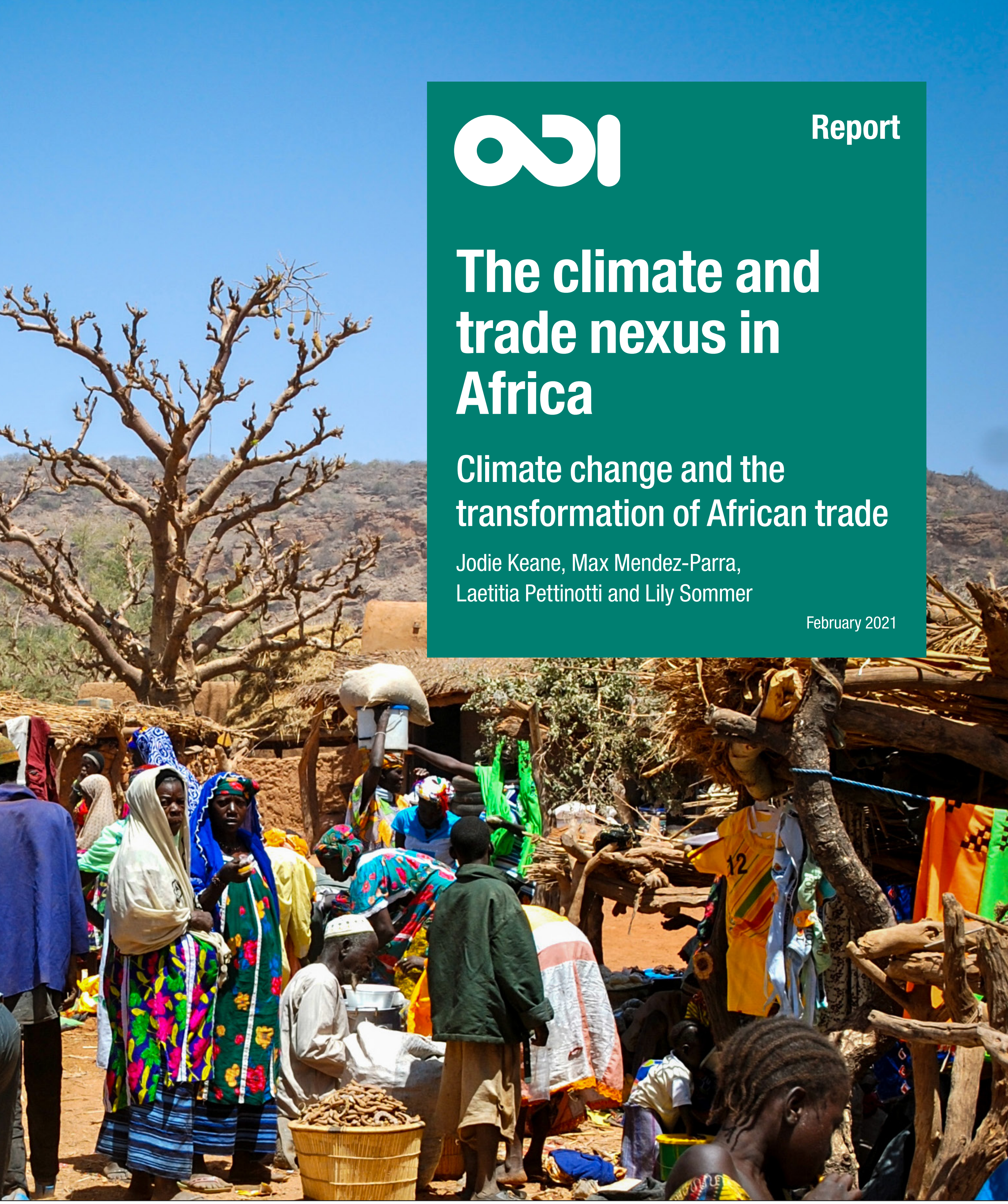

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Report

The climate and trade nexus in Africa

Climate change and the transformation of African trade

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Cover photo: A market in Bandiagara, Mali. © Irina Mosel / ODI

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Acronyms

AfCFTA	African Continental Free Trade Area
AfT	Aid for Trade
BCA	border carbon adjustment
CDP	Committee for Development Policy
CO_2	carbon dioxide
CO_2eq	carbon dioxide equivalent
COP	Conference of the Parties
EEVI	Economic and Environmental Vulnerability Index
EU	European Union
FTA	Free Trade Agreement
GDP	gross domestic product
GhG	greenhouse gas
GVC	global value chain
IPCC	Intergovernmental Panel on Climate Change
LDC	least-developed country
MRIO	multi-region input–output
Mt	megatonnes
OECD	Organisation for Economic Co-operation and Development
ROW	rest of world
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WTO	World Trade Organization

Executive summary

This report presents the first part of ongoing research assessing the relationship between trade and climate change in Africa. This first part presents a description of the main dynamics of this relationship. The second part, in a separate paper, will discuss the policy options available to African countries as well as the opportunities that the African Continental Free Trade Area (AfCFTA) presents to bring forward development and trade-friendly climate action policies.

This report first analyses the impacts that changes in trade structures, economic growth and technology have had on the greenhouse gas (GhG) emissions generated in the continent. Second, it sets out climate change adaptation and mitigation strategies in the context of Africa's economic transformation and development. In this sense, it aims to identify the intersection between trade and climate policies and critical outcomes: the low-carbon and resilient economic development of the continent.

Trade is an underlying driver of GhG emissions globally. GhG emissions from trade depend on energy efficiency via the technique effect and on GhG intensity of production via the composition effect, the two effects being compounded by the scale effect. Each effect is underpinned by emissions linked to international freight transport.

What is the carbon intensity of Africa's trade?

Emissions generated in Africa have increased by 61% while exports of goods and services have risen by almost 200% since 1990. This means the carbon dioxide equivalent (CO_2eq) content in African exports has fallen from 8.52 kilograms per US dollar of exports in 1990 to 4.61kg per US dollar in 2017.

While technological change in production has played a key role, the rise of intra-African trade and changes in the structure of exports are likely to explain this trend. Intra-African trade grew by almost 800% over the period mentioned above, suggesting an even weaker relationship with the rise in African GhG emissions. Beyond the effect that shorter transport routes may have, more than 60% of products exported to the rest of the continent are manufactures with lower CO_2eq content than agricultural and mineral commodities, which represent more than 45% of exports to the rest of the world.

How will Covid-19 affect trends?

The Covid-19 crisis may have altered these trends and trade structures. In addition to emissions and trade being disrupted, the response to the crisis and the recovery is likely to have a significant impact on the relationship between trade and emissions on the continent.

Governments around the world are seeking not only to stimulate domestic production but also to enhance resilience to shocks, including through supporting multinational firms to reshore stages of production (even when this may not necessarily be efficient or may reduce resilience). The climate community is echoing this approach for particular sectors. Notwithstanding issues regarding economic efficiency, the shortening of global value chains (GVCs) for different reasons is likely to accelerate in the aftermath of the Covid-19 crisis.

What are the particular risks and opportunities facing Africa?

Indeed, before the shortening of value chains as a policy objective became a globally important point of deliberation post-Covid-19, it had come to rest implicitly at the heart of the African trade and regional integration agenda. This reorientation of GVCs in some respects provides important opportunities for the African continental and regional integration agenda. However, there are also particular challenges, which the likely effects of climate change may compound.

The position of Africa within the current GVC configuration creates particular susceptibilities to external shocks, including climate ones, because of a strong reliance on forward linkages. Changing Africa's position within GVCs, with a greater emphasis on intra-African value chains, could change current vulnerabilities.

However, the different types of vulnerabilities exacerbated or created by climate change deserve particular attention. Given the multiple and compounded vulnerabilities of African countries and their tradable sectors to climate change impacts, increased capacity to adjust is an imperative for the continent's continued economic development. Adaptation financing is falling short for Africa at $5 billion in 2018 as against adaptation costs estimated at around $47 billion a year by 2050.

In this context, developing trade and enhancing export and import diversification is a critical form of resilience-building, with implications for macroeconomic stability and for private actors (households and firms). But it is important to draw out the tensions and necessary conflicts if one trading partner wants to build resilience without consideration of the potentially adverse effects on trading partners. The climate vulnerability pathways related to trade for Africa should be distinguished on an extra- and intra-African basis, in view of the continent's integration agenda.

Understanding countries' exposure to climate change, as well as the risks arising from changes in value chain structures, requires a focus on how countries trade – whether organised through vertically fragmented and coordinated GVCs or through commodity markets – taking into account import and export exposure and the effects on productive structures, including firm-level behaviour. The value chain perspective underscores the importance of understanding climate vulnerabilities of inputs at each stage of the value chain – where and how stages of production are exposed to specific climate impacts – and the implications for value chain management at both strategic and operational levels, and on an intra- and extra-regional basis.

1 Introduction

We are in a climate emergency. To have even a one-in-two chance of arresting global warming at 1.5°C above pre-industrial levels, humanity needs to halve greenhouse gas emissions by 2030 (relative to 2010 levels) and then reach net-zero emissions by mid-century (IPCC, 2018). Africa, despite contributing the least to climate change, is expected to experience some of the most severe effects (Niang et al., 2014). Moreover, the continent faces an unprecedented developmental challenge: how to achieve structural economic transformation that lifts living standards for all within a stringent carbon budget.

The next few years will be of pivotal importance for two reasons. First, the 26th Climate Change Conference of Parties (COP26) in 2021 will prove the first real test of the Paris Agreement, with countries expected to commit to deeper emission reduction targets. Second, the choices made around the Covid-19 recovery will lock countries into more or less carbon-intensive development paths for decades to come.

This report therefore critically reviews the relationship between trade and climate change to understand how African nations can achieve economic transformation with the new constraints and challenges imposed by rising temperatures. It brings together three critical policy agendas: the reduction of GhG emissions, adaptation to emerging climate risks and the economic development of Africa.

The relationships are more important than ever in the aftermath of the Covid-19 pandemic. Governments around the world are seeking to bolster domestic production in the belief that this will enhance resilience to shocks. Expanding trade among African countries has always been at the heart of the African regional integration agenda, but this global trend towards shorter value chains poses threats to production capacity and economic diversification on the continent. While both free trade and protectionism are promoted for their economic development objectives, it is important they are critically reviewed through the lens of climate change adaptation and mitigation.

This report is the first of two papers. It begins by describing Africa's current trade and position in GVCs. It then summarises what we have learnt from the Covid-19 trade shocks and whether these lessons are likely to transform value chain configurations in the future. We then proceed to measure African emissions embedded within trade. Given these findings, we review trade vulnerability for Africa encompassing value chain dimensions on an intra- and extra-regional basis. Finally, we set out the adaptation gap for the continent. We conclude by summarising the major findings of our analyses; their implications for trade policy will be reviewed in our next research paper.

2 Trade and climate in the Covid-19 context

2.1 Resilience and robustness of value chains: what have we learnt?

The trade-related effects of the Covid-19 pandemic foreshadow those likely to arise as a result of climate change (Wolf, 2020). The pandemic has revealed how international trade brings tremendous benefits but also heightens economic vulnerabilities depending on how countries trade and how trade relationships are managed between firms. Increased interconnectedness means shocks are transmitted more quickly, affecting many interrelated stages of production and linkages within GVCs, and sometimes being amplified through them.

The efficient operation of value chains relies on specialisation in production tasks as well as minimal constraints on inputs and sourcing. It is this specialisation that generates efficiencies across the whole chain, as long as the connections of each sequence in the chain are facilitated by low restrictions and costs and coupled with effective trade, transport and logistics services; together these enable just-in-time operations (Banga et al., 2020).

If the vulnerabilities of GVC trade became apparent during the global financial crisis of 2008–09, the trade-related effects of Covid-19 have been even more dramatic. Efforts to reduce trade vulnerabilities are being accomplished through specific policy measures, including the shortening of GVCs (reducing the number of stages of production located abroad).

However, GVCs had been shortening before Covid-19. According to Miroudot and Nordström (2019), the reasons for supply chains becoming more domestic as opposed to more regional may be structural, related to digital transformation, or a result of production moving closer to consumers. The effects of Covid-19 and efforts to enhance resilience and reduce trade-related vulnerabilities are likely to accelerate these trends.

The European Union (EU) has signalled its intent to pursue strategic autonomy as a trade policy, increasing domestic production. Japan is actively encouraging firms to relocate from China. Policy measures to support the reshoring of activities include the deployment of financial incentives. While international organisations such as the Organisation for Economic Co-operation and Development (OECD) advocate open markets (OECD, 2020a), given trade vulnerabilities potentially accentuated by the shortening of GVCs, governments must balance the economics with the politics. Unilateral measures adopted during the Covid-19 era, such as the use of export restrictions claimed to be motivated by public health and security concerns, have hindered trade and broken down supply chains. And supply chains are now actively changing in response to public policy objectives as well as structural factors.

Digital technologies are enabling new production techniques and new business models focused on delivering services as well as manufacturing products (Miroudot and Nordström, 2019). However, shorter GVCs are also a function of political, social and environmental objectives. There are calls to reduce emissions associated with freight transport and industry fears of competition from jurisdictions with less stringent environmental regulations.

The pandemic has come at a time of more overt protectionism, with many governments deeply concerned over their producers' and consumers' reliance on the small number of suppliers (notably concentrated in China). The effects of Covid-19 and efforts to enhance resilience and reduce trade-related vulnerabilities are likely to accelerate these trends.

In some ways, trade and climate policy have therefore been pursuing similar outcomes: the shortening of GVCs as a means of boosting resilience and reducing greenhouse gas (GhG) emissions (Keane et al., 2020). However, it is important to note that these relationships may not always hold true. For example, the consumption of locally produced food may enhance food security and reduce GhG emissions from transportation (Mbow et al., 2019), but it depends on the carbon intensity of different agricultural practices (for example, the amount and composition of energy required to warm a greenhouse or the conversion of natural ecosystems to cultivated land) (Beattie, 2020). As a result, geographical proximity to end consumption markets does not always mean less GhG-intensive production as the food miles or air miles debate of 2007 highlighted – see Garside et al. (2007).

In the same way that shortening supply chains does not guarantee reduced emissions or vulnerabilities, enhancing resilience along GVCs will require a nuanced risk management strategy. This is because not all stages of production will be exposed to the same shocks or vulnerable to the same extent, whether pandemics, protectionism or a warming planet. Building the resilience of GVC trade to all shocks at each stage – production, transportation, sale – in a way that ensures sufficiency of all inputs – water, energy, intermediate products and services – will be complex. Enhancing export, import and trade route diversification will be a critical form of resilience-building, and this is the reverse of protectionism.

However, the effects of the pandemic are likely to accelerate political impetus towards shorter GVCs. Unilateral measures adopted during the Covid-19 era, such as export restrictions allegedly motivated by public health and security concerns, have hindered trade and broken supply chains. These unilateral measures are unlikely to be lifted soon; even if they were, those supply chains are now actively changing and are unlikely to quickly revert to their pre-pandemic configurations.

The changes in GVCs will profoundly influence economic development trajectories for the African continent, including its contribution and vulnerability to the climate emergency.

2.2 Africa's participation in GVCs

Africa is primarily involved upstream in GVCs: providing intermediate products and services within a wide range of global supply chains, through forward linkages.[1] Around 80% of Africa's exports of intermediate products go to China, the EU and the US. More than 60% of African value added in global exports is embedded in European production – as shown by Figure 1 – in part directly in exports to Europe but also indirectly in the exports of third countries to Europe.

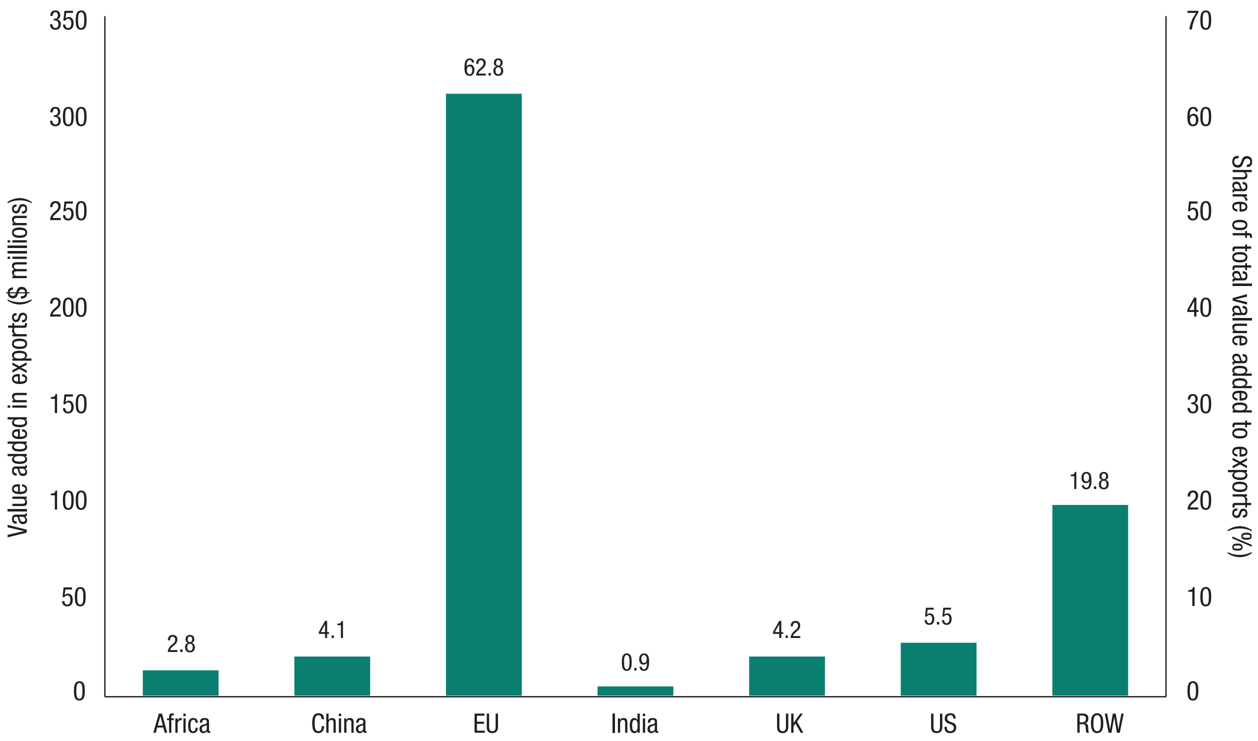
Demand and price shocks tend to hit countries with high forward linkages more than they do those with backward linkages (World Bank, 2020). Indeed, the Covid-19 pandemic has exposed Africa's reliance on imports for access to essential products in a major way. Subsequently, it has led to an increased focus on regional value chains and intra-regional trade for economic recovery.

For specific industries such as the pharmaceutical industry, the continent has a huge dependence on imports. Local production is extremely weak: domestic manufacturers produce 25–30% of the pharmaceuticals and less than 10% of the medical supplies in the African market (Lannes, 2014).

As other countries are adopting specific trade policy measures which they believe will boost resilience and reduce the vulnerabilities associated with GVC trade, African trade will need to adjust. African trade will also have to adjust to the shortening of GVCs driven by policy choices in other countries and regions.

1 This section is adapted from Banga et al. (2020) unless otherwise specified.

Figure 1 African value added in third countries' exports, 2015



Source: Banga et al. (2020)

Looking forward, Africa's export diversification efforts into high-value agriculture could be curtailed by these shocks and trends. At the same time, however, a shortening of GVCs and more general acceptance of import substitution policies in critical sectors could provide an important boost to the continent's industrial development objectives (though the efficacy of such measures remains debateable). Multinational firms, with support from governments, could decentralise supply chains in such ways as to ensure greater participation by emerging African hubs.

Broadly speaking, the following trends can be identified:

- **deconcentrating supply chains:** moving away from reliance on a dominant hub within a particular region or globally and establishing more geographically diverse production nodes
- **movement from 'just-in-time' models of value chain organisation to 'just in case',** including through more effective stock management and inventory
- **boosting domestic productive capacities:** alongside managing and increasing inventory stocks to support 'just in case' models of production
- **supporting firms' diversification efforts,** including entering value chains and undertaking a greater number of functions in the value chain
- **enhancing robustness of supply relationships:** strengthening firms' trading relationships and better understanding of tiers of producers can enhance traceability.

Governments can coordinate with companies and use policy measures to promote changes in the way that supply chains are operated. The extent to which trade and climate policy serve to support or undermine African trade and development strategies through integration with global or regional value chains requires scrutiny.

2.3 The future of GVCs: recovering from Covid-19 and adapting to climate change

We have around 10 years left to achieve the Paris Agreement commitments. To do this, COP26 must deliver deeper nationally determined contributions and unlock blockages in negotiations regarding finance, carbon accounting and transparency and difficult issues related to loss and damage. There has been significant momentum since 2018, with many of the world's largest emitters committing to reach net-zero emissions by mid-century – including countries and companies. Emissions have also fallen significantly in 2020 due to the economic collapse (Le Quéré et al., 2020), although this looks likely to be a temporary drop rather than the start of deep decarbonisation. However, negotiations come at a time of profound economic uncertainty in view of the Covid-19 pandemic, with global growth and international trade slashed and unprecedented budgetary pressures on governments. In light of the global recession arising from the lockdown, and dramatic reductions in emissions experienced so far in 2020, some industries are calling for new baselines. In order to support economies at low cost, climate change concerns take a back seat within economic stimulus packages (Dagnet and Jaeger, 2020). Several countries have allocated their fiscal stimulus packages in ways that favour fossil fuels rather than a low-carbon transition, including Indonesia, Russia and the US, and the hosts of COP26 (Italy and the UK) (Energy Policy Tracker, 2020).

Meanwhile, some policy-makers are seeking to enhance trade and climate resilience, believing they can achieve this through the shortening of GVCs. But the reality is more complex: building the resilience of GVCs to shocks, including climatic shocks, at each stage (production, transportation, sale) and considering all inputs will take different forms. At least 1.1°C of global warming is locked in, and recent analyses suggest that the world remains on track for an average temperature rise exceeding 3°C above pre-industrial levels (UNEP, 2020). It is therefore urgent that firms and governments find ways to enhance their economic resilience to climate hazards such as more frequent and severe heatwaves, storms, flooding, droughts, fires and ecosystem collapse, as well as their human consequences: food insecurity, water scarcity, infrastructure damage, displacement, migration and conflict. Existing trade routes may need to be buttressed and new ones found as either specific production hubs or trade routes succumb to climate change.

The identification of new trade routes in view of resilience-building against future pandemics will also need to be weighed carefully against the new risks and vulnerabilities arising from climate change. The imperative of enhanced productive capacity and export diversification, as a means through which to mitigate the physical (as well as, in some cases, the regulatory) effects of climate change, is acute. While contributing the least to historical emissions, the continent faces an unprecedented development challenge: the reduction of poverty within a carbon-constrained global economy, adaptation to the physical effects of climate change and regulatory changes to support net-zero emissions by 2050.

2.4 Sectoral considerations

The primary sector: agriculture and natural resources

Structural transformation of economies becomes an imperative to adapt to the physical effects of climate change: African economies dependent on rainfed agriculture for production and trade will invariably be hit hardest. The growing vulnerability of agricultural production expected to result from climate change is likely to increase the importance of off-farm activities in rural households' livelihoods as they, in theory, offer opportunities for diversification away from agriculture as it becomes riskier (Lemma et al., 2015).

Climate change effects on agricultural yields will be uneven around the world; a few countries, mostly in high latitudes, may experience gains but most will see average yields decrease (Gouel and Laborde, 2018). Climate-induced yield changes generate large price movements that incentivise adjustments in acreage and trade, meaning trade patterns are likely to change – with large welfare losses from climate change

Figure 2 Climate change impacts on crop yields, accounting for CO_2 fertilisation

Source: Adapted from Gouel and Laborde (2018)

when adjustments in trade flows are constrained versus when they are not (ibid.).[2] Sub-Saharan Africa is expected to experience the largest declines across all crops (Figure 2).

The expansion of carbon markets for carbon sequestration services, including within the agriculture and forestry sectors, as well as related to biodiversity, must be explored carefully by African policy-makers. Although no international agreement has yet been reached on trade of emissions permits and credits, interim guidelines have been developed (by Costa Rica and Switzerland).

The secondary sector: manufacturing

There will be trade-related costs of adjustment to new regulatory measures arising in trading partners as part of efforts to mitigate climate change. While the trade in agricultural products may be primarily at risk from the physical effects of climate change, the trade in manufactured goods also faces transition risks – the risk of stranded assets and stranded workers due to new regulatory measures arising in trading partners as part of efforts to mitigate climate change. As Pettinotti et al. (2020) discuss, energy use targets have implications for standards and labelling, with potential for technical barriers to arise as a result of carbon labelling schemes, and subsequent competitiveness issues arising between countries undertaking more or less stringent measures to address climate change. Movement up the value chain and into processed manufacturing could become constrained by more stringent standards, including on producer carbon content, which will increase costs for exporters.

The EU has already announced its intention to impose border carbon adjustment (BCA) measures on imports from high-carbon emitters. While the overall efficiency of these measures – both economically and in relation to climate change mitigation – has been questioned (Mendez-Parra et al.,

2 The authors also note that, without the proper policies in place to address the root of the issue – climate change agreement – and the resilience of existing trading institutions, political pressure to use trade policy instruments to mitigate the terms-of-trade impact of an agricultural productivity shock may in fact exacerbate the initial efficiency shock.

forthcoming), they look set to be designed in such a way as to be compatible with World Trade Organization (WTO) rules and may indirectly affect African exports.

In the design of its BCA measures, the EU's preferred option is the inclusion of non-EU firms in its existing Emissions Trading Scheme (Dreyer, 2020). Sectors such as steel, cement and aluminium will be targeted. Exporters of these products, such as Brazil, China, Russia and South Africa, will be required to purchase carbon allowances or face a carbon-related tariff, and therefore de facto participate in the Emissions Trading Scheme.

There could be knock-on effects on suppliers, including in Africa. Analyses have identified least-developed countries (LDCs) such as Mozambique as vulnerable to EU border adjustment measures – in Mozambique's case because it supplies the raw materials for other developing country suppliers: around 80% of its exports to the EU are energy-intensive (aluminium, iron, cement, paper), and add up to almost 50% of its total exports (see Brandi, 2010). The extreme export dependence of countries like Mozambique on a few products and commodities, often trading within highly asymmetrical or captive value chains and with weak capacity to negotiate with buyers, results in more limited capacity to adapt.

In a world where the welfare effects of BCA measures have the potential to shift the burden of climate adjustment through supply chains including to commodity exporters in Africa (Krishnan and Maxwell, 2020), it is imperative to keep avenues for export diversification open. The shortening of GVCs, as advocated by some policy-makers, could jeopardise trade, production efficiencies and development strategies, as well as not necessarily being the best option for climate change mitigation and adaptation (Keane et al., 2020).

Greater alignment of institutional mechanisms to address climate change and international trade issues is required to better support developmental objectives. The enhanced integrated framework for LDCs could provide a model for a broader Environment Facility and demonstrate how Aid for Trade (AfT) could work with climate finance to unlock new trade opportunities arising from the global transition to net-zero carbon by 2050.

2.5 Business model considerations

One of the lessons of Covid-19 is that governments need to better understand the organisation of tiers of suppliers: improvements in tracking subcontractors helps in understanding exposure to risks, including climatic risks. Financiers and insurers are also demanding that businesses better understand risks across their supply chains.

More proactive supply chain management will be required in the future, which increases the demands on trade policy-makers. For example, there will be a greater need to understand how GVCs are aligned with local and national innovation systems; how inventory management influences the resilience, flexibility and responsiveness of value chains (given the shortcomings of just-in-time models of delivery); and, finally, how business intends to respond to risks and the appropriate public policy frameworks to assist in reducing these in the most socially optimal ways (see Keane et al., 2020).

Risk management systems must become more integrated between the public and private sectors. For example, companies might conduct supply chain risk assessments focused specifically on climate resilience to ensure their business models are robust in the short and long term, but broader societal concerns must become better integrated. In cases where the private sector is unable or unwilling to share assessments details, the public sector may play a facilitating role – mandating the disclosure of climate risks, creating tax incentives for climate risk assessments or investments in resilience, and/or providing training and technical support materials and clear regulatory signals (Adams et al., 2020). The recommendations and guidelines of the Taskforce on Climate-Related Financial Disclosure are likely to be an important resource, though most businesses have not yet applied this to their supply chains, or governments to their trade strategies. All of this demands greater trade governance capabilities.

3 The trade and GhG emissions link in Africa

3.1 Mapping the links between trade and GhG emissions

Trade is an underlying driver of GhG emissions globally (Blanco et al., 2014). Immediate drivers of GhG emissions that contribute to climate change include energy intensity, GhG intensity, gross domestic product (GDP) per capita and population. In this context, trade is understood as part of the 'processes, mechanisms and characteristics of society that influence emissions' through the immediate drivers (ibid.).

Following the three trade effects of scale, technique and composition (Grossman and Krueger, 1991), the conceptual interaction between trade and GhG emissions can be framed as:

- **Composition effect:** countries specialise in certain production sectors, hence the GhG intensity of trade depends on products' specialisation and the energy intensity of their production.
- **Technique effect:** trade can support improvements in efficiency gains. In the context of high emission intensity of energy, improving energy efficiency can lead to emissions reduction.
- **Scale effect:** underpinning every production process is energy and resources. If the energy used for production has high GhG intensity, potentially compounded by low energy efficiency production processes and high energy intensity product specialisation, then increased trade equates to more GhG emissions.

The composition effect is directly related to the structure of African production and trade. In the case of a low-carbon transition, as the structure of economies changes, the total volume of emissions may decrease, less emission-intensive sectors expand and more emission-intensive contract. The reverse would occur in the case of the pursuit of a carbon-dependent pathway. In this sense, the expansion of modern services would reduce emissions as, in general, these sectors tend to be less emission-intensive.

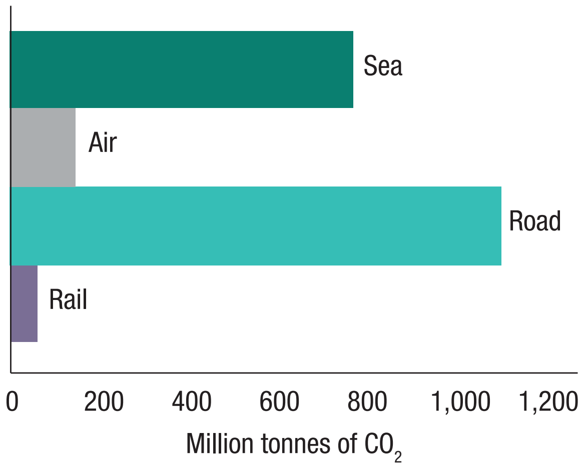
The technique effect is associated with the technological change applied to production. New technologies applied to production processes involving less energy consumption will generate reductions in the level of emissions. This also applies to organisational changes that could also deliver reductions in the use of energy. Moreover, the technique effect, which could apply across all sectors or in specific sectors, could interact with the composition effect by expanding or offsetting the effects of the latter.

Finally, the scale effect indicates that, everything else being equal, an increase in output will lead to an increase in emissions associated with the higher use of energy. Therefore, a country that expands its output by virtue of higher export demand will necessarily incur higher emissions.

These three effects are exclusively applied to production rather than trade. The three effects would characterise perfectly the mechanisms behind the generation of emissions in the domestic consumption of products. However, exclusive to trade is the effect associated with international transport.

International transport is largely powered by fossil energies and is a contributor to GhG emissions from most types of trade. Global

Figure 3 Global CO_2 emissions from international freight transport, 2010



Source: Calculations based on Martinez et al. (2014)

aggregate figures for 2010 estimate that CO_2 emissions from international freight from production to consumption centres amount to 7% of global emissions (about 2,108 million tonnes of CO_2), corresponding to 30% of all transport-related CO_2 emissions (ITF, 2015). Projections pre-Covid-19 had anticipated a 3.5% annual trade growth up to 2050, mainly concentrated between non-OECD countries in Asia and Africa, leading to three times more CO_2 emissions over the 2010–2050 period (equivalent to about 6,324 million tonnes of CO_2) (Martinez et al., 2014).

According to modelling by Martinez et al. (2014), in 2010 roads accounted for 53% of international freight-related CO_2 emissions, sea shipping for 37%, air for 7% and rail for 3% (see Figure 3). These estimates do not include other GhGs, which can be emitted in particular for aviation and shipping, but recent advances in methodology apportioned a share of shipping to international transport and estimated total GhG emissions (see Box 1).

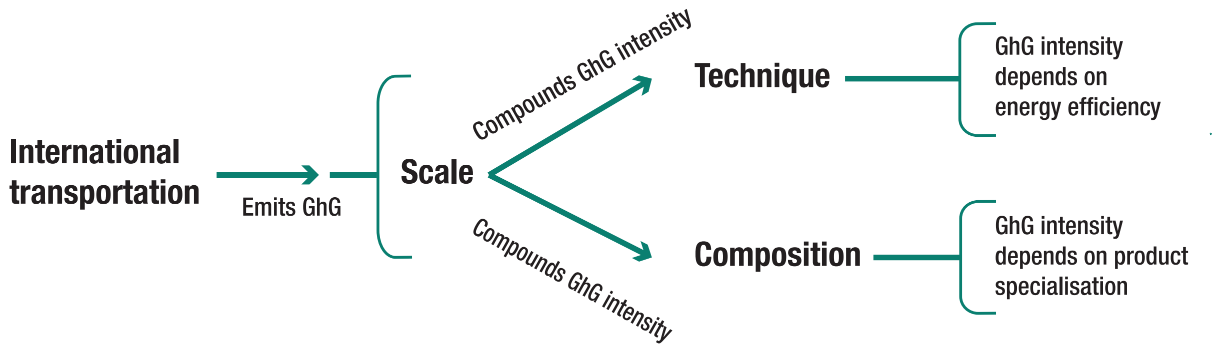
The transport parameter in the climate and trade nexus may be affected by increased horizontal production processes whereby production stages are broken down and outsourced or traded (Fischedick et al., 2014). In other words, more CO_2eq can be embodied in the production of a final product or service given that its production would have taken place in many different countries, entailing transport emissions between each transformation stage. Indeed, in 2020, the average length of supply chains is estimated to be 1,524km (Miroudot and Nordström, 2019).

Box 1 International shipping – GhG emissions

Globally, CO_2 emissions from international shipping in 2018 amounted to 740 million tonnes (Faber et al., 2020). From 2012 to 2018, international shipping emissions increased by 5.6% from 701 million tonnes, while the share of overall shipping emissions (from international, domestic and fishing shipping) remained constant relative to global emissions, at about 2%, with a 0.13-point progression over the same period (2012–2018). To put this in perspective, if the international shipping industry were a country, it would be the seventh-largest emitter in the world in 2018 (ranking based on converted data from Friedlingstein et al., 2019).

International shipping GhG emissions are currently not allocated under the United Nations Framework Convention on Climate Change (UNFCCC) framework owing to complexities around rules of emissions' attribution (UNFCCC, 2020). Indeed, given that a significant part of international shipping emissions occurs in the international waters where no national jurisdiction applies, ruling on fair allocation of emissions has been contentious. Allocation options include the jurisdiction where the ship is registered, where the ship owner is a national and/or where the operating company is based (Heitmann and Khalilian, 2011). The allocation discussion eventually stalled within the UNFCCC forum, compounded by fragmented governance between the International Maritime Organization and the UNFCCC (Hackmann, 2012; Shi and Gullett, 2018), but a global UNFCCC-backed campaign is advocating that the issue be taken up again at COP26 in 2021 (We Mean Business Coalition, 2020).

Figure 4 Trade and GhG emissions nexus



Source: Authors

To summarise, GhG emissions from trade depend on energy efficiency via the technique effect, and on GhG intensity of production via the composition effect, with the two effects being compounded by the scale effect (Figure 4). Each effect is underpinned by emissions linked to freight transport.

As to the net effect of trade liberalisation on overall GhG emissions, evidence is mixed. In the case of the North American Free Trade Agreement, Grossman and Krueger (1991) projected an emissions increase (for one gas out of the ones classified as GhG) up until a national average income threshold (at about $4,500) is reached, past which emissions would decrease for Mexico. Antweiler et al. (2001) found the impact of the technique effect to be greater than the scale effect, resulting in a 1% decrease in emissions in the case of a 1% increase in GDP per capita as a result of trade liberalisation. Other studies, such as Cunha and Mani (2011) and Salman et al. (2018), estimate that the scale effect outbalances the technique effect and results in increased GhG emissions in the case of the Dominican Republic and the Central America Trade Agreement with the US and in the free trade agreements Pakistan is party to, respectively. Nemati et al. (2019) review and compare free trade agreements to conclude that agreements between countries at the same development level do not result in increased emissions, but those between developed and developing countries do.

While disentangling causation and attribution is complex, correlation is clear: the simultaneous expansion of trade and greater trade liberalisation are correlated with unparalleled levels of GhGs in the Earth's atmosphere (Onder, 2012). Furthermore, improvements in emission efficiency as a result of structural or technological changes have been smaller than the increase in the volume of trade-enabled consumption, and global emissions related to consumption have increased (Blanco et al., 2014). Finally, given that any new emissions of GhGs reinforce climate change and its set of gradual and extreme climate events, in terms of both intensity and frequency, trade has a role to play in climate mitigation to avert a catastrophic increase in global average temperature (IPCC, 2018).

3.2 Embodied carbon in African trade

3.2.1 Limitations of existing data on Africa's trade-related emissions

To give a stock-take view of the carbon content embodied in African trade (both exports and imports), we use input-output modelling. This analysis is an accounting method used to investigate the production factors contained in trade (Leamer, 1980; Leontief, 1953). While widely applied to analyse value added in trade, researchers turned to it for carbon content accounting in trade mostly after the 1997 Kyoto Protocol to the UNFCCC, when GhG national accounting started having a more binding implication internationally (Peters and Hertwich, 2008).

This analysis relies on multi-region input–output (MRIO) tables that record transactions within and between sectors, within countries

Table 1 Calculations of GhG emissions in exports (gigagrams of CO_2eq)

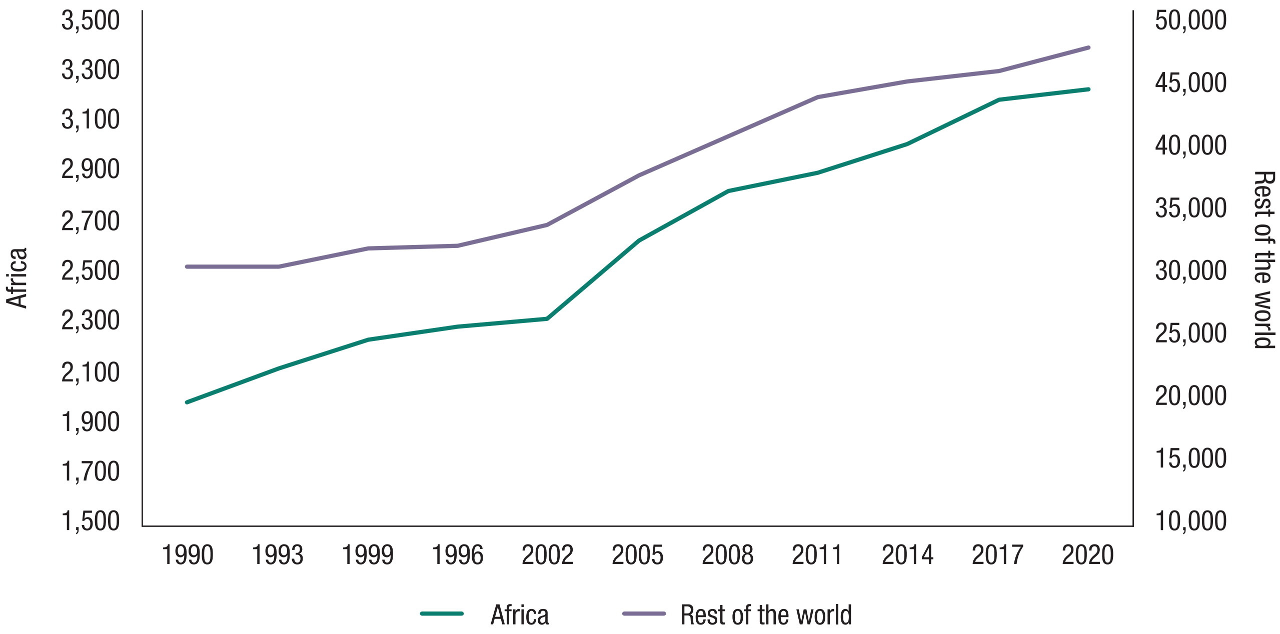
	2015		1995			2015		1995	
	Africa	ROW	Africa	ROW		Africa	ROW	Africa	ROW
South Africa	9,682	1,027,318	9,159	1,053,389	Mali	9	900	2	152
Nigeria	2,694	424,096	651	142,735	Malawi	5	264	4	249
Algeria	1,845	476,984	336	95,526	Eritrea	3	285	3	242
Morocco	953	152,351	348	65,727	DRC	2	256	1	121
Egypt	615	60,482	138	16,687	Gabon	2	380	2	410
Tunisia	347	25,269	129	14,326	Senegal	2	159	1	88
Guinea	279	41,287	162	29,128	Benin	1	31	0	23
Angola	261	55,357	51	12,115	Côte d'Ivoire	1	104	3	428
Libya	233	35,206	341	62,631	Swaziland	1	55	1	194
Cameroon	174	21,923	123	20,610	Seychelles	1	66	0	35
Tanzania	121	11,560	145	16,119	Togo	1	33	1	62
Kenya	120	13,092	70	8,333	Uganda	1	63	0	38
Burkina Faso	101	12,169	6	595	Burundi	0	29	1	62
Ghana	65	8,527	34	5,951	CAR	0	4	0	31
Madagascar	63	5,184	38	3,526	Cape Verde	0	7	0	3
Rep. Congo	61	11,576	19	3,161	Djibouti	0	4	0	8
Chad	61	7,335	2	146	Gambia	0	1	0	1
Ethiopia	56	6,808	0	33	Liberia	0	1	0	1
Zimbabwe	52	6,250	65	1,200	Lesotho	0	22	0	8
Zambia	30	821	5	202	Niger	0	9	0	3
Mauritius	28	2,857	9	1,104	Rwanda	0	35	0	3
Mauritania	27	3,341	8	1,107	Sierra Leone	0	7	0	1
Namibia	23	468	18	1,308	Somalia	0	2	0	10
Botswana	13	1,387	36	3,346	ST&P	0	1	0	1
Mozambique	11	451	1	81					
						2015		**1995**	
						Africa	**ROW**	**Africa**	**ROW**
Total						**17,945**	**2,414,815**	**11,913**	**1,561,256**

Note: ST&P is São Tomé and Príncipe, DRC is Democratic Republic of Congo, CAR is Central African Republic.
Source: Authors' own elaboration based on Eora-MRIO

(domestic transactions) and between countries (trade). Emissions are treated in this context like any other production factor. Relevant African data necessary for this analysis is scarce. Only the Eora MRIO database (www.worldmrio.com) includes a significant number of African countries; other data sources, such as the OECD's MRIO, have more limited coverage.

Table 1 presents calculations of the CO_2eq emissions embedded in African exports to the rest of Africa and to the rest of the world (ROW) in 1995 and 2015. The figures suggest significant anomalies associated with the underlying data. First, the calculations alter notably the order of countries when compared by total emissions (Figure 5). Although South Africa, for example,

Figure 5 GhG emissions in Africa (thousands of gigagrams of CO_2eq)



Note: 2017 is the last year for which data is published. Data from 2018 onwards is estimated based on actual GDP real growth and 2020 GDP growth forecast.
Source: Authors based on Gütschow et al. (2019)

is the largest emitter based on the size of its economy, the calculations suggest its exports are substantially more intensive than its total emissions. This is likely to be the case in small economies where trade represents a significant part of economic activity but is unlikely to be the case for the continent's largest economy.

Meanwhile, the carbon intensity of exports to the rest of Africa appears substantially smaller than the intensity of exports to ROW. This is possible and likely – but not to such a magnitude where the emission content of exports to ROW is many times higher than in exports to Africa. At the same time, as we will see, export structures differ in terms of product composition. The combination of both elements could generate lower intensity in emissions in exports, but it is unlikely that they would generate such a large difference.

Analysis of the underlying Eora data indicates some mistakes that could explain these differences. For example, there are several instances of negative values where only positives are possible. There are also several instances of sums across rows not matching the sums across columns. Moreover, the underlying emissions data is available at the total level only for each country (except South Africa) and not each individual sector. Typically, the electricity, gas and water sector in Eora accounts for all the direct emissions in a country, and the input-output calculations just allocate indirect emissions to the rest of the sectors. However, these affect the technical coefficients that relate to emissions and output, making emissions too sensitive to exports.

These issues suggest that, without new and improved data, it will be inaccurate to present calculations on emissions embedded in exports. Instead, we try to build an analysis of trade-related emissions on an analysis of emissions and trade data.

3.2.2 African emissions from 1990

Given the issues associated with calculating emissions embedded in trade, we aim to describe a series of facts and elements that will allow us to characterise the relationship between the contribution of Africa to global emissions and its trade. We will base this analysis mostly on the export side.

Emissions data available is related primarily to the production processes occurring on the continent. Even when data on emissions is assigned to a single sector, it is expected that the production processes occurring on the continent will be the main actors behind these emissions. Meanwhile, this analysis aims to put trade-related emissions in Africa in the context of global trade-related emissions. The single-sided analysis avoids the double counting of emissions (counting the emissions embedded in imports in Africa and in the exports of the origin of the imports) and allows this study to be comparable with similar analysis of other regions.

African emissions have been growing since 1990 following the path that global emissions have traced. In fact, the share of Africa in total emissions has remained almost unchanged in the past 30 years, at around 6.5% in 2017. Emissions in Africa went from just under 2 megatonnes (Mt) of CO_2 equivalent in 1990 to 3.2 in 2020. They have accelerated particularly in the past 20 years, following a period of faster economic growth. In addition to economic growth, emissions have been explained by the expansion of population (the fastest in the world).

While Africa's contribution to GhG emissions has remained constant, the same cannot be said of other regions (Table 2). With the exception of Central and South America, all other regions have observed significant changes in the contribution to GhG emissions. Notable are the rise in the share of Asia-Pacific (which includes China and India) and the fall in the shares of North America and Western Europe. In this sense, Africa has accompanied the global trend but has had a marginal role in the change of the global emissions trajectory. This situation is reflected in its association to non-Annex I countries to the UNFCCC, which acknowledge common but differentiated responsibility to the climate crisis given historical development.

In terms of distribution of emissions within Africa, there was little change between 1990 and 2017 (Figure 6). Only Egypt and Nigeria had observed an increase in their share in total emissions. Within the continent, total emissions seem to be explained primarily by a combination of economic size, population and, of course, productive profile. This combination of factors could explain some interesting features, such as the low share of Morocco in total emissions, even though it is Africa's fourth largest economy, and the relatively high share of Tanzania, with roughly the same population as South Africa.

Table 2 Share of territorial emissions by region (%)

	2017	1990
Africa	6.5	6.1
Asia-Pacific	52.8	40.6
Central and South America	5.7	5.3
Middle East and Central Asia	8.7	6.6
North America	16.3	22.2
Western Europe	7.6	14.2
Other Europe	2.4	5.0

Source: Authors based on Gütschow et al. (2019)

3.2.3 The relationship with exports

African exports (goods and services) have expanded by 197% since 1990 (Figure 7), going from $233 billion in 1990 to 693 billion in 2017. This is impressive when considered in isolation but disappointing in the global context. At the same time, African output has expanded slightly less (164%). This implies that the share of exports in total African output grew very little, contrasting notably with the evolution of trade in other regions in the world where the effect of regional and global value chains has led trade to expand substantially more than output. In the same period, exports of East Asia and Pacific expanded by 442% and output by 201%, leading to an increase of the share of exports to GDP from 20% to 29%.[3]

A first element to highlight is that, given the limited expansion of exports, rather than trade it has been the expansion of the African economies that has been behind the growth in emissions. This growth, which also includes a population growth component, thus appears as a stronger factor in the evolution of emissions. Trade has maintained its scale effect on emissions but has not increased its impact.

3 World Bank World Development Indicators.

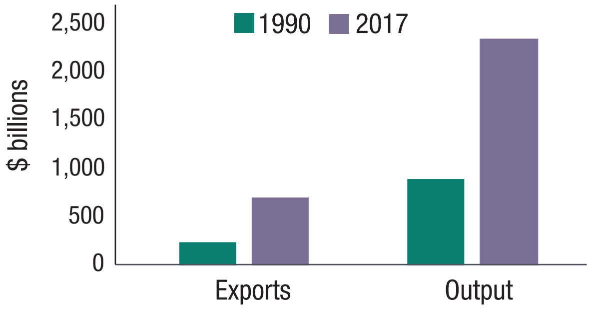
Figure 6 Share in territorial emissions in Africa by country in 1990 (top) and 2017 (bottom) (%)

Source: Authors based on Gütschow et al. (2019)

The second element to highlight is the underlying technological change that has affected the intensity of emissions in trade and output. While emissions have expanded by 61% in the past 30 years, exports and output have expanded more than four times faster. This led to a fall in the marginal emissions content from 8.52kg CO_2eq per US dollar of exports in 1990 to 4.61 in 2017. In the same period, global emissions went from 4.78kg CO_2eq per US dollar of exports in 1990 to 1.99kg CO_2eq per US dollar of exports in 2017.

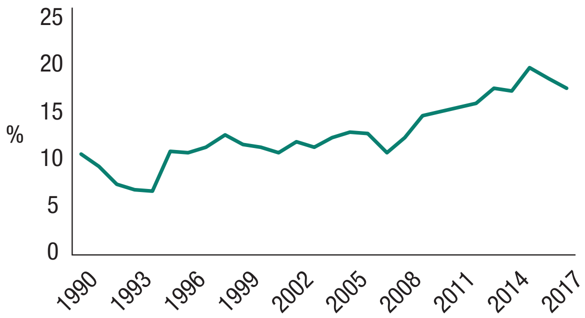
During the same period, there have been significant changes in the composition of African trade. Africa has seen an important rise in intra-continental trade. This change has significant implications with regard to the basket of products exported. Intra-continental trade has not reached the levels observed in South East and East Asia, where intra-regional trade reaches 40%, but the

Figure 7 African output and exports (goods and services) 1990 and 2017



Source: Authors, based on World Development Indicators

Figure 8 Share of intra-African exports in total African exports



Source: Authors, based on UN Comtrade

share of intra-African trade has almost doubled in the past 30 years (Figure 8). This has been driven by two factors. On the one side, a process of regional integration on the continent has contributed to reducing trade barriers within particular regions of Africa. At the same time, though, the reduction of barriers has contributed to the creation of clusters of integration where trade has grown but with little trade between them. On the other side, although with less impetus than in other regions, value chains have contributed to expand cross-border trade in certain sectors. This has contributed to an increase in the trade of intermediate products between countries of the same bloc.

The simultaneous effect of the reduction of barriers to trade within regions and the still high level of tariffs applied to the rest of the world has had differing effects across products and sectors. The differential effect is reinforced by the existence of non-tariff barriers and transport costs with heterogeneous effects on certain

Table 3 Sectoral composition of African exports (goods and services) by destination (2015) (%)

	Africa	ROW
Agriculture	4.0	6.5
Fishing	0.4	0.4
Mining and quarrying	6.1	38.3
Food and beverages	6.7	5.1
Textiles and clothing apparel	6.3	5.1
Wood and paper	3.8	2.1
Petroleum, chemical and non-metallic mineral products	14.2	10.2
Metal products	5.4	6.7
Electrical and machinery	19.1	3.6
Transport equipment	7.0	1.3
Other manufacturing	3.8	0.8
Recycling	1.0	0.7
Electricity, gas and water	0.2	0.1
Construction	0.4	0.7
Maintenance and repair	0.2	0.2
Wholesale trade	0.9	1.3
Retail trade	1.0	0.7
Hotels and restaurants	2.5	2.4
Transport	9.3	7.2
Post and telecommunications	1.3	1.5
Financial intermediation and business activities	4.5	2.9
Public administration	0.4	0.3
Education, health and other services	1.1	1.7
Others	0.0	0.0
Re-export and re-import	0.1	0.1

Note: ROW, rest of world
Source: Authors, based on Eora MRIO

sectors and products. This trade-diverting effect has contributed to the expansion of certain manufacturing products in intra-African trade as against the more traditional commodity-based exports to the rest of the world.

Table 3 shows that, by 2015, and at aggregate levels, Africa presented a dual export structure in intra-continental trade and in its trade with the rest of the world (Sommer et al., 2017; ECA, 2017). Mineral commodities, which represent more than 38% of total African

Table 4 Main products exported, average 2014–2018 (% of exports)

Africa		Rest of world	
270900 – Crude oil from petroleum and bituminous minerals	9.7	270900 – Crude oil from petroleum and bituminous minerals	31.3
271000 – Oils petroleum, bituminous, distillates, except crude	5.4	710813 – Gold, nonmonetary, semimanufactured forms nesoi	4.0
710231 – Diam ex ind unwkd or smpl swn clvd or bruted	2.9	271000 – Oils petroleum, bituminous, distillates, except crude	3.1
710812 – Gold, nonmonetary, unwrought nesoi	2.7	271111 – Natural gas, liquefied	3.1
710813 – Gold, nonmonetary, semimanufactured forms nesoi	2.2	180100 – Cocoa beans, whole or broken, raw or roasted	2.2
890190 – Vessels, nesoi, for transport of goods and persons	2.0	710812 – Gold, nonmonetary, unwrought nesoi	2.0
271600 – Electrical energy	1.8	710231 – Diam ex ind unwkd or smpl swn clvd or bruted	1.8
240120 – Tobacco, partly or wholly stemmed/stripped	1.4	271121 – Natural Gas, gaseous	1.5
890520 – Floating or submersible drilling or production	1.0	270112 – Bituminous coal, not agglomerated	1.5
870421 – Trucks, nesoi, diesel eng, gvw 5 metric tons & und	1.0	260112 – Agglomerated iron ores	1.1
Rest	70.1	Rest	48.5

Note: nesoi, not elsewhere specified or indicated. Codes based on the Harmonised System.
Source: Authors based on UN Comtrade

exports to the rest of the world, including services, represent only 6% of intra-African exports. Manufactures, on the other hand, represent 66% of total intra-African trade but only 35% of exports to the rest of the world.

Looking into the export of goods and into much more disaggregation (Table 4), we can see a more diversified export structure in intra-African trade. Moreover, exports of fuels and minerals dominate exports to the rest of the world. Many of these products, although present in exports to the rest of the continent, appear to be less important. Exports to Africa appear more diversified and oriented towards manufactures.

Without adequate data, it is difficult to assess the emissions content of each type of product represented in each type of trade. It is impossible to determine whether this pattern of specialisation has contributed to the observed reduction in the intensity of emissions in African exports or, on the contrary, dampened a potentially even stronger reduction.

This different export structure between intra- and extra-African trade leads to a different structure in terms of the countries engaged in both types of trade. Figure 9 compares the share of each African country in exports to the continent and to the rest of the world. A couple of features appear clear. Exports, in terms of origin, appear more diversified in intra-African trade. Moreover, while the two largest economies are the top exporters to the rest of the continent and the rest of the world, there are significant differences among the rest.

The joint analysis of emissions and trade allows us to infer some conclusions with respect to the relationship between them. The first element to highlight is the lower correlation between the evolution of emissions in the past 30 years and the evolution of total African exports. CO_2eq territorial emissions in Africa

Figure 9 Intra- (top) and extra- (bottom) African exports by destination, 2014–2018 (%)

Source: Authors, based on UN Comtrade

have expanded by 61% and total exports by almost 200%. While the relationship remains positive, it is clear that African exports have become 'greener' or less intensive in emissions over the same period. Technology is likely to have played a significant part in this.

In parallel with this is the growth of intra-African trade, which relates directly to the composition effect described above. This suggests that intra-African exports have grown substantially faster than the CO_2eq emissions, positing an even weaker relationship between these two elements. Effectively, most of the intra-African trade is in manufactures, particularly light manufactures, which appear to be less intensive in emissions. The data does not allow us to calculate precisely the emissions content of intra- and extra-African exports. However, these elements suggest that, in general, intra-African trade is significantly less intensive in GhG emissions than Africa's traditional exports.

4 Adaptation and trade nexus

4.1 Transmission of climate change impacts to trade

In Africa the frequency and intensity of extreme weather and climate events has already increased as a result of global warming, and this trend is set to continue. Heatwaves and droughts in areas already prone to such events, such as southern Africa, will continue to increase in duration, frequency and intensity (Shukla et al., 2019). Desertification of drylands will continue, in particular at the fringe of the Sahara and West Africa. Furthermore, changes in the duration, seasonality and intensity of floods, cyclones and rainfall patterns are set to further disrupt the continent (Niang et al., 2014). The rise in average temperature is projected to be 2°C at least by the end of the 21st century and possibly 6°C (ibid.).

All these climatic changes trigger onward effects related to biodiversity loss, shifts in agro-ecological zones, soil degradation and water resources, which in turn affect food security, poverty incidence and socioeconomic welfare (ibid.). This is especially critical as the African continent presents high vulnerability to climate change. Vulnerability is defined by the IPCC as 'the propensity or predisposition to be adversely affected' and it 'encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt' (ibid.; Van Diemen, 2019). Furthermore, it is 'dynamic, varying across temporal and spatial scales, and depend[ent] on economic, social, geographic, demographic, cultural, institutional, governance, and environmental factors' (Cardona et al., 2012).

In effect, as Figure 10 illustrates, sudden and gradual climate impacts can lead to disruptions and changes in production and productivity. These changes can be positive but in the case of Africa they mostly reduce output and in turn affect the composition of tradable sectors and countries' economic structure as certain sectors lose competitiveness, or simply the ability to produce the same goods and services. As a result, international trade patterns may change and countries may shift their imports and exports in reaction. This could lead to increases in import prices and decreased export revenues.

There are causal effects between this pattern of climate impact transmission and the GhG emissions nexus outlined in Section 3.1, as changes in tradable sectors link back to the composition effect and its GhG implications.

There is a need to understand not only the direct impacts of climate change on sectoral production and trade flows but also the possible

Figure 10 The trade and GhG emissions nexus

Source: Authors

impacts of climate change on competitors in specific markets. For example, despite negative impacts, a region could increase its competitiveness if other competitors for the same market are more severely damaged, or if there is a move to specialise in the production of other goods. An OECD study finds that sub-Saharan Africa would face a dual burden, with import prices rising due to higher production costs abroad while its export position weakens because of the disproportionate impacts of rising temperatures on climate-sensitive sectors such as agriculture (OECD, 2016). These shifts in comparative advantages induced by climate change and different types of shocks arising, as explored in the following sub-sections, will be felt within specific stages of value chains.

4.2 Trade vulnerability pathways

The international community's understanding and definitions of trade vulnerabilities induced by climate change have improved considerably over recent decades. This section briefly reviews internationally recognised definitions, then reviews other indicators that seek to transcend international borders and identify value-chain-specific trade vulnerabilities.

4.2.1 The UN definition of an LDC

The recognition of specific trade vulnerabilities can be traced back to the use of certain criteria to identify LDCs when the category was created in 1971. Initially, only three indicators were used: GDP per capita, adult literacy rate and share of manufacturing in GDP. From 1999, attention shifted towards economic vulnerability arising from limited economic diversification, with indicators such as instability of export earnings and export concentration. Then, from 2005, the Committee for Development Policy (CDP) included greater recognition of trade costs (remoteness) and the effects of natural disasters. Indicators related to share of the population in low elevation coastal zones were included in 2011.

Box 2 Selected climate change impacts on tradable sectors in Africa

Climate impacts vary across sectors and countries, depending on their degree of exposure and risks. For example:

- Agriculture: increase in temperatures coupled with heightened variability of inter- and intra-annual precipitations is expected to particularly impact rainfed agriculture, with a yield decrease of up to 30% estimated across the continent. As a climate-sensitive sector, agriculture is most vulnerable to climate change, especially in Africa, where the majority of crops are rainfed.
- Tourism: tourism, on which many African countries rely, may see its revenues affected as a result of change in geoclimatic conditions and extreme event frequency or because of sea-level rises (loss of coastline and infrastructure).
- Transport infrastructure: port facilities, as well as buildings, roads, railways, airports and bridges, are dangerously at risk of damage from rising sea levels and the increased occurrence of extreme weather events (heatwaves and extreme precipitation).

Source: Adapted from IPCC (2018)

While the economic vulnerability pillar of the overarching framework distinguished between economic and environmental vulnerability and then derived combined scores, more recently this distinction has been collapsed as a result of a comprehensive review undertaken by the CDP in 2020. A combined assessment of economic and environmental vulnerabilities is now undertaken. The trade and climate indicators presented in Table 5 are being reviewed and will be applied in 2021 to identify the most environmentally and economically vulnerable economies.

It could be said that the revised indicator now captures structural constraints and related

Table 5 Trade and climate change vulnerability indicators

Economic and Environmental Vulnerability Index (EEVI)	Economic Vulnerability Index	Share of agriculture, forestry, fisheries in GDP
		Remoteness and landlockedness
		Merchandise export concentration
		Instability of goods and services*
	Environmental Vulnerability Index	Share of population in low elevated coastal zones
		Share of population living in drylands
		Instability of agricultural production
		Victims of natural disasters

*Defined as the standard deviation of the difference between the value of export earnings and its 20-year trend.
Source: Adapted from www.un.org/development/desa/dpad/least-developed-country-category/ldc-criteria.html

economic and environmental vulnerabilities, including climate change.[4] However, major concerns remain, particularly for small island states,[5] which have proposed alternative indicators specifically for environmental vulnerabilities, classified into categories such as climate change, biodiversity, water, agriculture and fisheries, human health aspects, desertification and exposure to natural disasters.[6]

Within this context, the Africa Climate Policy Centre of the United Nations Economic Commission for Africa (ECA) has begun to explore indicators of vulnerability to climate change, including sector indicators of water resources; agriculture and food security; coastal ecosystems; and human health, including infectious diseases (ACPC, 2013). Frameworks have been applied in Rwanda (Rwanda Environment Management Authority, 2015).

The choice of indicators to define vulnerability deserve further attention by African trade policy-makers and negotiators. As emphasised by Guillaumont (2015), structural economic vulnerability is higher in the continent than in other developing economies, reinforced by physical vulnerability to climate change. Africa also has the highest proportion of fragile states among all continents.

The WTO's Enabling Clause has established the legal basis for the preferential tariff treatment granted by developed countries to the legal category of LDCs. However, debate continues on how to recognise countries' environmental (as well as other) vulnerabilities. There are differences across developed country Generalised System of Preferences regimes and some refinements, such as the EU's on vulnerabilities to enable access to GSP+.7 The provision of AfT is not based on any legal definition of a developing country or criteria of economic or environmental vulnerability.

4.2.2 African LDCs: the most economically and environmentally vulnerable

Application of the CDP's EEVI locates most LDCs in Africa (33 out of 47 countries). Most score well above the threshold for economic and environmental vulnerability, which partly determines if LDCs graduate from the category

4 Further to a comprehensive review undertaken by the CDP (2020).

5 For example, the Barbados Programme of Action called for the development of vulnerability indices that reflect the status of small island developing states. As a result, a vulnerability index for the environment has been constructed by the South Pacific Applied Geoscience Commission and the United Nations Environment Programme (UNEP) that identifies 50 indicators related to hazards, resistance and damage; these are then classified into sub-indices such as climate change, biodiversity, water, agriculture and fisheries, human health, desertification and exposure to natural disasters (see www.vulnerabilityindex.net/category/indicators).

6 Advocacy continues for the recognition of structural factors that accentuate vulnerabilities to external shocks for small states, associated with (i) remoteness from global markets; (ii) lack of diversification; (iii) dependence on external financing; (iv) susceptibility to natural disasters; (v) small internal markets and lack of economies of scale; and (vi) dependence on non-renewable sources of energy (Ram et al., 2019).

7 This includes import share and diversification criteria (see https://trade.ec.europa.eu/tradehelp/gsp).

Table 6 LDCs with high economic and environmental vulnerabilities

	EVI
Senegal	43.19
Sudan	40.92
Zambia	40.90
Mozambique	40.80
Guinea-Bissau	40.45
Timor-Leste	40.14
Comoros	39.71
Liberia	39.57
Vanuatu	39.14
Burundi	38.35
Sierra Leone	37.30
Ethiopia	34.75
Rwanda	33.84
Madagascar	33.80
Haiti	33.38
Tanzania	33.25
Yemen	33.20
Benin	33.02
Cambodia	30.51
São Tomé and Príncipe	29.91
Uganda	28.21
Bangladesh	27.27
Central African Republic	27.27
Guinea	26.94
Lao People's Democratic Republic	26.59
Bhutan	25.90
Myanmar	25.50
Nepal	25.40
Togo	24.98
Democratic Republic of Congo	23.59

Note: Estimates for 2020. EEVI, economic and environmental vulnerability index.
Source: Adapted from www.un.org/development/desa/dpad/least-developed-country-category/ldc-data-retrieval.html

(currently 10% below the threshold set at 32), as Table 6 shows.

The EEVI identifies vulnerability indicators related to the physical effects of climate change and structural constraints like geographical factors. However, it does not provide information on vulnerability to effects transmitted through trade, e.g. market structure factors and reliance on a limited number of importers.

These pathways could be the more challenging vulnerabilities to overcome, even for larger African economies not classified as LDCs. Covid-19 has demonstrated clearly the trade vulnerabilities that may be transmitted across borders by way of the actions adopted by trading partners. There are alternative indicators that seek to capture these aspects, which we proceed to review for Africa. However, the point to emphasise here is that these indicators do not yet feature within the international community's review process of economic and environmental vulnerabilities.

4.2.3 Transboundary trade vulnerabilities

Adaptation is key to reducing vulnerabilities but can also trigger risks. For example, adaptation strategies that make sense for individual countries, such as restricting exports during food crises, may exacerbate risks at the global and regional levels as other countries find their food supply chains break down – precisely the effects of such measures introduced during the Covid-19 pandemic. The effects of individual countries' attempts to deal with their own problems on their suppliers and/or markets encompass transboundary vulnerabilities.

Failing to account for the indirect effects of climate change and climate policy poses significant adverse implications for African countries. Given this, Adaptation Without Borders (2019) distinguishes between different types of trans-boundary climate risks in terms of:

- **Type of event:** shock, slow onset, adaptation action
- **Where the event spreads and scale:** regional, systemic
- **How risk is transmitted:** direct, cascade, contagion
- **How it can be managed:** at source, along the pathway, at the point of impact.

Countries' exposure – as opposed to vulnerability – includes but is not limited to:

- **International trade:** supply disruptions, product losses, export bans, new trade routes, higher prices;
- **Finance and business:** capital flows and profit margins affected, insurance premiums increase, asset losses, increased indebtedness and/or credit ratings reduced.

This approach begins to focus on types of trade – organised through vertically fragmented and coordinated GVCs, or through spot markets and commodity markets – taking into account both import and export exposure and effects on productive structures, including firm-level behaviour. Different pathways are identified (see Box 3) and indicators assigned (see Sundin, 2014). The indicators reveal that, for example, the cereal import dependency ratio in African countries is typically higher than the global average. Zambia is the only net exporter of cereals in Africa. African countries that rely heavily on imported cereals are particularly vulnerable to climate-induced price shocks and droughts elsewhere. And many may have limited import coverage through reserves.

Table 7 applies some of these indicators to African countries.

Clearly, it is not just trade openness that is important, but also the type of trade, how it is organised within a value chain and the degree of socioeconomic dependency on both the import and the export sides. A high dependence on food imports may indicate a form of climate vulnerability; however, imported food also provides a form of adaptive capacity and and can reduce exposure to domestic crop risks (see Sundin, 2014). It may reduce vulnerabilities that may arise from dependence on a single zone of local production. Overall, it is important to understand degrees of dependence on production within geographical zones with the same levels of vulnerability.

Box 3 Trade and other vulnerability pathways

The **biophysical pathway** encompasses trans-boundary ecosystems, such as international river basins, oceans and the atmosphere. Adverse climate impacts on one part of a trans-boundary ecosystem can create impacts for all the countries that share the ecosystem's services (e.g. droughts in the upper basin reduce water availability in delta cities). Indicators include trans-boundary water dependency ratio.

The **trade pathway** transmits climate risks within regional and global markets and across international supply chains. For example, where severe drought destroys harvests in producer countries, import-dependent countries thousands of miles away feel the effects on commodity prices acutely (e.g. extreme weather events disrupting production at manufacturing sites, causing ripple effects across just-in-time delivery systems). Indicators include trade openness, cereal import dependency ratio, and embedded water risk.

The **finance pathway** represents the effect of climate impacts on the flow of capital, including the exposure of both publicly and privately held assets overseas that suffer lower yields or devaluation as a result of major disasters, or over time as climate change erodes the profitability and returns from various enterprises (e.g. lower yields or devaluation as a result of major disasters). Indicators include bilateral climate-weighted foreign direct investment and remittance flows.

The **people pathway** refers to the effect of climate change on the movement of people between countries, or via the economic impacts of new tourism patterns or climate-sensitive human health risks that result from the movement of people across borders (e.g. adverse weather events being a driver of new migration patterns). Indicators include openness to asylum and migration from climate vulnerable countries.

Source: Adaptation Without Borders (2019)

Table 7 Selected trade vulnerability pathways for Africa

	Indicator 1: trans-boundary water dependency ratio (%)	Indicator 7: trade openness (% of GDP)	Indicator 8: cereal import dependency ratio		Indicator 1: trans-boundary water dependency ratio (%)	Indicator 7: trade openness (% of GDP)	Indicator 8: cereal import dependency ratio
Angola	0.0	95.0	54.6	Madagascar	0.0	-	9.2
Burundi	19.8	-	24.9	Maldives	0.0	191.7	99.7
Benin	61.0	-	18.6	Mozambique	53.8	128.1	30.5
Burkina Faso	0.0	-	8.4	Mauritania	96.5	169.2	75.0
Botswana	-	107.6	-	Mauritius	0.0	118.0	110.1
Central African Republic	2.4	-	19.4	Malawi	6.6	-	6.4
Côte d'Ivoire	5.3	-	58.8	Namibia	65.2	103.0	64.8
Cameroon	4.4	-	32.6	Niger	89.6	-	7.0
DRC	29.9	-	38.6	Nigeria	22.8	60.0	14.5
Congo	73.3	-	90.2	Rwanda	0.0	49.4	21.9
Comoros	0.0	-	73.9	Sudan	96.1	-	-
Cape Verde	0.0	91.8	94.3	Senegal	33.5	-	55.0
Djibouti	0.0	-	100.0	Sierra Leone	0.0	-	27.9
Algeria	3.6	65.5	70.7	Somalia	59.2	-	74.9
Egypt	96.9	45.4	35.5	ST&P	0.0	-	84.9
Eritrea	61.7	-	58.6	Seychelles	0.0	184.0	100.1
Ethiopia	0.0	45.8	10.1	Chad	65.1	-	8.4
Gabon	0.0	-	83.3	Togo	21.8	-	16.2
Ghana	43.1	85.6	30.6	Tanzania	12.8	65.5	13.8
Guinea	0.0	-	14.5	Uganda	35.1	55.1	17.7
Gambia	62.5	78.1	45.9	South Africa	12.8	64.8	19.3
Guinea-Bissau	48.4	-	27.3	Zambia	23.8	-	4.9
Equatorial Guinea	0.0	-	-	Zimbabwe	38.7	-	52.2
Lesotho	0.0	136.3	84.8				

Note: ST&P is São Tomé and Príncipe. Data not available for each indicator for all countries.
Source: Adapted from Adaptation Without Borders (2019)

In sum, the mechanisms of transmission for trans-boundary climate risk are complex because a plethora of environmental, economic and socio-political factors could – individually or in concert, directly or indirectly – affect vulnerabilities and resilience (see Mikaelsson, 2020). Risk is a component of vulnerability, which, given its different facets, has no single method for assessment. In practice, however, most methods are usually divided into those that consider physical (or built environment) vulnerability and those that consider socioeconomic vulnerability (Brooks, 2003). Broadly speaking, identified risks translate into vulnerabilities – which represent a set of socioeconomic factors

Table 8 Climate change risks across the value chain

	Stages of production	Risks (direct)	Examples	Transmission
Production	Agriculture and mining Manufacturing	Biophysical risks Trade risks	Extreme weather events Shortages of labour Limited water supply Transport hubs disrupted with knock-on effects on supply of inputs	Global supply affected
Goods and services providing sectors	Retailers and distributors	Trade risks	Interruptions or delays in supply	Switches of supply
	Transportation	Biophysical risks	Access to transport routes affected by extreme weather	
	Utilities	Biophysical risks	Reduced output owing to water scarcity	
	Information businesses	Biophysical risks	Disruption of operations by extreme events	
Services providing sectors	Financial businesses	Finance risks	Increased risks of default	Financial contagion
	Real estate businesses	Biophysical risks Finance risks	Damage to buildings Loss of value	

Source: Adapted from Agrawala et al. (2011); risks identified using Adaptation Without Borders (2019)

that determine the ability to adapt or absorb stress or change (Allen, 2003).[8]

4.2.4 Value chain perspectives on vulnerability

Value chain-specific analyses are required in order to understand the degree of exposure to climate-related shocks and then subsequently to understand vulnerability pathways. For African economies, this could entail an exacerbation of pre-existing vulnerabilities owing to relative positions within the value chain; the interaction between direct and indirect effects will be complex. For example, different sectors may be vulnerable to climate change-related water risks (shortages) at different levels. A number of sectors will confront high water risks in at least one level of their supply chain, in particular raw material production and direct operations (apparel; electronics; beverages; food; pharmaceuticals; forest products; extractives; energy – adapted from Morrison et al., 2009).

Pre-existing trade challenges, such as the distance from end markets and weak transportation systems, which create vulnerabilities through limiting diversification, will be exacerbated. For example, poor road infrastructure already limits market access in many African countries. Changes in precipitation levels could increase road and infrastructure maintenance requirements or destroy whole tracts of road and rail. There could be demand for cooling in vehicles as a result of higher temperatures, road safety risks caused by infrastructure problems and natural disasters, and diminished reliability in passenger and freight services (CJBS et al., n.d., in Lemma et al., 2015). Both transportation infrastructure and related operations and logistics services would be affected:

- Transport infrastructure: road softening (temperature increases); damage to roads, railways, bridges (extreme event); damage to coastal infrastructure (sea level rise)
- Transport operations: increased maintenance and air conditioning (temperature increase); impact on safety and reliability (extreme events); decreased

8 In comparison, climate scientists often view vulnerability in terms of the likelihood of occurrence and impacts of weather- and climate-related events (Nicholls et al., 1999).

capacity for inland navigation (water availability) (Arent et al., 2014).

As discussed in Chapter 2, while the full details of the EU's proposed BCAs remain to be worked out, steel, cement and aluminium are the sectors most likely to be targeted; suppliers of raw commodities, including in Africa, may still be affected.

Within this context, the value chain perspective underscores the importance of understanding vulnerabilities not just at the country level but also at each stage of production and with regard to specific inputs (including raw materials as well as capital and labour) at the firm or farm level. This requires an understanding of how many stages of production are exposed to specific risks that have major implications for value chain management, at both the strategic and the operational level. An example of such a mapping exercise is summarised in Table 8. In addition to this type of mapping, it is important to understand the organisation of tiers of suppliers, their degree of market power, primary and secondary suppliers, district headquarters and so on. Hence, movement from sole consideration of direct, in-country vulnerability assessments towards consideration of indirect effects which could be transmitted to other countries, including through policy responses.

4.2.5 Intra- and extra-regional trade vulnerability pathways

The dual export structure of Africa and the large differences in composition between intra- and extra-regional trade suggest important differences in trade-related vulnerabilities. The data suggests intra-regional trade may be less susceptible to the physical risks of climate change, as well as some of the regulatory effects, because it tends to include more light manufactures than trade with the rest of the world. However, there could be greater susceptibility to a climate effect which impacts both a country and its trading partners within the same region, e.g. water shortages affecting manufacturing.

However, trade data analysis is unable to reveal all of the different value chain dynamics at play, which requires detailed case studies. It is notable that, while products may be more diversified within intra-regional trade, the same large economies account for dominant shares (South Africa and Nigeria) of intra- and extra-regional trade; this suggests that the import side for intra-regional trade could be highly concentrated in particular markets – a risk the Covid-19 pandemic has exposed and that deserves closer scrutiny in view of future shocks arising from climate change.

4.3 Laying out the climate gap for African trade

4.3.1 Adaptation gap

Given the multiple and compounded vulnerabilities of African countries and their tradable sectors to climate change impacts, climate-resilient development and increased adaptive capacity are imperative for the continent's continued economic development (Van Diemen, 2019).

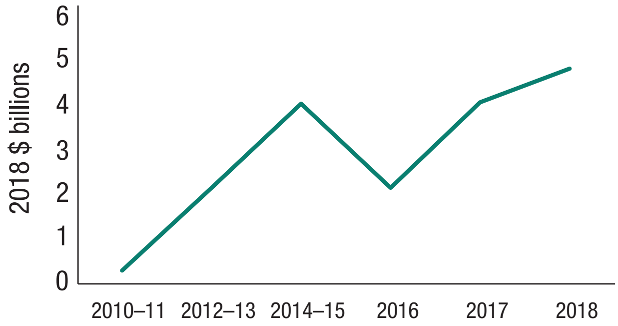
To this effect, adaptation action financing for developing countries was targeted to reach $100 billion annually by 2020 (UNFCCC, 2010) and the Paris Agreement in 2015 urged a significant increase in adaptation finance (UN, 2015). Globally, UNEP (2016) estimates the costs of adaptation by 2030 to be between $140 billion and $300 billion a year, rising by 2050 to between $280 billion and $500 billion.

In 2018, however, African economies received close to $5 billion in adaptation finance from public sources (see Figure 11).[9] To put the figure in context, in the same year total public development finance flows to Africa amounted to $8.9 billion in 2018 dollars (OECD, 2020b) and total adaptation finance globally reached $30 billion (Buchner et al., 2019). In other words, adaptation flows to Africa represented 17% of total public adaptation financing in 2018.

While adaptation financing was 16 times higher in 2018 than in 2010, the gap between

9 The observed drop in finance flows for the year 2016 may be attributed to a change in definition and reporting, which, as a joint effort between different multilateral development banks, took time and may have affected the tracking exercise (UNEP, 2016).

Figure 11 Evolution of adaption-related development finance flows to Africa



Note: The flows concern only public finance and do not include private firms and individuals' funds. Adaptation finance tracking started only in 2010 in the OECD Development Assistance Committee climate finance database, reflecting the shift at the time towards greater scrutiny of adaptation commitments under the UNFCCC with the creation of the Adaptation Committee in 2010.
Source: Calculations based on OECD data

the costs of adaptation for African economies and the finance committed (let alone disbursed) is stark (Bird et al., 2017; Buchner et al., 2019). The World Bank (2010) estimates adaptation costs for Africa to be $45 billion to $50 billion a year by 2050 and $350 billion a year by the 2070s. In sub-Saharan Africa, essential sectors like water supply, infrastructure and agriculture will incur the highest adaptation costs, while in North Africa the focus will be on infrastructure, coastal zone protection and adapting to extreme weather events (Schaeffer et al., 2013). Given the credit-constrained situation of governments, firms and households on the continent especially post Covid-19, the action needed to close this gap is significant, but trade can contribute to adaptation.

4.3.2 The role of trade in adaptation

Trade can contribute to climate-proofing African economies, which in turn can increase the resilience of trade. Indeed, as adaptation actions feed into maintaining a sector's or a country's capacity to trade, there is a positive feedback loop.

Increasing the resilience of tradable sectors requires acting on both public and private sectors. On the one hand, public assets and infrastructure systems, in particular transportation infrastructure such as ports and roads, will need public sector investments based on critical risk assessments and implemented through effective governance. On the other hand, the adaptive capacity of private firms depends on ensuring adaptation information and finance are accessible, that regulatory support is in place and that the insurance sector is developed for climate risks.

Trading, in itself, can mitigate the severity of climate events. Supply shocks can be countered by accessing supply surpluses in unaffected places through trade (Gouel and Laborde, 2018), although potentially at the cost of trade imbalances and reduced revenues, with implications for public finance and spending programmes. But, more than this, gradual onsets of climatic conditions, by affecting production patterns, will imply structural changes in countries' sectoral comparative advantage. The difficulty, when some sectors decline and others need to grow, resides in managing a successful transition in a situation of limited investment capacity, a narrow-based economy and a low-skilled population. This means investing in the new sectors when government revenues are drying up as a result of declining competitiveness in other sectors. Trade and, more broadly, economic diversification can hedge against climate impacts and support necessary structural change and transition.

Furthermore, trade can participate in the diffusion of adaptation technologies and innovations, especially for the agriculture and health sectors. Here, transfer of innovation from developed to middle-income and developing countries can be supported by trade policies related to tariffs (e.g. on disaster management products), intellectual property rights barriers and technical trade barriers (standards, eco-labelling), along with other facilitation processes (regulatory and investments) (African Union, 2014). This will be necessary as international patents for innovation in adaptation are for the most part registered in high-income countries (Hallegatte et al., 2020).

5 Conclusion

Climate change is deeply affecting Africa's development trajectory. While the continent contributes little to the accumulation of GhG in the Earth's atmosphere, gradual and sudden impacts of our changing climate are constraining African countries' sustainable economic development.

Trade policy and investments have a critical role to play in delivering against these multiple objectives. As this report explains, trade can affect the carbon intensity of production and consumption via the technique effect, composition, scale effect and emissions from transport. It also outlines potential trade vulnerabilities to direct and indirect climate risks, and how the impacts of global warming can drive changes to international trade patterns. Simultaneously, trade constitutes a necessary condition that can deliver economic growth and the necessary economic transformation in the African continent. This report has mapped the climate and trade nexus for Africa and identified the space of intersection between critical policy outcomes: the reduction of GhG emissions and resilient economic development, including through the promotion of intra-regional value chains. There is a low correlation between the evolution of emissions in the past 30 years and the evolution of total African exports: CO_2eq territorial emissions in Africa expanded by 61% and total exports by almost 200%. Exports and output expanded more than four times faster than emissions.

This means the marginal emissions content fell from 8.52kg CO_2eq per $1 of exports in 1990 to 4.61 in 2017. Overall, African exports have grown by three times and output has expanded slightly less (2.7 times), with an important increase in intra-regional exports from around 10% to 20% of total exports. This process has resulted in a dual export structure whereby we see a more diversified export structure in intra-African trade and greater orientation towards manufactures. This different export structure between intra- and extra-African trade leads also to a different structure in terms of the countries engaged in both types of trade.

Nonetheless, the data shows that intra-African exports have grown substantially faster than CO_2eq emissions, which suggests an even weaker relationship between these two elements. Effectively, most intra-African trade is in manufactures, particularly light manufactures, which appear to be less intensive in emissions. The data does not allow us to calculate precisely the emissions content of intra- and extra-African exports. Nevertheless, these elements enable us to suggest that, in general, intra-African trade is significantly less intensive in GhG emissions than the continent's traditional exports.

However, without adequate data, it remains difficult to assess the emissions content of each type of product represented in each type of trade. This means it is not possible to assess whether this pattern of specialisation has contributed to the observed reduction in the intensity of emissions in African exports. This also means in some ways it is not possible to fully assess trade vulnerability pathways, including susceptibility to the regulatory effects of climate change policies.

The position of Africa within the current GVC configuration highlights particular susceptibilities to external shocks, such as strong reliance on forward linkages. The shortening of the continent's position within GVCs could assist in reducing some of these vulnerabilities. However, the different types of vulnerabilities arising from climate change will challenge such a narrow approach to resilience-building. Developing trade and enhancing export and import diversification will be critical. In view of the continent's integration agenda, the vulnerability pathways arising from climate change must be distinguished on an extra- and intra-African basis. Within this context, the value chain perspective underscores the importance of understanding vulnerabilities at each stage of production and with regard to specific inputs (including capital and labour) at the firm or farm level. This requires an understanding of how many stages of production are exposed to specific risks currently, and where these stages of production may be located in the future given the reconfiguration of GVCs anticipated.

There will be important differences in intra- and extra-regional trade vulnerability pathways, some of which have been alluded to, but all of which require closer scrutiny within specific country and value chain contexts. Similarly, adaptation pathways will differ and so too will the role of the state and the private sectors in overcoming these.

In the Covid-19 crisis context, public spending has been allocated as a priority to the health crisis and its socioeconomic impacts, and hence there is seemingly little room for manoeuvre for increased spending on climate. There are calls for a climate-compatible recovery, and, while this is an opportunity that should be seized, we have yet to see this happen for African countries. Already, climate finance from high-income countries is failing to reach its announced commitment – let alone to meet the actual finance needed for a low-carbon transition and resilient economic growth.

This report has provided a review of trade vulnerability pathways and adaptation gaps, illustrating why it is important to distinguish between the intra- and extra-regional dimensions. It has not been able to undertake an in-depth analysis. Nor have the trade policy implications of our findings been explored in any detail: we intend to complement this stocktake of the African climate and trade nexus with a trade policy-oriented analysis. Finally, it should be noted that, while we have analysed African exports, data limitations mean we have not been able to look at import flows in detail. This has clear implications for discussions regarding imported carbon and consumption. In this sense, this report provides for a number of future avenues of research as we approach COP26.

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