16	6.19	-20.40
Southeast Asia	19.74	-147.14	39.08	-279.30
Pacific	0.01	0.26	0.08	0.65
PRC	43.25	-1429.26	88.08	-2546.10
India	30.55	-398.50	60.90	-723.82
Republic of Korea	-99.55	-80.36	-178.51	-144.30
European Union	-395.41	-334.42	-706.75	-594.83
OECD Europe	-50.83	-43.56	-100.62	-87.73
Eastern Europe	35.38	99.23	75.54	216.92
North America	-659.80	-570.42	-1240.09	-1070.53
Latin America	10.48	36.74	22.14	78.41
Other West Asia and North Africa	45.61	154.55	94.07	335.14
Sub-Saharan Africa	11.88	38.81	24.08	82.16
World	-1,226.22	-2,993.66	-2,190.10	-5,306.33
World percentage change	-3.65	-8.68	-6.43	-14.87

CBAM = carbon border adjustment mechanism, CO_2 = carbon dioxide, ETS = emissions trading system, MT = metric ton, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China.

Sources: ADB calculations using data from Global Trade Analysis Project. GTAP 11 Data Base. https://www.gtap.agecon.purdue.edu/databases/; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (both accessed November 2023).

[68] Unsurprisingly, the estimated effects for developed Asia and the Republic of Korea from an extension to other OECD economies are relatively large and negative.

Figure 6.21: Percentage Change in Asian Exports with an Expanded Carbon Border Adjustment Mechanism



CBAM = carbon border adjustment mechanism, CO_2 = carbon dioxide, ETS = emissions trading system, MT = metric ton, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China.

Sources: ADB calculations using data from Global Trade Analysis Project. GTAP 11 Data Base. https://www.gtap.agecon.purdue.edu/databases/; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (both accessed November 2023).

Table 6.10: Percentage Change in Gross Domestic Product under Different European Union Carbon Border Adjustment Mechanism Modeling Scenarios

	ETS and CBAM for All OECD (€100/MT CO_2)	ETS and CBAM for OECD and ADB Regional Members (€100/MT CO_2)	ETS and CBAM for All OECD (€200/MT CO_2)	ETS and CBAM for OECD and ADB Regional Members (€200/MT CO_2)
Developed Asia	-1.555	0.075	-3.670	-0.178
Central and West Asia	0.522	0.984	1.323	0.799
East Asia ex-Japan	0.304	-0.669	0.685	-2.342
South Asia	0.517	0.160	1.191	-0.100
Southeast Asia	0.312	0.051	0.682	-0.675
Pacific	-0.479	0.164	-0.874	0.641
PRC	0.205	-1.882	0.400	-4.764
India	0.354	-1.921	0.726	-4.845
Republic of Korea	-2.256	-0.562	-5.027	-1.521
European Union	-1.378	0.145	-3.358	-0.115
OECD Europe	-0.643	0.054	-1.644	-0.149
Eastern Europe	0.161	1.923	0.557	4.610
North America	-0.574	0.898	-1.487	1.718
Latin America	0.239	1.483	0.578	3.357
Other West Asia and North Africa	0.236	2.383	0.713	5.759
Sub-Saharan Africa	0.214	1.450	0.563	3.399
World percentage change	-0.509	0.206	-1.261	0.137

CBAM = carbon border adjustment mechanism, CO_2 = carbon dioxide, ETS = emissions trading system, MT = metric ton, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China.

Sources: ADB calculations using data from Global Trade Analysis Project. GTAP 11 Data Base. https://www.gtap.agecon.purdue.edu/databases/; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (both accessed November 2023).

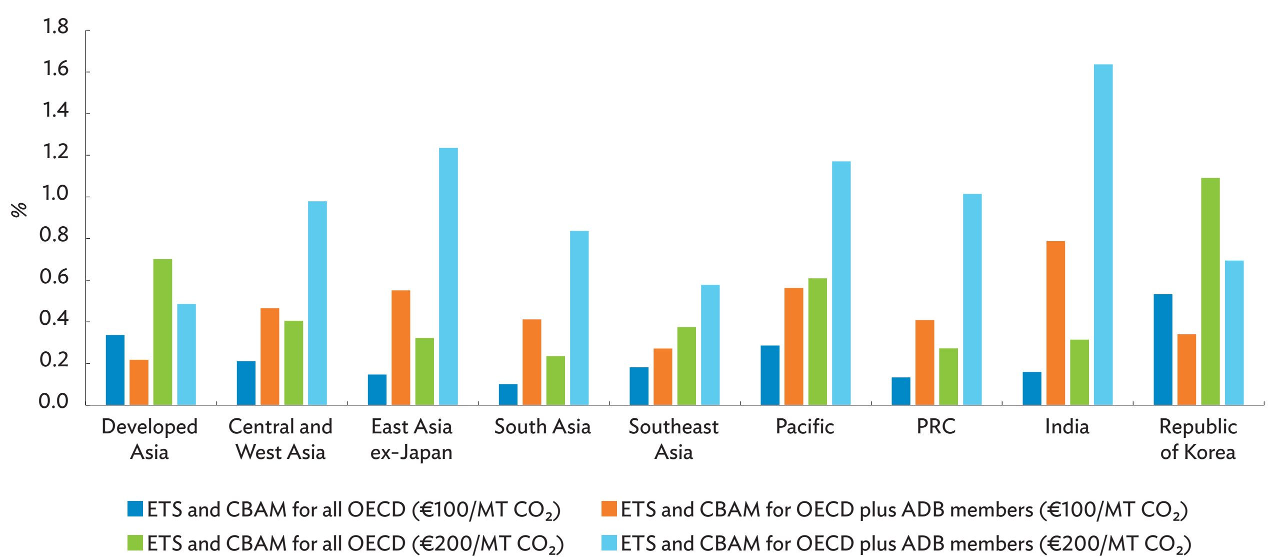
through supply chain linkages. These spillover effects may partially explain the relatively large reductions in GDP in East Asia and Southeast Asia. The extension of the ETS and CBAM to Asia is also estimated to lead to a relatively large amount of labor displacement, and therefore structural change, with labor displacement in developing Asian regions tending to be larger than the global average, with the exception of the Republic of Korea and Southeast Asia (Figure 6.22).

Embedded Emissions Accounting Frameworks

There is a need to develop embedded emissions accounting frameworks (EEFs) for traded products. Approaches to meeting a net zero transition—including carbon pricing and BCA mechanisms—require a consistent and accurate way to measure the emissions embodied in goods and services. Depending on the type of policy and regulation, EEFs will likely account for emissions directly associated with a certain segment of the value chain ("Scope 1" emissions), those associated with the energy produced elsewhere used in that part of the value chain ("Scope 2" emissions), as well as emissions associated with upstream parts of the value chain (upstream "Scope 3" emissions). Accounting for embedded emissions has only recently started to attract attention. Measuring territorial GHG emissions and constructing national accounts has been a centerpiece of the United Nations Framework Convention on Climate Change (UNFCCC) from the outset. These accounts and the emissions reductions targets associated with them remain the centerpiece of climate policy in most economies. In contrast, governments are only now beginning to develop frameworks to account for emissions embedded in products.

By providing a tool for measuring, reporting, verifying, and regulating, EEFs can lay the foundation for decarbonizing GVCs in both developed and developing economies. Accurately measuring emissions in products is crucial to avoid carbon leakage in a globalized world. Indeed, one of the potential advantages of BCAs is that they can encourage transparency in emissions, with firms required to report those embodied in the products they trade. The development of EEFs can potentially support public and private efforts toward climate change mitigation and improve the efficiency and

Figure 6.22: Extent of Labor Displacement under Different European Union Carbon Border Adjustment Mechanism Modeling Scenarios (% of workforce displaced)



CBAM = carbon border adjustment mechanism, CO_2 = carbon dioxide, ETS = emissions trading system, MT = metric ton, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China.

Sources: ADB calculations using data from Global Trade Analysis Project. GTAP 11 Data Base. https://www.gtap.agecon.purdue.edu/databases/; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (both accessed November 2023).

transparency of BCAs. As the basis for firms to voluntarily disclose embodied emissions as environmental, social and governance reporting—or for domestic and eventually international efforts to identify ways to green production and GVCs—EEFs can be powerful tools to support decarbonizing GVCs. Accounting frameworks need to be carefully designed to ensure they align with domestic frameworks and those of major trading partners. The measurement challenges are further compounded when considering the indirect emissions embodied in goods and services—Scope 2 and Scope 3 emissions.

Box 6.7: Principles of Public Embedded Emissions Accounting Frameworks

The increasing number of private emissions accounting frameworks are creating challenges for consumers and firms alike. These proliferating schemes confuse customers, leaving them unsure whether they are being "greenwashed," while firms absorb increasing costs as they obtain certification or verification from these multiple schemes to retain access to diverse markets. One solution is a public embedded emissions accounting framework (EEF). Aisbett et al. (2024) argue that an EEF should

- have one or more government principals for design, implementation, and operation;
- contribute to producing credible information about emissions embedded in products;
- help create and provide information about embedded emissions specific to products produced at a given facility, during a specified time period; and
- specify acceptable methods used in estimating embedded emissions.[a]

To succeed in supporting climate change mitigation while protecting global trade, a common set of principles is needed to facilitate the development of comparable EEFs by different jurisdictions that potentially increase the ability of independently developed public schemes to be recognized by trade partners. Clear statements of the underlying principles are ubiquitous within existing emissions accounting frameworks, including those by the

Principles Relevant to the Design of Embedded Emissions Accounting Frameworks for Achieving Both Climate Change Mitigation and Free Trade Goals

Principle Source	Definition
Accuracy (CAP and CAL)	True embedded emissions should neither be underestimated or overestimated.
Conservativeness (CAP and CAL)	Where further accuracy cannot reasonably be achieved, assumptions, default values, and alternative methods should be chosen such that the risk of reported emissions (removal) being an underestimation (overestimation) of the true values is minimized.
Monotonicity (CAL)	Embedded emissions accounting systems should not allow actors to decrease their reported emissions in a way that may increase overall emissions.
Nondiscrimination (TLL)	Embedded emissions accounting systems should not generate explicit or implicit advantage or disadvantage for like products, where "like" includes true emissions impacts.
Least restrictive means (TLL)	Embedded emissions accounting systems should be designed to meet the requirements of their intended use in the least trade-restrictive means possible.
Relevance (CAP)	Embedded emissions accounting systems should be designed to support the needs of the intended uses and users.
Subsidiarity (TLL)	Data collection and accounting should be conducted at the lowest level of aggregation and control that is consistent with meeting its intended use.
Transparency (CAP and TLL)	Information should be provided sufficient to allow stakeholders to assess robustness and reliability.

CAP = carbon accounting practice, CAL = carbon accounting literature, TLL = trade law literature.

Source: White et al. (2024).

continued on next page

Box 6.7: continued

Intergovernmental Panel on Climate Change (IPCC), the International Organisation for Standardisation (ISO), and the Greenhouse Gas (GHG) Protocol. Principles can be defined as unspecific prescriptions (Braithwaite 2002), with the box table from White et al. (2024) providing a summary of recent attempts to identify a set of principles based on trade law and carbon accounting practice. If applied to embedded emissions accounting, they could underpin a system that works toward the simultaneous goals of supporting climate change mitigation and free trade.

Principles from carbon accounting practice highlight the importance of accuracy, conservativeness, relevance, and transparency in EEFs. Achieving accuracy in EEFs requires that all emissions within agreed boundaries are counted, that double-counting is avoided, and that data sources for calculations and modeling use the best available figures. Conservativeness is an essential principle when further accuracy cannot reasonably be achieved—due to a lack of data or accounting capacity by a small organization or developing economy. This relatively recent addition to developing principles for carbon accounting arose as a means to promote developing economies' participation (Baker et al. 2010). Conservativeness is important to maintain the environmental integrity of EEFs and prevent the erosion of trust. While it may involve applying default emission factors to some locations where facility-level calculations cannot reasonably be done, appearing like those with less capacity are disadvantaged, it is a compromise between creating a prohibitive burden and actions that risk running counter to climate goals. Relevance requires that EEFs serve the needs of the user, both those reading and producing the emissions accounts. It implies that accounting should include all information necessary to inform consumers, investors, and regulators, and that it should be tied to factors that producers can account for and reasonably influence. In this sense, conservativeness and relevance both address who should be asked to bear which burdens in providing embedded emissions accounts. Finally, transparency requires that sufficient information be provided to allow stakeholders to assess robustness and reliability, and is a key principle in building trust and legitimacy in accounting schemes.

Certain principles from trade law not currently part of carbon accounting practice will be critical in developing EEFs. The principle of nondiscrimination requires that like products are treated alike, and extends to environmental attributes of products in many cases, but not yet definitively to embedded emissions (Charnovitz 2002; Bacchus 2017). There is the potential for non-discrimination to clash with other principles. For example, a system that places a higher (or lower) burden of evidence on products produced in certain locations could be viewed as discriminatory. Given that governance quality (and capacity) varies by location, however, these clauses may be necessary for accuracy or conservativeness. The least restrictive means (LRM), as articulated by the World Trade Organization, says that governments should pursue non-trade policy objectives using the least trade-restrictive means possible (Costinot 2008). For an EEF, the LRM implies minimizing the regulatory burden created by the system, including burdens of cost and time. The LRM thus requires actors to consider the capacities of reporting entities and other economies when setting accounting requirements. Finally, subsidiarity implies that counting and reporting emissions should be done at the lowest level possible while maintaining standards of accuracy. However, this should be balanced against resourcing constraints—not all facilities will have the capacity to rigorously count and report emissions. While national carbon accounting requires national aggregation, embedded emissions accounting holds the option to count distinct "modules" within the supply chain, keeping them visibly separate for traded products (White et al. 2021). This approach could support subsidiarity by allocating reporting responsibility most directly to the emitting entity, while verification and accounting could still be done nationally by public agencies.

[a] Acceptable methods can be directly specified or embedded in a scheme, or acceptable externally specified methods may be referenced.

Sources: ADB using Aisbett et al. (2024); Bacchus (2017); Baker et al. (2010); Braithwaite (2002); Charnovitz (2002); Costinot (2008); and White et al. (2021, 2024).

EEFs intended to be used in conjunction with trade-related carbon policies face a larger number of design constraints than those used for other purposes. EEFs for use in trade-related carbon policies obviously need to be designed in alignment with trade rules (including those governed by the WTO). But they should also try to align with the EEFs and regulations of their trading partners. The complexity arising from the link between trade-related climate policies and EEFs can be illustrated by the example of the Australian Government's Guarantee of Origin Scheme for Hydrogen (White et al. 2021). Key drivers of the scheme were to enable export market access and attract foreign investment. In addition to providing trusted information to private markets, the scheme holds the potential to lower the regulatory burden faced by Australian firms wishing to export clean hydrogen. This can only happen, however, if it is accepted by overseas regulators. For firms wishing to export to European customers, this means it will need to be recognized by the EU as an acceptable means of calculating CBAM certificate requirements. These examples highlight how the development of EEFs in the context of international trade can quickly become prohibitively complex, especially for governments operating under tight resource constraints. These complexities will only multiply as more, and more complex products are integrated into EEFs and as the number of national EEFs increase. The only feasible and inclusive path forward is for government officials to work together to establish common basic approaches to EEF design. Without global cooperation, an overly complex regime will disadvantage smaller producers and producers from economies with bureaucracies that lack sufficient resources.

Aligning EEF methodologies to those used under an economy's carbon pricing scheme may help avoid trade disputes. Although existing national carbon accounting structures cannot support embedded emissions accounting themselves, building on these structures could be an efficient starting point (Reeve and Aisbett 2022). Firms would face lower participation costs, as existing accounting methods and experience could be used, while governments could reuse investments in policy and digital infrastructure. Economies aspiring to introduce BCAs will need to develop or identify acceptable EEFs to calculate the border adjustment required. However, international trade law requires that the imports exposed to a BCA are afforded "like treatment" to domestic products. Aligning EEF methodologies to those used under the economy's carbon pricing scheme may thus help avoid trade disputes by ensuring that accounting requirements for foreign producers are no more burdensome than those for domestic producers.

Identifying priority products to include in EEFs will determine their success in helping reduce CO_2 emissions. Identifying priority products will allow an assessment of products that are in the best current position to maximize utility from an EEF, as well as assessing which products need EEF support to steer them toward a net zero future. Products with relatively large emissions intensities without current decarbonization methods, for example, will uncover a green premium, potentially drawing them into a net zero position. Jackson and Aisbett (2024) identify five relevant dimensions when identifying products to include in an EEF:

(i) **Emissions relevance.** Products with high emissions footprints and intensities, or products with the potential to displace other products with higher emitting levels should rank highly.

(ii) **Export relevance.** The development of EEFs is being driven in large part by the emergence of trade-related climate policies such as certification schemes and BCAs, highlighting the global relevance of EEFs.

(iii) **Policy relevance.** While public EEFs are being developed primarily in response to trade-related climate policies, if designed well, they can be relevant for a range of domestic and international policy and regulatory efforts. The regulatory burden of these policies will be lower if a single EEF can be used to support a wide range of policies. Thus, it is helpful to prioritize industries for which relevant policies are being developed.

(iv) **Technology readiness.** Decarbonization on a commercial level does not happen at the flick of a switch. Research and development is an integral part to this transition, which takes time and resources. This dimension evaluates the proximity to and effectiveness of low emitting production methods for a product.

(v) **Regulatory burden.** Developing a unified and reputable EEF is full of challenges and constraints. This dimension forecasts the difficulties associated with a product's embedded emissions calculations, as well as the product's position within supply chains. If downstream, it may be able to adapt upstream input EEFs. If upstream, its EEF could prove important for many other products.

Using a single regulatory instrument across sectors and products creates substantial measurement challenges, especially in agriculture. Single regulatory instruments may apply to both agricultural and nonagricultural products. For example, the EU is increasingly talking about the risk of carbon leakage for agricultural products and the need to extend CBAM to include agriculture: "The inclusion of agricultural products in the scope of the CBAM is all the more important as the agriculture sector will be both directly and indirectly affected by the inclusion of other products, notably fertilizers, steel and aluminum" (European Parliament 2021). Coherent and consistent cross-sectoral regulatory instruments will require coherent and consistent cross-sectoral EEFs. Calculating emissions for agricultural products is more challenging and costly than for extractive and manufactured products. This stems from the importance of carbon pools for calculating carbon emissions from agriculture. There are four main types of carbon pools: above and below ground biomass, dead organic matter in or on soil, soil organic matter, and harvested products that can be further subdivided (Greenhouse Gas Protocol 2014). They act both as sources and as sinks of CO_2 and flow constantly. Carbon sequestered in carbon pools is reversible and eventually emitted back into the atmosphere. Natural variations in biological productivity and decomposition between seasons, years, and locations in the fluxes in and out of carbon pools interact with land management practices (Hurtt et al. 2020). In addition, changes in farm and land management can take decades to reach new equilibriums (Greenhouse Gas Protocol 2014).

Data on emissions due to land use and changes in land use remain fragmented and weak, increasing the measurement uncertainty in some sectors such as agriculture. Variability in calculating agricultural product emissions is much higher than for extractive and manufactured products. While calculating CO_2 emissions from fossil fuels and industrial activities can be done with relatively high confidence, accurately accounting for non-CO_2 gases and emissions in the land sector is more complicated (Luers et al. 2022). Currently, land-use emissions data are neither accurate, complete nor consistent, particularly for low- and middle-income economies (Dittmer et al. 2023; Friedlingstein et al. 2022; Grassi et al. 2021; Rosenstock and Wilkes 2021). Relative to fossil-based CO_2 emissions, emission estimates from land-use change are characterized by substantial spatial and annual variability. Historically, this has led to relatively poor accuracy in emissions accounting. It has been estimated that these uncertainties typically amount to approximately 43.8%, whereas fossil CO_2 emissions have a much lower uncertainty of 5.2% (Friedlingstein et al. 2022; Ganzenmüller et al. 2022). Some of these uncertainties stem from different terminologies and definitions, and diverse model assumptions and parameters. These uncertainties may be substantially reduced by developing uniform and widely accepted public approaches in EEFs. However, much of the uncertainty is intrinsic to the variability of biological processes and the importance of carbon pools. Resolving these sources of uncertainty will require ever increasing temporal and spatial disaggregation of measurement. This is currently happening thanks to better technology, particularly satellite imagery and analysis (Burke et al. 2021).

The rising importance of negative emissions has implications for the design of EEFs. Negative emissions technologies and services, where carbon is removed from the atmosphere and locked away in storage or a stable product, will be an important component of climate change mitigation for the rest of this century (IPCC 2022b). As with emissions attributable to a product, the absolute emissions removed from the atmosphere by CO_2 removal (as a negative emission), could be recorded transparently within EEF systems. To support rigorous accounting of negative emissions services, EEFs additionally require careful tracking and information on attributes of storage or utilization, including the type, expected timescale, and storage location (White, Aisbett, and Widnyana 2023). These aspects will be important for the integrity of EEF systems and will be a critical component of the information needed by purchasers to decide whether a given product meets their emissions requirements.

New technologies can secure the benefits of EEFs by forging trust and accountability. Even with appropriate accounting frameworks in place, trust, engagement, and transparency are issues that new technology can help alleviate. The widespread introduction of blockchain technology, for example, could potentially be an important complement to EEFs (UNFCCC 2017). The immutability and transparency blockchain technologies provide can help combat climate change in various ways, by improving the trust in tracking and monitoring GHG emissions, by transparently recording a firm's carbon footprint, and by monitoring and reporting GHG emissions reduction efforts.

Trade Policy, Preferential Trade Agreements, and the Decarbonization of Global Value Chains

Trade Policy as Climate Change Policy

Trade policy can be effective in promoting climate change mitigation and adaptation. Measures aimed at lowering tariff and nontariff barriers on climate-friendly products and services, reducing and removing subsidies and other support for carbon-intensive products and sectors, and encouraging the transfer of green technologies are some of the important ways to mitigate and adapt to the effects of climate change. These policies can help economies diversify into greener sectors and away from carbon-intensive sectors (UNFCCC 2016). Regional cooperation and integration can further encourage the decarbonization of GVCs, with environmental provisions in preferential trade agreements (PTAs) leading to greater cooperation in meeting climate commitments.

Current trade policies favor carbon-intensive imports. The IPCC (2022a) highlights that tariff and nontariff barriers tend to be lower in high-carbon-intensive sectors, with these goods traded more than low-carbon-intensive goods (Le Moigne and Ossa 2021). GVCs are important here, with trade barriers tending to be lower on upstream products, and upstream products tending to be more carbon-intensive than downstream products. Those sectors providing raw materials and intermediate goods tend to be the highest emitters of CO_2 per unit of value-added, yet they tend to face lower tariff and nontariff barriers compared with lower carbon-intensive activities (Shapiro 2021). These differences often arise for reasons unrelated to trade policy—such as lobbying activities—but can have a large impact on the structure of trade. The bias has been estimated as equivalent to a negative carbon price of $90 per MT of CO_2, with recent evidence suggesting that removing these trade policy biases could both increase global real income and reduce global carbon emissions (Shapiro 2021).

There are often strong linkages between climate mitigation policies and trade. Trade-related climate change mitigation policies raise concerns about discrimination between partners and between imported goods and domestic substitutes. Yet, these policies can also encourage trade to become greener (Fadly and Fontes 2019; Shahnazi and Shabani 2019). Trade with economies with strong environmental regulations can be a source of climate-friendly goods, services, and technology, which can help climate mitigation efforts. Trade can also raise ambitions on environmental standards and regulations, with firms exporting to highly regulated economies required to develop or adopt the higher standards that become market entry requirements. While meeting standards may increase costs for firms, they may also be an external force pressuring economies without high standards, thereby enhancing their environmental regulations (Crippa et al. 2016; Perkins and Neumayer 2012).

Carbon policies have trade implications and can be a source of trade tensions. Certain policies aimed at climate change mitigation can lead to trade tensions. One example is subsidies with local content requirements. While they may hope to encourage investment in local climate-friendly infrastructure and technology and build competitive innovation capabilities, they can also restrict trade (IPCC 2022a). These concerns have been raised with recent industrial strategies enacted by many economies. Legal challenges to subsidies have also emerged, with the EU, for example, complaining to the WTO about the UK policy of awarding subsidies for offshore wind projects (European Commission 2022).

Reducing trade policy distortions on climate-friendly goods, services, and technologies can be an important way to reduce emissions. By encouraging trade in low-carbon-intensive products, trade policy can help increase global access to clean goods and services and encourage competition in producing these goods and services. Given the non-discriminatory treatment of foreign products and the WTO's most favored nation (MFN) principle, reducing trade barriers on clean goods further broadens the spread of clean technologies. More generally, reducing trade distortions can provide appropriate incentives for economies with technological know-how to specialize in producing clean goods and services. Through these effects, trade policy can shift global demand toward low-carbon-intensive goods and services and encourage the transition toward low-carbon-intensive production. To reduce the barriers on climate-friendly goods, agreement on a set of products that are considered climate friendly would be needed, although there has been little progress since the original attempts by the Asia-Pacific Economic Cooperation (see, for example, APEC 2021). Also important will be to ensure nontariff measures are an important component of any liberalization on climate-friendly goods. Jakob et al. (2022) point out that nontariff measures can play an important role in limiting access to climate-friendly goods—as packaging and labeling requirements, technical standards and norms add substantial costs to trade in climate-friendly goods. In addition, measures related to labor market regulations—like visa and work permit requirements—can potentially limit trade in environmental services, including the sustainable management of energy, water, and forest resources.

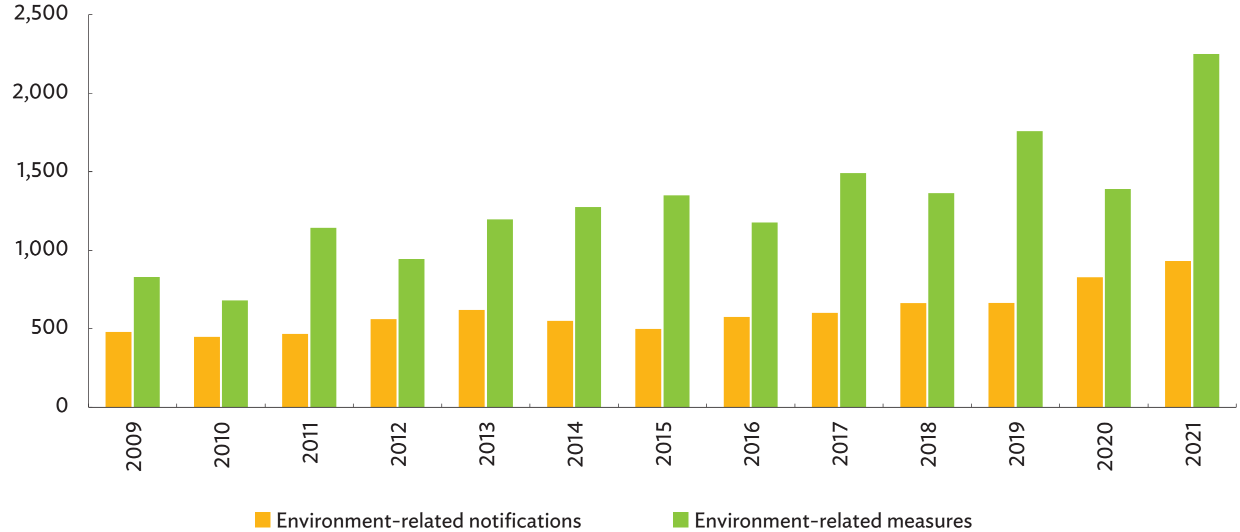
Trade policies also play an important role in economies' strategies to decarbonize. According to WTO (2022a) and UNCTAD (2016), trade-related measures pervade the Nationally Determined Contributions (NDCs) submitted by parties to the UNFCCC. Despite this, the studies argue that NDCs do not integrate trade strategies and perspectives systematically. Environmental notifications and measures reported to the WTO are also rising. According to data from the WTO's environmental database, the number of environmental measures and notifications reported by WTO members increased during 2009–2021 (Figure 6.23). The number of environment-related measures increased from 829 in 2009 to 2,250 in 2021, while the number of notifications increased from 480 to 931 over the same period.

Notifications to the WTO on climate change objectives have been rising over time. The WTO's environmental database also includes information on notifications directly or indirectly linked to climate change, including those on afforestation or reforestation, air pollution reduction, ozone layer protection, climate change mitigation and adaptation, energy conservation and efficiency, and alternative and renewable energy. While there is great variation in the number of notifications each year, the number of climate-related objectives have been rising over time, both in absolute terms and relative to other policies notified (WTO 2022a). The number of climate-related notifications increased from 413 in 2009 to 939 in 2021 (Figure 6.24). Considering the different subcategories, the share of notifications related to climate change mitigation and adaptation increased from 16.7% to 22.0%, while the shares related to air pollution reduction declined from 14.5% to 10.0% and alternative and renewable energy from 28.3% to 24.6%. According to the IPCC (2022a), most notifications on trade-related climate change mitigation involve support measures and technical regulations and conformity assessment procedures, such as those related to regulatory requirements to reduce use of fluorocarbons, preferential tax treatment for energy saving and new energy vehicles, and use of import licenses to regulate lighting with minimum energy performance standards (IPCC 2022a).

Preferential Trade Agreements and the Decarbonization of Global Value Chains

Given the current challenges for global cooperation on climate change issues, PTAs can play an important role in making GVCs more climate friendly. The number of PTAs has expanded rapidly since the 1990s, with their breadth also increasing. Data from the World Bank show

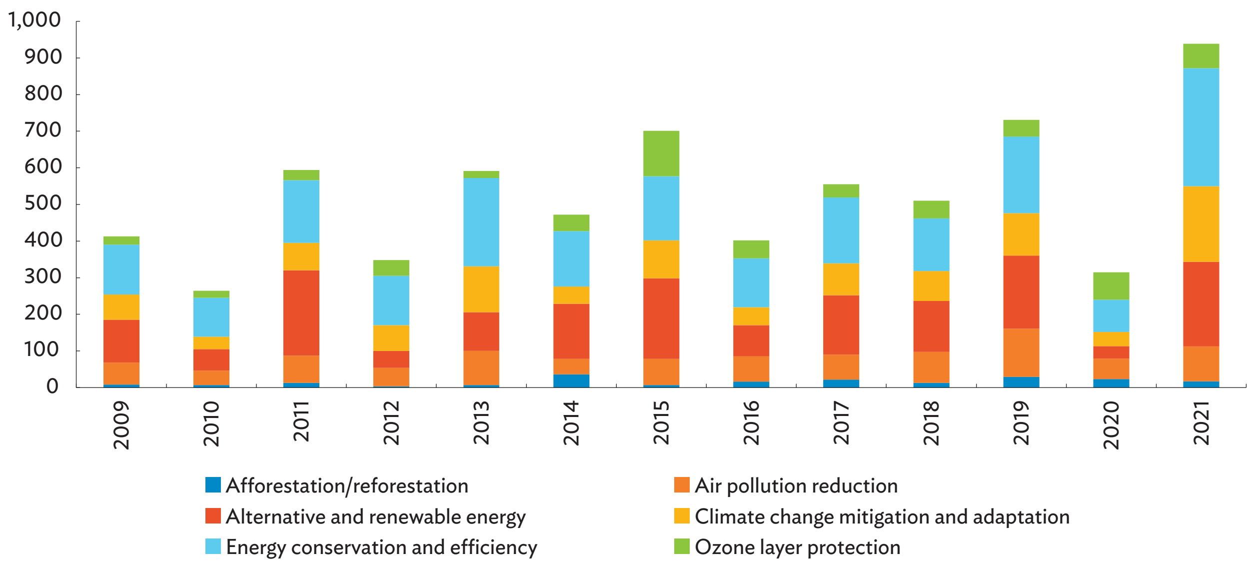
Figure 6.23: World Trade Organization Members' Environment-Related Notifications and Measures (number)



Note: Number of environment-related notifications and measures notified to the World Trade Organization, further split by category.

Source: World Trade Organization. Environmental Database. https://edb.wto.org/charts (accessed November 2023).

Figure 6.24: Number of Climate Change Objectives by Type

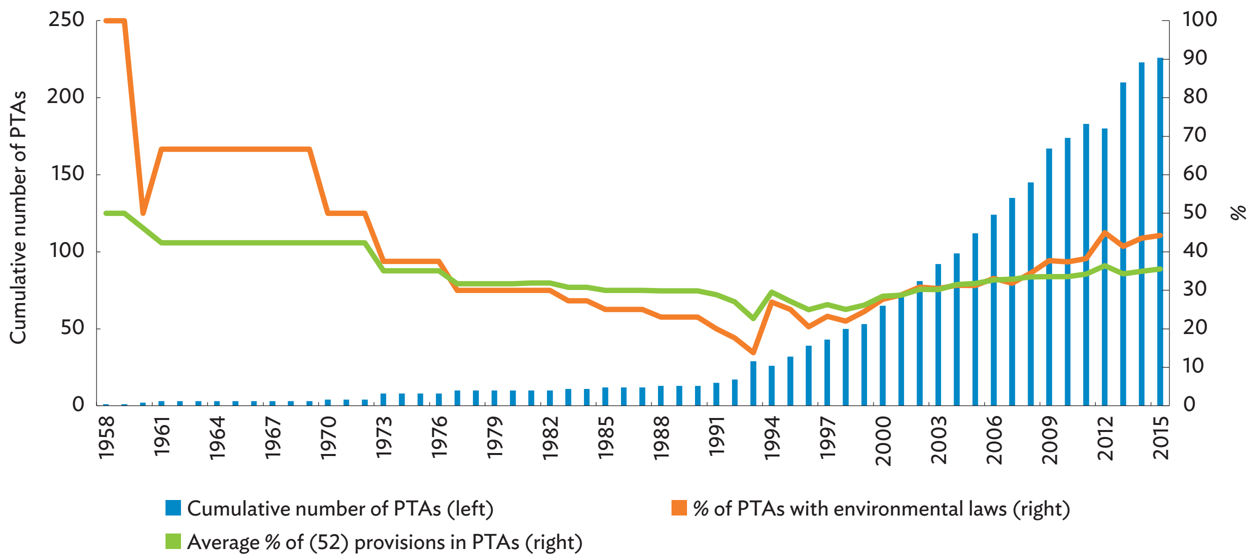


Notes: The number of objectives notified to the World Trade Organization (WTO) on six categories linked directly or indirectly to climate change: afforestation/reforestation, air pollution reduction, ozone layer protection, climate change mitigation and adaptation, energy conservation and efficiency, and alternative and renewable energy. Classification follows WTO (2022a).

Source: WTO. Environmental Database. https://edb.wto.org/charts (accessed August 2023).

the rapid rise in the number of PTAs, especially since the mid-1990s (Figure 6.25). This increase is associated with an increase in the breadth of agreements, with data showing that the average percentage of policy areas covered (from a list of 52 policy areas identified in Hofmann, Osnago, and Ruta 2017) increased from 25% in 1996 to 36% in 2015.

Figure 6.25: Number and Breadth of Preferential Trade Agreements

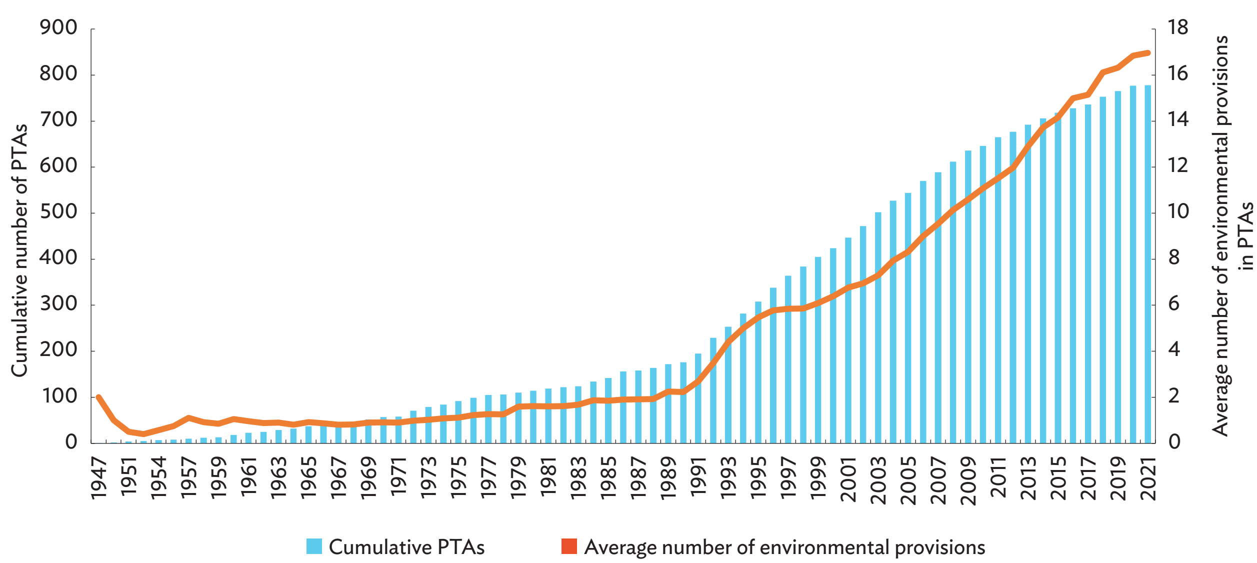


PTA = preferential trade agreement.

Note: The database includes information on 279 PTAs signed by 189 economies during 1958–2015, which includes all PTAs in force and notified to the World Trade Organization.

Source: Hofmann, Osnago, and Ruta (2017).

Figure 6.26: Environmental Provisions in Trade Agreements



PTA = preferential trade agreement.

Note: The Trade and Environment Database (TREND) of Morin, Dür, and Lechner (2018) identifies 298 environmental provisions in a broader set of 775 trade agreements, including World Trade Organization trade facilitation agreements.

Source: Morin, Dür, and Lechne (2018).

Environmental provisions are an increasing feature of trade agreements. The share of PTAs with provisions related to environmental laws have also increased, from 21% in 1996 to 44% in 2015. Those explicitly promoting trade in environmental goods and services are increasingly incorporated into PTAs, with recent agreements further encouraging cooperation on sustainable transport (WTO 2022b). Data from the

Trade and Environment Database (Morin, Dür, and Lechne 2018) indicate that the average number of environmental provisions has increased relatively rapidly since the early 1990s (Figure 6.26) from an average of around two provisions in 1990 (out of 298 provisions) to around 17 in 2021. While 13% of agreements do not include provisions and 46% include less than five, 11% include more than 50 provisions related to the environment. These cover efforts to liberalize trade in certain goods and services (e.g., in green products) and to restrict trade by raising trade costs (e.g., for dirty products).

Environmental provisions in PTAs have ambiguous effects on GVCs and on trade in CO_2 emissions. By lowering the cost of trade, PTAs should enhance trade between partners. Conversely, by increasing relative trade costs for nonmembers, they can lead to trade diversion, with trade shifting from nonmembers to PTA members (Viner 1950). Also, PTAs (and especially broader PTAs) often include nondiscriminatory provisions, potentially reducing trade costs for nonmembers and creating a positive spillover or negative trade diversion effect (Mattoo, Mulabdic, and Ruta 2022; Baldwin 2014; Baldwin and Low 2009). Moreover, a proportion of the environmental provisions involve potentially higher trade costs (e.g., those regarding trade in dirty goods), which can reduce trade among PTA partners and potentially redirect trade to nonmembers. In general, therefore, the relationship between PTAs (and the provisions within PTAs) and trade, especially trade in particular types of products, remains ambiguous. This also extends to CO_2 emissions embodied in PTA trade. Increases in PTA trade should lead to increased emissions. But if PTAs alter the structure of trade toward green products and away from dirty goods—or if they encourage a shift to cleaner production methods—their effect on trade in CO_2 emissions could be negative.

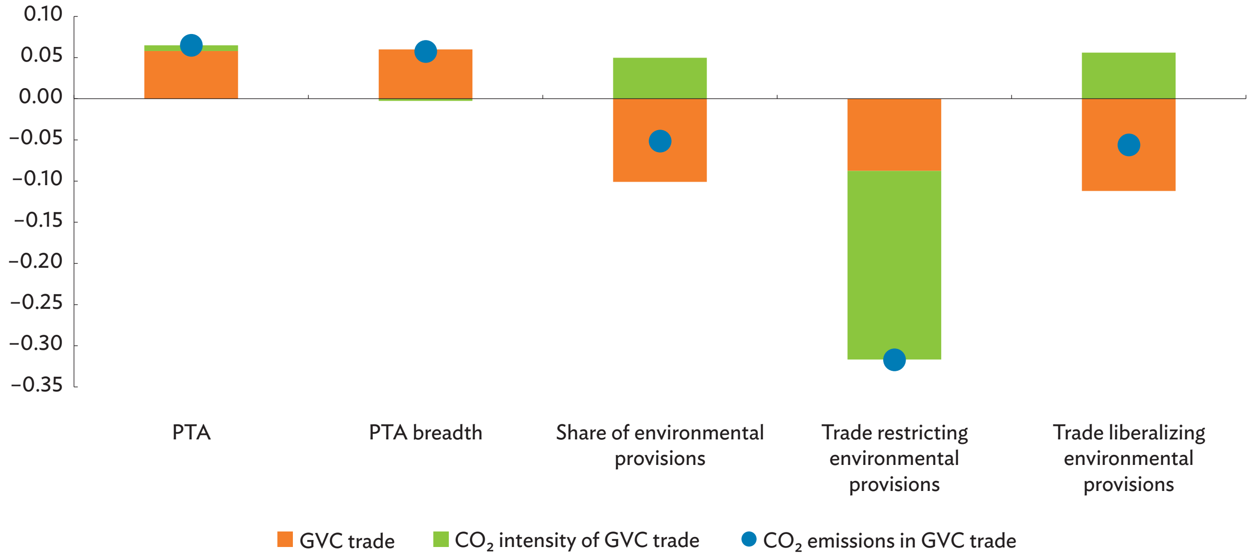
By encouraging GVC trade, the presence and breadth of a PTA are positively associated with trade in CO_2 emissions through GVCs. Estimating the impact of the presence and breadth of a PTA on the CO_2 emissions embodied in GVC trade shows that PTAs are associated with an increase in CO_2 emissions traded through GVCs (Figure 6.27). Specifically, the presence of a PTA is associated with an increase in CO_2 emissions trade through GVCs of around 6.7%, with a movement from the narrowest to the broadest PTA associated with an increase in CO_2 emissions trade through GVCs of 5.9%.[69] This increase in CO_2 emissions embodied in GVC trade is driven almost exclusively by scale effects due to an increase in the level of GVC trade (the value added that is exported through GVCs).[70] For PTA presence, the level of GVC trade accounts for 89% of the increase in CO_2 emissions in GVC trade, with an increase in the CO_2 intensity of GVC trade accounting for the remaining 11%. For PTA breadth, the impact of breadth on CO_2 intensity in GVCs is negative, such that the scale effect of GVC trade accounts for more than 100% (104%) of the increase in CO_2 emissions in GVCs.

Environmental provisions within PTAs are associated with reduced CO_2 emissions embodied in GVC trade between PTA partners. A higher share of environmental provisions within PTAs is found to be associated with lower levels of CO_2 emissions trade between PTA partners (Figure 6.28). A higher share of environmental provisions in PTAs is also associated with a reduced level of GVC trade as well as greater emissions intensity of GVC trade—which partially offsets the negative scale effect of environmental provisions. Specifically, a one standard deviation increase in the share of environmental provisions included in a PTA is associated with a reduction in CO_2 emissions in GVC trade of around 0.24%, with the same increase lowering GVC trade by 0.47% and increasing CO_2 intensity by 0.23%. Differences exist when considering trade restricting and trade liberalizing environmental provisions within PTAs. While a higher share of trade restricting provisions reduces CO_2 emissions in GVCs through both scale and intensity effects, trade liberalizing provisions reduce emissions through a scale effect but increase them through an intensity effect. A one standard deviation increase in the share of trade restricting environmental provisions in PTAs

69 PTA breadth is defined as the number of core provisions identified by Hofmann, Osnago, and Ruta (2017), the maximum being 18, with the variable normalized to lie between 0 and 1.

70 Using the identity $CO_2 = (CO_2/GVC) \times GVC$, with CO_2 being the emissions embodied in GVC exports and GVC the level of GVC exports, and rewriting as $\ln CO_2 = \ln GVC + \ln(CO_2/GVC)$, the level of CO_2 emissions in GVC exports can be decomposed into a scale effect (the level of GVC exports) and an intensity effect (the ratio of emissions to GVC exports).

Figure 6.27: Estimated Impact of a Preferential Trade Agreement on Global Value Chain Trade



CO_2 = carbon dioxide, GVC = global value chain, PTA = preferential trade agreement.

Notes: The figure reports the estimated coefficient on PTA variables from a structural gravity model of (i) the log of the bilateral export of CO_2 emissions embodied in GVC trade, (ii) the log of the bilateral export of value-added embodied in GVC trade, and (iii) the log of the CO_2 intensity of GVC trade (the ratio of CO_2 emissions in GVCs to exports of value added in GVCs). As $\ln CO_2 = \ln GVC + \ln(CO_2/GVC)$, where GVC refers to value added embodied in GVC exports, and given that the regression method (ordinary least squares) is a linear operator, the approach allows for decomposing the effect of PTAs on CO_2 emissions in GVCs into a scale effect (on the level of GVC trade) and an intensity effect (on the ratio of CO_2 emissions to value added in GVC trade). Trade in CO_2 emissions in GVCs is constructed using the approach described in Box 6.3. In addition to the PTA variables, the model includes economy-pair, exporter-time, and importer-time fixed effects. In specifications where environmental provisions are included, the PTA breadth variable is also included so the results on the environmental provisions variables should be interpreted as conditional on a given level of PTA breadth. Similarly, the share of environmental provisions variable is included alongside the trade restricting and trade liberalizing variables.

Sources: ADB calculations using data from Eora Global Supply Chain Database. https://worldmrio.com/eora26/ (accessed November 2023); Hofmann, Osnago, and Ruta (2017); and Morin, Dür, and Lechne (2018).

is associated with a reduction in CO_2 emissions in GVCs of 1.2%, with the scale effect accounting for 0.34 percentage points and the intensity effect 0.90 percentage points. These results suggest that trade restricting provisions can reorient the structure of trade between PTA partners. A similar increase in the share of trade liberalizing provisions is associated with a reduction in emissions in GVC trade of 0.37%, with GVC trade reduced by 0.74% and emissions intensity increased by 0.37%.

In addition to PTAs, other forms of regional cooperation can also be important drivers in decarbonizing production. In 2023, for example, members of the Central Asia Regional Economic Cooperation (CAREC) Program agreed to work together to cut GHG emissions, build resilience to climate change, and help members achieve their Paris Agreement commitments. The "Regional Action on Climate: A Vision for CAREC" highlights the need to enhance collaboration and coordinate with development partners to support the region's climate agenda. It includes the use of renewable energy sources, the energy transition, and innovative financing solutions, among others, as means of helping decarbonize the region's production. The vision further emphasizes the importance of identifying opportunities to reduce the carbon footprint of regional transport services and improving regional connectivity.

Beyond Trade Policy—Additional Ways to Decarbonize Global Value Chains

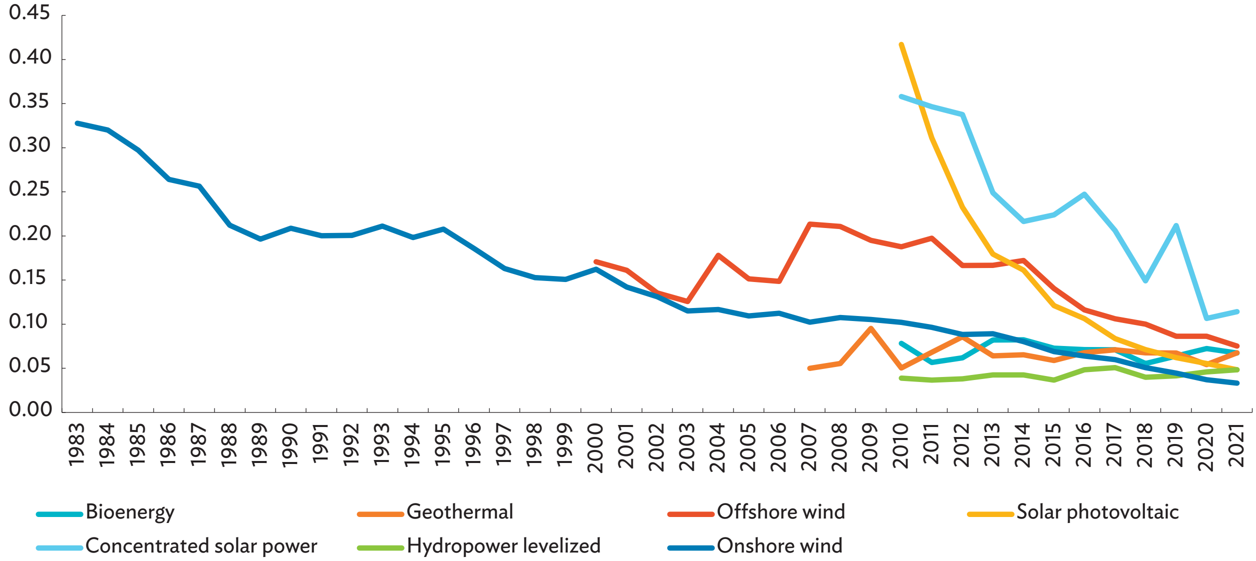
While carbon pricing and regional cooperation can drive the decarbonization of GVCs, policies involving subsidies and technology diffusion provide other opportunities, with multilateral development banks able to further support the greening of production. Without a strong expansion in geographic coverage, BCAs will unlikely be enough to reduce emissions in GVCs by the amounts needed or encourage non-participants to change their behavior. With the exception of the few economies with substantial export shares in the sectors covered, BCAs are considered unlikely to provide the necessary incentives to join a climate club (Jakob 2023). Thus, they will be limited in how much their policies can incentivize trade partners to adopt climate policies. Regional cooperation, and importantly PTAs, can encourage more ambitious climate goals, especially where the possibility of multilateral cooperation appears increasingly challenging. Regional cooperation is limited in its coverage and risks being driven by the member with the weakest climate ambitions, however. Other policies and areas also need to be considered when identifying approaches to decarbonize GVCs.

The structure of industry subsidies encourages carbon-intensive production, particularly in energy. According to the International Energy Agency (2021), fossil fuel subsidies reached $440 billion in 2021. They support carbon-intensive production and consumption, exacerbating the climate crisis, and further reduce the competitiveness of renewable energy sources. However, subsidy reforms will likely have far-reaching effects. They will likely affect trade competitiveness by raising the price of intermediate inputs in energy-intensive sectors, such as steelmaking, petrochemicals, and aluminum (Burniaux, Château, and Sauvage 2011; Cockburn, Robichaud, and Tiberti 2018; Ellis 2010; Jensen and Tarr 2003). In addition, removing subsidies may encourage firms to substitute certain energy inputs for alternative sources and improve their resource efficiency (Rentschler, Kornejew, and Bazilian 2017). Jakob et al. (2022) argue that the WTO can play an important role here, strengthening "transparency through improved notification by its members, counternotification by other members, and by addressing fossil fuel subsidy reform in the Trade Policy Review Mechanism." A new category of prohibited subsidies could be agreed upon, potentially limited to a subset of fossil fuel subsidies, based on their trade and/or environmental effects and considering the challenges faced by developing economies in reforming subsidies. Given the WTO's current challenges, and as acknowledged by many others, subsets of economies could proceed with developing plurilateral agreements rather than waiting for all WTO members to agree on fossil fuel subsidies (Bacchus 2021).

The price of green technology, particularly for energy production, has decreased substantially, with global competition providing further opportunities for green technological change. In recent years, the price per kilowatt-hour of energy has dropped substantially across a range of green technologies, with the drop in solar power cost particularly strong in recent years (Figure 6.28). This makes green energy highly competitive in terms of price relative to energy produced by fossil fuels.[71] Moreover, recent policies such as the US Inflation Reduction Act and the EU's mission-oriented approach to innovation aim to encourage research and development in renewable energy along with climate adaptation and mitigation. These initiatives offer an opportunity to encourage competition in developing new climate-related technologies that can help mitigate climate change using technology-based solutions (Mattoo and Subramianian 2013). If these technologies, including low-cost batteries and carbon capture and storage techniques, are more easily spread to developing economies, economies may be able to meet their energy needs without increasing CO_2 emissions. The possibility of opening green windows of opportunity in developing economies (UNCTAD 2023) through technological change, along with changes to public institutions and markets, may allow developing economies to quickly catch up and potentially leapfrog in applying green technologies, avoiding development of a carbon-based production system. GVCs, particularly the approaches of lead MNEs, can be important in decarbonizing GVCs and production more broadly through technology diffusion and adoption. Given the sectoral structure of developing Asian economies in GVCs, shifting to green energy sources can be an important source of GVCs emission efficiency.

[71] While the price of green energy is highly competitive, energy produced through green sources remains relatively small. Scaling up these technologies to meet total energy needs may involve substantial costs and challenges.

Figure 6.28: Levelized Cost of Energy of Alternative Renewable Energy Sources ($/kWh)



kWh = kilowatt-hour.

Notes: Data on the average cost per unit of energy generated across the lifetime of a new power plant. Data are expressed in constant 2021 United States dollars.

Source: Our World in Data. Levelized Cost of Energy by Technology. https://ourworldindata.org/grapher/levelized-cost-of-energy.

The diffusion of technology that improves CO_2 emissions intensities can also help reduce global emissions, while stimulating international trade in the process. Adopting the CGE model used to consider the impacts of CBAM, it is further possible to study the effects of a convergence in CO_2 emissions intensities across economies. Specifically, the effect of allowing for a partial convergence of the emissions intensity of these economies toward the average OECD CO_2 intensity (50% convergence)—in the policy scenario that extends CBAM to the rest of the OECD and to ADB regional members at a carbon price of €200 per MT—is examined. With the exceptions of developed Asia and the Republic of Korea, both included in the OECD group, and relative to the baseline, GDP is estimated to increase across the different Asian regions, with relatively large increases in Central and West Asia, India, the PRC, and Southeast Asia (Table 6.11). These changes reflect the relatively high CO_2 emissions intensities in these regions, with a convergence to 50% of the OECD level implying a significant decline in emissions intensity. Compared to the baseline, exports are also found to increase in most Asian regions, with the exceptions of developed Asia and the Pacific. Relative to the earlier scenarios, the extent of labor displacement is also found to be large when allowing for a convergence in emissions intensities, suggesting that the convergence could lead to substantial structural changes. Finally, in terms of global CO_2 emissions, while the extended CBAM with a carbon price of €200 per MT is predicted to lower global emissions by 14.9%, when a partial convergence in emissions intensity is also allowed for, global emissions are predicted to drop by 17.2%. These results highlight the importance of technology diffusion and other means of improving emissions intensities. While the effects of CBAM often involve a trade-off between emissions reduction and trade and GVC activity, this exercise suggests that improvements in emissions intensities could mitigate this trade-off, making it possible for both emissions to fall and exports to rise in response to emissions intensity convergence.

Multilateral development banks are an important source of finance for climate change mitigation and adaptation, though current financing falls short of what is needed. Perhaps the worst bottleneck in decarbonizing production is finance, with the climate finance gap particularly pronounced in developing economies. Multilateral development banks (MDBs) already play an important role in providing climate finance, using their ability to mobilize finance cheaply on capital markets. They accounted for $51 billion in climate finance to low and middle-income economies in 2021 (EIB 2022). Initiatives such as ADB's commitment for at least 75% of its operations to support climate change by 2030 (ADB 2023c) further signal the importance of climate change and climate finance in MDB activities. Innovative financing mechanisms such as ADB's Innovative Finance Facility for Climate Asia and the Pacific, which will use partner guarantees for leverage, could accelerate billions of dollars in much-needed climate change funding.

In addition to increasing the value of climate change funds, MDBs will need to ensure they are deployed more efficiently and effectively. To use resources effectively, MDBs need to direct these resources toward sustainable activities, which requires them to appropriately define sustainable activities and assess and track the impact of their investments (St George and Marten 2023). Various challenges must be addressed, including a lack of capacity to evaluate the returns to green technologies and projects. This reflects both a lack of knowledge on the environmental impact of the technology and appropriate ways to measure the return on investments, the increased risk associated with new business models serving climate-friendly growth, and on choosing the most appropriate financial instruments. MDBs will need to develop innovative tools to evaluate potential projects. This will allow them to build a pipeline of climate-related projects, develop a knowledge-base on successful projects (for capacity building within MDBs and governments in developing economies), de-risk climate projects to attract private investment, and explore new and innovative financing options to support investment in new and innovative climate technologies. MDBs can also help mitigate the financial risks associated with climate projects, potentially crowding-in private sector investment. An important component will be developing robust monitoring and evaluation systems, using common standards to monitor and evaluate projects, such as those for climate mitigation finance tracking (ADB 2021).

Beyond climate finance, MDBs can be an important source of technical support, capacity building, and policy advice, ensuring that developing economies are investing in green infrastructure. MDBs can assist economies to build the capacity to design, implement, and

Table 6.11: Predicted Changes in Macroeconomic Variables in Response to Carbon Dioxide Emissions Intensity

	Change in GDP (%)	Change in Exports (%)	Labor Force Displacement (% of workforce displacement)
Developed Asia	-1.29	-4.31	0.86
Central and West Asia	12.07	6.38	2.76
East Asia ex-Japan	0.69	-1.04	1.42
South Asia	1.18	7.67	1.36
Southeast Asia	5.20	2.67	1.50
Pacific	3.62	-4.98	1.63
PRC	6.33	0.27	1.41
India	7.68	0.40	2.57
Republic of Korea	-0.86	-2.23	1.25
European Union	-1.16	-1.54	0.91
OECD Europe	-0.74	-2.47	0.73
Eastern Europe	15.91	9.70	3.37
North America	1.90	-0.65	0.47
Latin America	1.71	-4.04	0.92
Other West Asia and North Africa	2.83	-6.15	1.75
Sub-Saharan Africa	1.38	-7.48	1.16
World percentage change	2.30	-3.48	1.08

GDP = gross domestic product, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China.

Sources: ADB calculations using data from Global Trade Analysis Project. GTAP 11 Data Base. https://www.gtap.agecon.purdue.edu/databases/; and International Energy Agency. Data and Statistics. https://www.iea.org/data-and-statistics (both accessed November 2023).

monitor climate change mitigation projects, and provide training and technical support to ensure effective project management and sustainable outcomes. By assisting in the design and implementation of climate-related projects, MDBs can help economies develop projects that both reduce emissions and enhance socioeconomic development. MDBs also have an important role to play in offering policy advice that helps economies create and implement effective climate change mitigation policies. MDBs can also use their convening power as a platform for exchanging knowledge and best practices among economies.

Technology transfer, especially in the context of GVCs, is another area where MDBs can play a role. Access to green infrastructure will become increasingly important for lead firms in GVCs, both in response to more aggressive climate policies of different economies and to the increasing relevance of environmental, social, and governance commitments. MDBs can help facilitate sustainable investments along value chains, assist with the spread of green technologies and ensure appropriate standards are in place (UNEP 2022). Adopting common principles for accounting and tracking climate finance by MDBs can be useful in ensuring climate finance is targeted appropriately (ADB 2021). They can also help ensure transparency and traceability of CO_2 emissions in GVCs. One important challenge in developing EEFs, for example, is the difficulty in ensuring alignment with trade rules and with those of diverse trade partners. MDBs can work to help create an alignment mechanism through their capacity-building activities in green trade facilitation, with the strong potential to help in decarbonizing GVCs. By doing this, MDBs can play a role both in decarbonizing GVCs and cementing their continued role as development escalator for developing economies.

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