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Climate change policies and trade: Implications for industrial policy in South Africa

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1. Framing the issues: Climate change policies, trade and structural transformation

The acceleration of climate change and the rollout of policies to mitigate and adapt to climate change has far-reaching implications for developing countries like South Africa. Generally, developing countries are likely to bear the brunt of climate breakdown because they have relatively fewer resources and capabilities to respond to the environmental, humanitarian, and economic impacts of changing rainfall patterns, increased frequency of extreme weather events, and threats to food security (Ravindranath & Sathaye, 2002; Global Commission on Adaptation, 2019).

Southern Africa is expected to experience significantly hotter and drier conditions over time, and these climatic changes have implications for agriculture, mining, and other critical sectors in South Africa (Ziervogel, et al., 2014; Montmasson-Clair & Zwane, 2016). Moreover, the necessary resources for sustained public investment in adaptation measures may be hard to raise in the context of overlapping political crises, fiscal constraints, and a sluggish recovery from the economic shock of COVID-19 (Sachs, 2021). South Africa is not alone in facing these constraints. The United Nations Commission on Trade and Development (UNCTAD, 2021: 105) highlights that:

> *"In many developing countries, vulnerability to economic and climate shocks are compounding each other, locking countries into an eco-development trap of permanent disruption, economic precarity and slow productivity growth. The greater the rise in global temperatures, the greater the damage to countries in the South."*

1.1. Differential responsibilities, trade-related climate policy and structural transformation

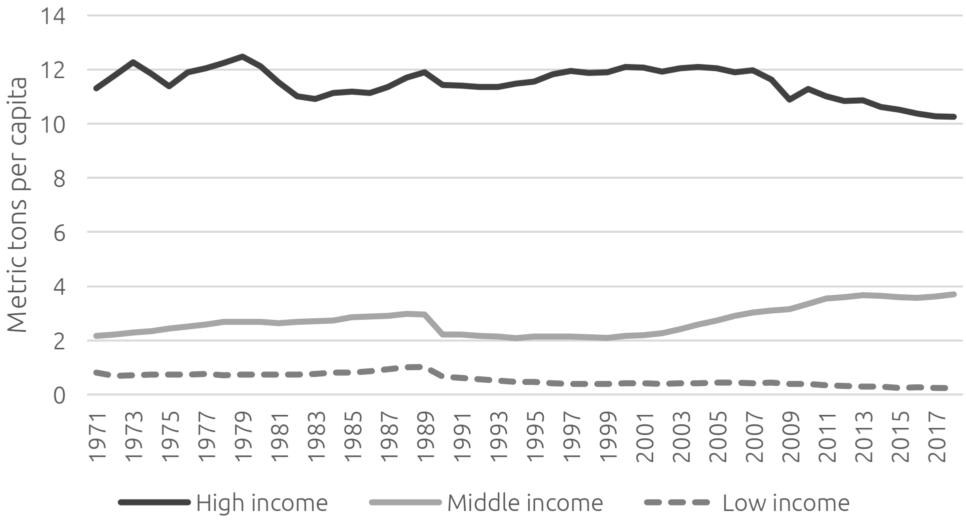
The inequity of these outcomes is compounded by the fact that the overwhelming share of historical carbon dioxide (CO_2) emissions have been produced by high income, industrialised nations (Mertz et al., 2009) (Figure 1). While China's rapid growth has driven the total annual CO_2 emissions of middle-income countries higher than those of high-income countries, the latter continue to produce far greater carbon dioxide emissions than middle and low-income countries on a per capita basis.[1]

In addition, the economic structure and productive capabilities of many carbon-intensive developing economies today remain conditioned by strong path dependencies generated by the combination of histories of colonisation[2] and natural resource endowments.[3] In the South African case, state formation was directly shaped by British imperialism and the demands of mining capital on whose behalf the British state intervened in South Africa in the late 19th and early 20th centuries (Marks & Trapido, 1979). A direct line can be drawn from this history to South Africa's "uniquely electricity-intensive", coal-dependent 20th-century development

[1] Although the gap is beginning to narrow as climate change mitigation policies gain momentum in high income countries.
[2] For example, Weber et al. (2021: 24) find that "former European overseas colonies are performing significantly worse in terms of all proxies for productive capabilities".
[3] According to the Department of Mineral Resources and Energy, "South Africa has the 5th largest recoverable coal reserves in the world, estimated at 66.7 billion tons. Consequently, South Africa's indigenous energy-resource base is dominated by coal. By international standards, South Africa's coal deposits are relatively shallow with thick seams, which make them easier and cheaper to mine" (2019: 18).

(Fine & Rustomjee, 1996: 8), and from there to a modern political economy that has entrenched reliance on coal-fired power generation post-1994 (Baker et al., 2014; Ashman, 2021). In short, developed economies – especially former colonial powers – bear responsibility both for their historical emissions and for a significant portion of the emissions of carbon-intensive developing countries, whose role in the global division of labour has been to provide the raw materials and labour that have fuelled industrialisation in the global North.

Figure 1: C02 emissions per capita



Source: World Development Indicators

Developing countries are also likely to be heavily impacted by the indirect effects of climate change. International trade will be a critical channel for such indirect effects (Cameron et al., 2021). Climate policies being developed in advanced economies appear likely to impact developing countries' export prospects in two main ways. Some will reduce consumer demand for certain products exported by developing countries. Others will act directly on the "rules of the game" in international trade by imposing a "carbon price" or "carbon border tax" reflecting the CO_2 emissions embodied within imports, thereby rendering them less competitive (Mataba, 2020; UNCTAD, 2021).

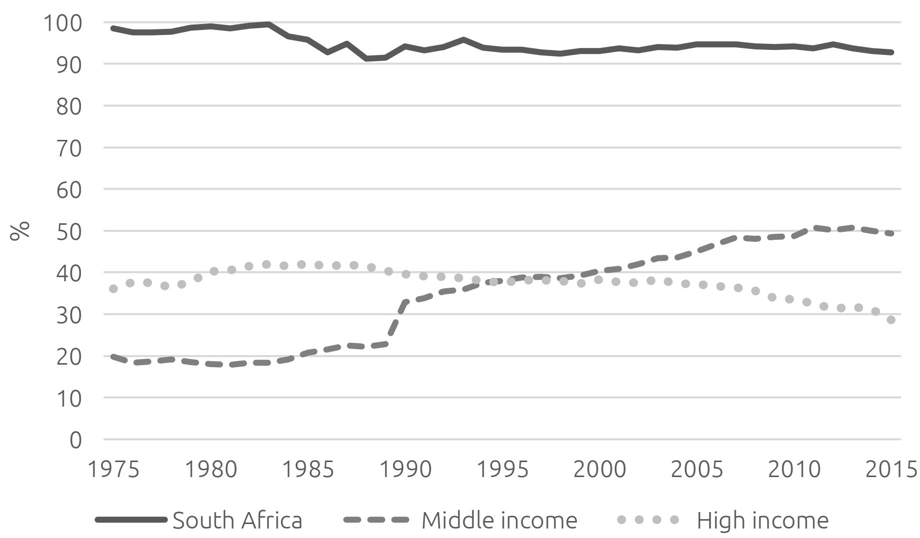
Export production plays a number of important roles in processes of development and structural transformation: generating the foreign exchange required to import capital and intermediate goods, thereby reducing external borrowing needs; facilitating processes of technology transfer and learning that in turn support capabilities upgrading and innovation; and creating possibilities for achieving economies of scale and scope not supported by small or under-developed domestic markets (Braunstein et al., 2019; UNCTAD, 2021). From a structural transformation perspective, policies that weaken developing countries' access to key export markets are a major concern. Therefore, there is a risk that developed country policies aimed at climate change mitigation pull in the opposite direction to developing country policies aimed at achieving structural transformation, with the result that relevant goals are not achieved. Additionally, the push for decarbonisation more generally makes South Africa's need to transform its industrial base beyond energy-intensive resource-based sectors[4] (Bell et al., 2018) and into higher value-added sectors much more urgent (Montmasson-Clair, 2021).

1.2. South African vulnerabilities: The risk of unjust transitions and unjust futures

Emerging climate policies pose challenges for South Africa. First, the country's export basket is under-diversified and relies on a relatively small set of exports for most of its foreign exchange earnings. South Africa's top 10 exports account for 51% of total export value; of these, six are produced in resource extractive sectors (authors' calculations). This lack of diversirgfication makes the country acutely vulnerable to external shocks, as demonstrated during the COVID-19 crisis (Avenyo et al., 2021).

Second, according to the most recent statistics, coal contributed 87,2% of total electricity generated in South Africa (Stats SA, 2021), making it a major outlier relative to middle- and high-income country benchmarks (Figure 2). As a direct consequence of its coal-heavy energy mix, South African production, in general, tends to be more carbon-intensive relative to other countries, which places its exports at an acute competitive disadvantage in a world where critical advanced economy trading partners are beginning to experiment with carbon border taxes.

Figure 2: Electricity production from coal sources (% of total)



Source: World Development Indicators

Therefore, South Africa, and other countries like it face several significant structural transformation risks from trade-related climate change policies being developed in wealthier countries. These risks can be delineated into two broad, interrelated categories – those that threaten an "unjust transition" and those that lock in an "unjust future". In the first category, policies that result in the loss of both competitiveness and access to critical export markets pose a threat to **existing productive capabilities**, foreign currency income streams, jobs and

[4] At the heart of the apartheid state's development project were Eskom, Iscor and SASOL. Eskom generated and provided cheap electricity from coal to the mining and industrial sectors. The industrial sectors, in turn, were dominated by the metals, chemicals, and related sectors through initially state-owned Iscor (now Arcelor-Mittal South Africa) and Sasol which produced liquid fuel from coal and later gas and is South Africa's second largest green-house gas emitter (Ashman, 2021)

development prospects. These outcomes would ensure that the countries least responsible for environmental breakdown bear their most grievous costs.

In the second category, climate change policies that fail to equip developing countries to keep up with green technological change and lay the foundation for **future productive capabilities** as manufacturers of green products and "environmental goods" (Cameron et al., 2021; Davies, 2021) will relegate these countries to a permanently subordinate position in a future, low-carbon global economy. Hoarding of green resources – embodied in intellectual property, technological know-how, productive capabilities, decent jobs and the financial resources underpinning these - in the global North will thus risk discouraging global South participation in slowing climate change, a critical precondition for the future viability of life on the planet.

From a South African perspective, concern about the implications of the green transition for the economy in general, and workers in carbon-intensive sectors in particular, can also be understood in terms of these categories. While Eskom, the state-owned power utility, recently announced a $10 billion financing package to expedite the closure of coal-fired plants and transition to renewable energy,[5] there is significant concern around how the impact on existing jobs and producers will be managed in regions like Mpumalanga, which have historically developed around coal mining and coal-fired power plants (Makgetla, 2021).[6] Similar concerns apply to how global green transitions will affect other essential sectors such as mining, metals, automotives and agriculture.

There are also significant concerns regarding the distribution of the benefits generated by the transition away from fossil fuels. While renewable energy (RE) generation capacity has expanded considerably in the last ten years, significant de-risking of private investment in RE has yielded only minimal development of domestic capabilities for the manufacture of critical inputs (e.g., components used in solar panels and wind turbines). Furthermore, evidence for large-scale green job creation remains scarce (Kamanzi, 2021). Industrial policies aimed at inducing private investment in RE have indeed succeeded in establishing significant and growing RE capacity, generating healthy profits for financiers and the owners of the relevant intellectual property and technological capabilities utilised by independent power producers (IPPs). However, more concerted measures to promote local production of inputs as well as the application of RE to "green" downstream manufacturing will be critical for ensuring a broader distribution of benefits.

Following on from the discussion above, this paper sets out to make three main contributions. First, we provide an overview of trade-related climate policies developed by the EU, a key trading partner for South Africa and the most ambitious regional bloc concerning climate mitigation goals (section 2.1). Second, we discuss the composition of South Africa's top exports and the risks that EU climate policies pose for three key sectors selected based on their importance for the South African economy, the importance of EU market access for the

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[5] https://news.trust.org/item/20210929115308-3rdey/?utm_campaign=inDepth&utm_medium=inDepthWebWidget&utm_source=cliVerticalPage&utm_content=link1&utm_itemId=20210929115308-3rdey

[6] There is recognition of the need to develop alternative economic activities in Mpumalanga, which will be most severely impacted by the transition, but which also holds 40% of South Africa's most arable land. A study by the Bureau for Food and Agricultural Policy (BFAP) found that at the current rate of coal mining, about 12% of the country's total high potential arable land will be permanently damaged by coal mining with a further 14% being subjected to coal prospecting applications (Baskaran, 2021).

viability of South African exporters, and the likelihood of their being adversely or positively affected by EU policies (section 2.2). These sectors are basic metals and fabricated metal products, transport and automotive equipment, food and agricultural products. We also reflect on the mining and chemicals sectors. Lastly, we discuss policy implications and industrial policy strategies (section 3).

2. The European Green Deal and trade risks for South African exports

In December 2019, the EU launched a set of policies under the banner of the European Green Deal (EGD), with the overarching aim of achieving net-zero emissions by 2050, and thus becoming the first "climate-neutral" continent (European Commission, 2019a). The EGD is a framework for a wide range of policies and initiatives meant to transition Europe's economy towards a more sustainable future. In July 2021, the EU announced several EGD-related proposals under the "Fit for 55" package, which build on existing policies and legislation to provide a blueprint for achieving the EU's goal of reducing net emissions by a minimum of 55% by 2030, relative to emissions as of 1990 (European Commission, 2021a).

Most EGD measures are aimed at the EU's domestic markets, producers and policies, but some are likely to affect the EU's trading partners. Trading partners will be impacted through changing regulatory and reporting requirements, the evolving competitiveness of emerging technologies, and shifting consumer preferences. The most direct trade-related EGD measure is the Carbon Border Adjustment Mechanism (CBAM). The CBAM will impose an additional price on imports of certain goods from countries that "do not share a comparable ambition to the EU" concerning climate change mitigation (European Commission, 2021a: 7). This measure would force exporters to the EU to pay the same carbon price as local producers unless they are equally carbon taxed or have already decarbonised (Montmasson-Clair, 2021). For the transitional period from 2023-2025, CBAM will apply to the iron and steel, cement, fertiliser, aluminium and electricity sectors.[7]

Other initiatives that will impact trading partners include tighter emissions limits for cars and a range of initiatives under the "Farm to Fork" (F2F) strategy. Tighter emissions limits for cars are expected to effectively end new petrol and diesel vehicle sales by 2035 and expedite the transition to electric vehicles (EV). The demand for traditional vehicles and the internal combustion engines (ICE) that propel them as well as the many components and inputs used in their manufacture will fall. The F2F strategy, which aims to reduce the environmental impact of the EU's food systems, includes measures to harmonise and expand eco-labelling requirements for food and agricultural products, imposing costly traceability, transparency, and reporting requirements on producers.

The official reasoning for trade-related climate measures like the CBAM hinges on the concept of "carbon leakage" and greenhouse gas (GHG) emissions (European Commission, 2021b: 12):

> *"…there is a risk of carbon leakage when the GHG emission reduction in the EU comes from a reduction in EU production. If the production efficiency of a particular commodity in the EU is higher in terms of GHG and there is no change in domestic consumption, GHG emissions at global level can increase because EU production is simply replaced by imports*

[7] The proposals still need to be approved by the bloc's 27 member states and the EU parliament, and have come under criticism from BRICS countries.

of less efficient production outside the EU. This effect is not only applicable to the agricultural sector but to all sectors of the economy."

The EU response to carbon leakage aims to ensure that its emissions reduction efforts are not offset by the offshoring of carbon-intensive production, while recognising Europe's responsibility for "cumulative emissions" associated with its industrialisation (European Commission, 2021a: 12). However, the EU's trade-related measures will also subsidise the costs imposed on EU producers by its broader climate change agenda by shifting a portion of these onto developing country producers.

In the case of the CBAM, this will take place through the imposition of carbon price adjustments that reduce the competitive advantages of developing country producers with lower cost structures, thereby shifting the basis of competition from price efficiency to carbon efficiency. The imposition of carbon taxes such as CBAM marks a profound change in what has shaped the global division of labour and competition in export markets (in terms of low-cost structures in some market segments and high productivity in others). Furthermore, the capabilities present in advanced economies that allow these economies to produce in a "carbon efficient" manner are far more developed than those in developing economies such as South Africa. Therefore, the implied changes to the terms of trade facilitated by the CBAM are likely to be very disadvantageous for South Africa and others. South Africa's coal-intensive energy mix deepens this disadvantage.

Countries will be given some time to prepare for the implementation of carbon taxes like CBAM in the EU: i) the CBAM will only start from 2026 with a 3-year tax-free period between 2023 and 2026; ii) the carbon price will be ramped up progressively (in 10-percentage-point increments) for 10 years from 2026; iii) only a limited number of products will initially be covered under the CBAM, but there is a possibility of other products being included at a later stage; iv) only direct emissions linked to the production process of products will initially be covered, with indirect emissions linked to electricity consumption excluded initially.[8] Least developed countries will not be exempt from this tariff.

A number of non-EU countries have expressed concerns over the CBAM, including the treatment of developing countries. For instance, the BRICS countries have spoken out against the CBAM, arguing that the risks associated with the CBAM will disproportionately affect countries in the global South. The CBAM's value in mitigating climate change has also been questioned, as its thought that the mechanism would cut global $C0_2$ emissions by only 0.1% (UNCTAD, 2021). Finally, there is a risk that the CBAM would result in corporations shifting their export profiles over time, exporting cleaner products to the EU and the rest of production to countries with less stringent regulations.

Countries affected include those with export reliance on the EU and those with high emission intensity. In addition, the CBAM applies complex methodologies for carbon measurement and pricing and therefore the administrative burden is likely to be high.These implicitly add to the the relatively high expected level of the import levy itself. While the exclusion of indirect emissions for the initial implementation of the CBAM is a reprieve for South Africa in the short-term, its exports are carbon-intensive and several sectors and network industries (particularly

[8] The regulation targets direct emissions from the production process (scope 1), though the scope could be extended to purchased electricity (scope 2) and other upstream emissions (scope 3) after the transition period.

electricity generation) will have to adjust to cope with longer-term risks of increased carbon taxes and other punitive measures in future. Furthermore, several other countries such as Canada, the UK and the US have been considering setting up their own system of carbon taxes. Preparing for the CBAM will require interventions by both exporters (transitioning to greener production methods) and government (enabling investments and subsidies) to build trade resilience.

Possible methods discussed among EU policymakers for calculating and applying the CBAM and other trade-related policies include direct emissions (emissions taking place as part of a production process on which the producer has direct control, including from heating and cooling) and indirect emissions (emissions from the production of electricity which is consumed in a particular production process). The most significant potential risk is "cradle-to-grave" scoping and measurement. The cradle-to-grave approach (or full carbon footprint measurement) "includes all GHG emissions relating to the mining of raw materials, all emissions from the production of materials and components needed for the manufacture of the product, the emissions caused by the production process, including emissions from providing the necessary energy, emissions from the transport of raw materials and interim products to the site of the production process and of the product to the consumer, emissions caused during the use phase and emissions related to the disposal/end-of-life phase of the product" (European Commission, 2021c: 17).

At the end of the transition period for the CBAM, the EU will determine how the CBAM is working and whether to extend the scope to more products and services and whether to include indirect emissions. South Africa's dependency on coal for electricity poses a significant risk if indirect emissions are included. Considering the potential for adopting cradle-to-grave scoping for CBAM, it is necessary to view South Africa's vital exporting sectors within the context of their linkages to other sectors.

While the CBAM is the EU's flagship trade-related climate policy, other sector- and product-specific EGD measures and developments are likely to affect export producers in South Africa and other developing countries. While final plans for a variety of sector-level regulations and initiatives are not in place yet, indications are that policies and initiatives will be ramped up in the coming years.

3. Trade risks for South African exports to the EU – Towards a framework for understanding high-risk sectors

The composition of South Africa's exports and the carbon intensity of the energy mix underpinning production make it vulnerable to trade-related climate change policies in key export markets. This section details trade risks for key South African sub-sectors and associated exports arising from policies developed and adopted by the EU as part of the EGD.

We consider several key indicators when assessing risks and vulnerabilities. These are i) the likelihood of adverse effects from EGD policies; ii) the relative importance of EU exports to the South African economy (as measured by value and share[9] of exports to the EU, as well as employment and growth trends); and iii) the carbon intensity of South Africa's exports relative

[9] As in, what percentage of total South African exports in a given sector go to the EU.

to those of a set of comparators.[10] Combining these indicators allows us to see which sectors are particularly at risk from EGD policies.

Error! Reference source not found. provides a summary of South Africa's most important exports to the EU, organised by sub-sector and product, as well as the carbon intensity of the sub-sector and whether the sub-sector is affected by "green" policies / private standards. This allows us to identify the sectors that are most at risk, as indicated in the paragraph above. See Appendix A for a full table of SA's top 50 exports and key trading partners, excluding SADC.

Comparing and contrasting various sub-sectors and export products in terms of the indicators discussed above and presented in the table, we have identified and mapped a set of priority sub-sectors based on our framework and analysis. These are basic metals and fabricated metal products (metals henceforth); transport and automotive equipment (automotives); agriculture and food products (agri-food)[11].

The metals, automotive, and agri-food sub-sectors are likely to be adversely affected by EGD policies in the near term – metals directly through the CBAM, automotive through the impact of Fit for 55 on demand for internal combustion engine (ICE) vehicles, and agri-food through the Farm to Fork strategy and the negotiation of a new Common Agricultural Policy (CAP) for the EU. All three have relatively high EU export shares, export values, and total employment and have relatively robust growth rates. Most importantly, all three sectors are relatively carbon-intensive compared with other country exports to the EU; this reflects how adversely their competitiveness is likely to be affected by carbon border taxes and other trade-related measures.[12] This section maps out the specific issues facing these three priority sub-sectors, and provides some reflections on non-priority sectors such as the mining and chemicals sectors.

[10] These comparator countries are the top 10 exporters of a sector's products to the EU excluding EU economies and those with missing data points.

[11] Combining vegetable and fruit products; and prepared foodstuffs; beverages; spirits; tobacco.

[12] While the mineral products, precious metals and chemicals sectors have high employment numbers and export values, they will not immediately be subject to the CBAM; pulp of wood and paper has both low export share and value in addition to not being subject to CBAM and other measures.

Table 1: Summary table of SA's key export sectors and products to the EU; carbon intensity of sectors; and whether sector is affected by EGD policies

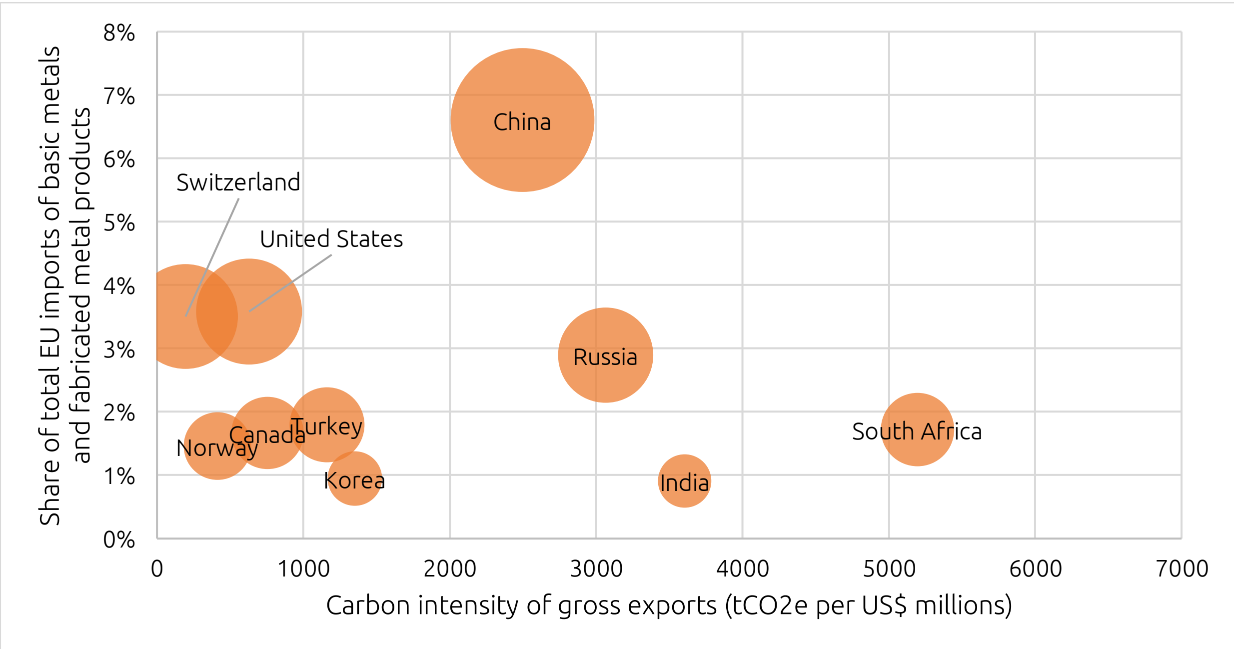
Sector	Sector employment (formal & informal)	Importance of EU market for SA	Growth in exports to EU (2011-2020)	SA carbon intensity (2015) [tCO2e per US$ Millions]	Key exports to the EU (export share; export value)	Affected by "green" policies/private standards?
Basic metals and fabricated metal products	97,794**	High export share (22.8%) High export value (R19.8bn)	4.4%	5196.3	Unwrought aluminium (36.9%; R6.18bn) Flat-rolled products of stainless steel (49.2%; R3.23bn) Plates, sheets and strip, of aluminium (41.3%; R2.11bn) Unwrought nickel (33.5%; R1.56bn) Ferro-alloys (14.9%; R6.56bn)	Yes, CBAM
Transport equipment, automotive & auto parts and components	123,403 ᵞ	High export share (55%) High export value (R70.96bn)	19.2%	1244.7	Motor cars (61.6%; R46.34bn) Motor vehicles for good transport (48.6%; R21.96bn) Centrifuges (60.2%; R17.45bn) Parts and accessories for tractors (30.9%; R2.66bn)	Yes, Fit for 55; EV incentives
Vegetable and fruit products	263,053*	High export share (26.6%) High export value (R16.84bn)	14.4%	1196.8	Citrus (33.1%; R9.25bn) Grapes (47.6%; R5.02bn)	Yes, Farm to Fork strategy; new CAP
Prepared foodstuffs; beverages; spirits; tobacco	311,492 ᵞ	High export share (28.5%) Low export value (R5.79bn)	7.6%	786.3	Wine (38.6%; R3.92bn) Fruit juices (26.7%; R1.09bn)	Yes, Farm to Fork strategy; new CAP
Mineral products	514,859 ᐞ	Low export share (12.4%) High export value (R38.09bn)	4%	1140.4	Precious-metal ores and concentrates (95.1%; R14.86bn) Titanium ores and concentrates (30.7%; R2.43bn) Niobium, tantalum, vanadium or zirconium ores and concentrates (30.5%; R2.01bn)	No, but potential candidates for future CBAM scope expansion
Pearls, precious stones, precious metals		Low export share (11.7%) High export value (R37.89bn)	14.6%	1140.5	Diamonds (30.1%; R6.74bn) Coin (93.2%; R10.01bn) Waste and scrap of precious metals (90.9%; R4.52bn)	No, but potential candidates for future CBAM scope expansion
Products of chemicals and allied industries	169,798***	High export share (34%) High export value (R15.73bn)	25.7%	1287,7	Reaction initiators (60.4%; R6.54bn) Acyclic hydrocarbons (21%; R1.41bn) Sulphates (92.4%; R4.99bn)	No, but potential candidates for future CBAM scope expansion Chemicals Strategy
Pulp of wood, paper	93,658****	Low export share (7.1%) Low export value (R0.79bn)	2.6%	902	Chemical wood pulp (7.1%; R0.79bn)	No, but potential candidates for future CBAM scope expansion

*Notes: * Fruit SA Statistics 2019 (https://fruitsa.co.za/wp-content/uploads/2020/10/FRUIT-SA-STATS-2019.pdf), ** WOW Manufacture and Wholesale of Basic Iron and Steel 2019, *** CHIETA Annual Report 2019/2020, **** Quantec EasyData (Sum of Wood and wood products and Paper and paper products), ᐞ Mining employment (http://www.statssa.gov.za/?p=14682), ᵞ Quantec EasyData (2020)*

a. **Basic metals and fabricated metal products**

Downstream from the minerals sub-sectors, the basic metals and fabricated metal products sub-sectors comprise a set of key sectors for South Africa regarding employment, exports and output. The steel sector received substantial support during apartheid and in the democratic era and generated crucial exports for South Africa. As the chart below shows, the basic metals and fabricated metal products sector is highly carbon-intensive, both because steel production is energy-intensive and South Africa's energy sector is primarily coal-based, which poses a longer-term threat to the sector. Along with the mining sector, basic metals and fabricated metal products accounts for significant end-use energy demand. The data shows that South Africa's relative carbon intensity compared to other suppliers outside the EU is high, given its relative importance to the EU market (Figure 3).

Figure 3: Key suppliers of basic metals and fabricated metal products to the EU (28) with carbon intensity, 2015



Source: Adapted from Montmasson-Clair (2020) based on OECD data

Notes: Imports from EU countries are excluded. The carbon intensity of gross exports indicator shows the intensity of CO_2 emissions, tonne CO_2 per Million USD, in gross exports of exporting country c sector i to the importing partner country p. The emissions can come from any domestic or foreign sector upstream in the production chain.

The EU, US and China are all important markets for South Africa's basic iron and steel (see Appendix A). The EU, in particular, accounts for substantial proportions of South Africa's exports of unwrought aluminium (36.9%), flat-rolled steel products (49.2%), plates sheets and strips of aluminium (41.3%) and unwrought nickel (33.5%). While exports of ferro-alloys to the EU do not account for a very high proportion of total ferro-alloy exports, in absolute value terms, ferro-alloys are South Africa's biggest export to the EU, accounting for R6.6 billion of exports to the EU in 2020.

The prevailing trend in the metals and metal products value chain is a transition to greener methods of production . Many countries, including Sweden and Germany, and producers, such as ArcelorMittal, have already announced net-zero commitments or are investing in net-zero technologies to produce green primary iron and steel (Trollip, et al., 2022). The global transition from 'dirty' metal and fabricated metal production towards greener methods of production, signified in the European Union's New Industrial Strategy (European Commission, 2021d), will put significant pressure on South Africa's sector due to its highly carbon-intensive production.

Leveraging policy to support South Africa's transition towards green metals is warranted given that the iron, steel, and aluminium sectors are among the highest direct emitters of those scoped for inclusion in the CBAM. Their inclusion is due to the high carbon intensity (specifically carbon dioxide) of produced and imported of products in this sector (European Commission, 2021c). Basic iron and steel production, for example, accounts for around 30% of industrial emissions in the EU-27 (European Commission, 2021c). Because of this, basic metals and fabricated metal products exports (specifically basic iron and steel and aluminium products) will be subject to the EU's carbon taxes under the CBAM, with exports of these products to the EU expected to be impacted going forward. In addition, the potential for "cradle-to-grave" measurement of carbon intensity for carbon border taxation in the future entails risks for South African producers downstream from highly carbon-intensive sectors like basic iron, steel and aluminium.

As of 2021, the list of products to be included in the CBAM remains limited to products on the upstream end of the spectrum. While unwrought aluminium appears likely to be included in the initial CBAM, the initial implementation of the CBAM is likely to have a limited impact on the aluminium sector in SA since 88% of the carbon footprint of the aluminium sector is in the form of indirect emissions (Cameron, et al., 2021). The focus on upstream production is due to the increasing complexity of the manufacturing process in downstream and final products. In any case, South Africa's machinery and equipment exports are focused on the southern African region, with the EU accounting for a small proportion of SA exports. Additionally, it is unclear that carbon policies in the EU will affect exports of machinery and equipment, and therefore this sector is not particularly vulnerable as far as climate policies are concerned.

EU policies regarding scrap metal will also impact global trade in scrap metal – the EU is looking to limit the export of waste to other countries, which would stop the export of scrap metal from the EU (Circular Economic Action Plan). Even though South Africa does not source scrap metal from the EU, this could lead to a shortage of scrap metal globally (Cameron, et al., 2021).

The South African Steel and Metal Fabrication Master Plan 1.0 recognises the importance of transitioning the steel and metal fabrication to greener production methods by 2050 (achieving carbon neutrality). There are some options for reducing the carbon intensity of steel production, including increasing the efficiency of existing production methods, recycling of steel, and carbon capture and storage (CCS) technologies. There is also potential for relative decarbonisation of steel by scaling up the use of green hydrogen in production. Similarly, renewable energy and hydrogen-powered plants will create commercially competitive green iron (Trollip, et al., 2022).

However, at this point, the production, storage and transportation of green hydrogen (i.e., hydrogen produced from renewable energy only) remains costly, presenting several technical challenges that require major upfront financial commitments (IEA, 2019; Deign, 2020; dtic, 2021a). In addition, the race to develop green hydrogen technologies and lead green hydrogen exports is a highly competitive one, dominated thus far by lead firms in countries that already have sophisticated and well-resourced hydrogen research and development capabilities (Deign, 2019; Material Economics, 2020; CSIS, 2021). We discuss some current debates on the potential for green hydrogen production in South Africa in section 3.

While the CBAM will impact the basic metals sector, it is important to recognise too that the sector is important in facilitating green economy sectors, including the move towards renewable energies and electricity generation. A shift towards greener and renewable sources of energy and electricity will assist South Africa’s wider industrial renewal project. From the perspective of the basic metals and fabrication sectors, a range of critical inputs for downstream greening of the value chain is well-documented. These include renewable energy, retrofitting buildings for enhanced energy efficiency, recycling facilities, and the infrastructure required for green transportation and EVs. The perceived continued robust demand for steel means that these sectors still have a long-term future and opportunities (World Steel Association, 2012). Similarly, aluminium is considered a key raw material in the EGD with expectations of period of renovations of building and infrastructure; renewable energy projects (wind, solar and hydrogen); and the transformation of transport and logistics (Cameron, et al., 2021).

It is envisioned that the greening of the basic metals sector (and its accompanying value chain) will open the door to developing new products and markets, including from the mining machinery and equipment and automotive value chains. The linkages between these two sectors can create a virtuous circle of new investment in carbon neutral and green technologies. Furthermore, developing green mining equipment built from green steel could give South African manufacturers a competitive edge in searching for new markets globally and regionally.[13] Green hydrogen is increasingly being touted as possessing potential significant potential for assisting South African sectors to mitigate their carbon intensity (Trollip, et al., 2022). In sum, while the basic metals sectors and accompanying value chains will be negatively impacted by CBAM, transitioning these sectors to cleaner production methods may create new opportunities for South African producers.

b. Transport and automotive equipment

The automotive value chain is a crucial sector for South Africa's industrial policy agenda. Subject to aggressive and targeted state support since 1994, South Africa's production of transport equipment has grown substantially (Barnes & Black, 2013; Barnes, et al., 2018). However, South Africa's domestic automotive supply remains relatively underdeveloped compared to the global automotive sector, with much of the domestic value addition concentrated among multinational corporations and tier-1 component manufacturers (Black, et al., 2018).

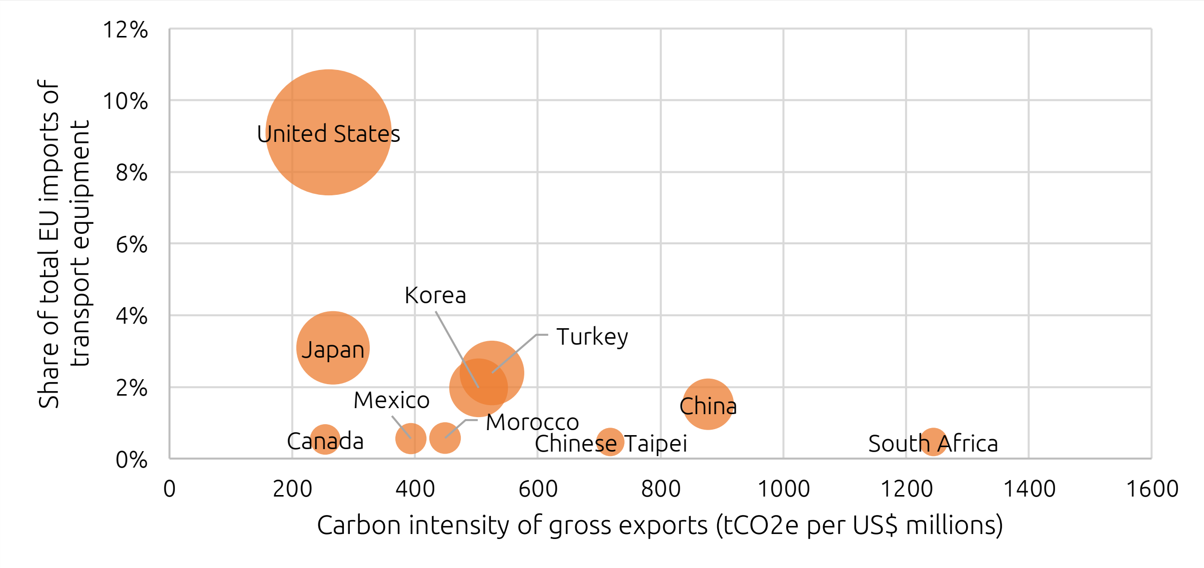
In the context of historical state support, the EU represents a critical market for the export of passenger vehicles, goods transport vehicles, and parts and accessories produced in SA, accounting for 62%, 49%, and 31%, respectively of total South African exports of those products in 2020. Exports of centrifuges to the EU are high, accounting for 60.2% of total

[13] The southern African market is one that offers tremendous potential for expansion and growth for South African mining machinery and equipment producers (Bell, et al., 2019, unpublished).

centrifuge exports. South Africa is a significant exporter to the EU of catalytic converters, a critical component for ICE vehicles.[14]

South Africa's transport equipment sector performs poorly in its carbon intensity compared to other countries exporting automotives to the EU, as reflected in Figure 4.

Figure 4: Key suppliers of transport equipment to the EU (28) with carbon intensity, 2015



Source: Adapted from Montmasson-Clair (2020) based on OECD data

Notes: Imports from EU countries are excluded. The carbon intensity of gross exports indicator shows the intensity of CO_2 emissions, tonne CO_2 per Million USD, in gross exports of exporting country c sector i to the importing partner country p. The emissions can come from any domestic or foreign sector upstream in the production chain.

The EU's policy on carbon emissions related to transport is very strong, with three priority areas identified: i) moving towards zero-emission vehicles; ii) increasing the efficiency of the transport system; and iii) speeding up the deployment of low-emission alternative energy for transport.[15] The European Commission (EC) has adopted ambitious CO_2 emissions standards for new cars and vans to help grow the amount of low and zero-emission vehicles on European roads. It has proposed a 55% reduction of emissions from cars by 2030; 50% reduction of emissions from vans by 2030; zero emissions from new cars and vans by 2035.[16]

As of 2020, global sales of new electric vehicles rose by 43% year-on-year, with the EU replacing China as the locus of demand for electric vehicles (dtic, 2021b). Increasing demand for electric vehicles is being driven by changing global regulations, technological changes and shifting consumer buying patterns, with the EU driving many of these shifts through various

[14] While catalytic converters are traditionally under machinery and equipment, we have grouped them with transport and automotive equipment for the purposes of this discussion because catalytic converters are part of the auto value chain.
[15] https://ec.europa.eu/clima/policies/transport_en
[16] While emissions limits were adopted in April 2019, stricter emissions limits have been proposed more recently.

policies (Bloomberg, 2020). These trends significantly affect the South African automotive sector as the EU transitions away from internal combustion engines.

The move towards electric vehicles will result in significant changes in demand for intermediate goods and raw materials. Electric vehicles have fewer parts than combustion engines, and as result, component manufacturers will be affected;[17] around 33.4% of South Africa's auto components at risk of being displaced (Wood, 2021). Catalytic converters are at highest risk (they are the largest export) as the move to electric vehicles will likely lead to significant declines in exports of these products (Cameron, et al., 2021).

The accelerated shift of EU policy linked to reducing carbon emissions embodied in its imports of automotives and components necessitates urgent attention by South African exporters and policymakers. However, South African automotive market dynamics are complex, with decisions made at overseas head offices by multinationals operating in South Africa. From the perspective of transitioning the South African automotive sector to a greener future, the Department of Transport has developed a Green Transport Strategy (2018-2050) that sets out several objectives aligned to combating climate change and ensuring a just transition (Department of Transport, 2018). The strategy also recognises and emphasises the barriers to entry in creating an enabling demand for a greener automotive environment. One of these is the well-documented high cost of electric vehicles (both in terms of production and end-use) that is currently limiting the domestic demand, which, in turn, may limit any potential growth in domestic production capacity.

The dtic's green automotive position paper proposes positioning South Africa at the forefront of advanced vehicle and vehicle component manufacturing. This objective is contingent on the sales of electric vehicles surpassing internal combustion engine vehicle sales by 2038 (dtic, 2021b). Despite this growing focus on electric vehicles, there are limited and inadequate strategies for mainstreaming green automotive manufacturing and procurement in South Africa (TIPS, 2020). For South Africa to achieve a sustainable and just transition concerning the EU's "Fit for 55" policy agenda requires careful consideration of these policies' various implications on the entire South African automotive value chain.

c. Food and agricultural products

As shown in Table 1, several food and agricultural products rank among SA's top 50 exports. These are split across two sub-sectors: 1. Vegetable and fruit products; and 2. Prepared foodstuffs; beverages; spirits; tobacco.

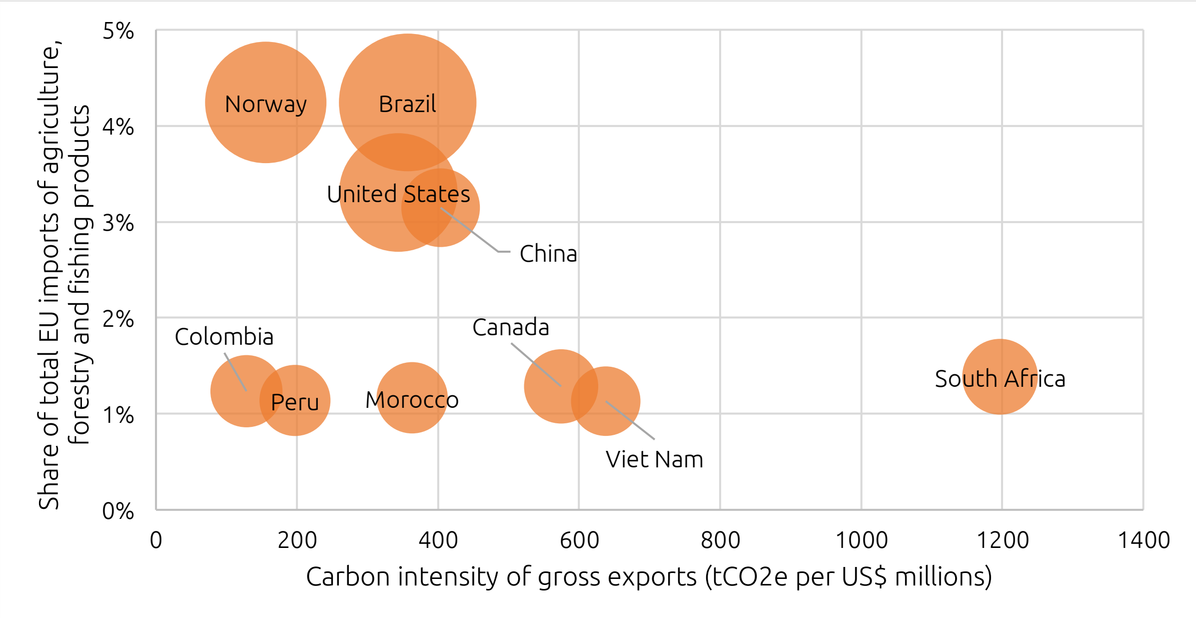
The three key products in the prepared foodstuffs, beverages, spirits and tobacco sub-sector are wine, sugar and fruit juice. In the vegetable and fruit products sub-sector, citrus exports to the EU make up 33,1% of SA's exports in this area, with SA contributing a significant 13,4% of the EU's imports (see Appendix A). In contrast, grape exports are far more EU-dependent, with 47,6% of SA's total exports bound for Europe (contributing 16,4% of the EU's grape imports). The EU's share of SA's total wine exports is high (38,6%), while SA's share of EU wine imports is relatively small (2,5%). This high export value implies significant vulnerability; SA

[17] The engine and drivetrain for a combustion engine has about 149 moving parts, while electric vehicles have about 29 (Wood, 2021). Furthermore, the parts that replace the mechanical components are much more specialised and constructed as a whole unit, implying less participation in terms of suppliers and manufacturers.

exporters rely significantly on access to the EU market, but the EU is not reliant on SA to satisfy its demand for wine imports. Similarly, the EU's share of SA's fruit juice exports is large (26,7%), but SA provides only 1% of the EU's imports.

As illustrated in Figures 5 and 6 below, the carbon intensity of South Africa's food and agricultural exports makes them an extreme outlier compared to the vast majority of other exporters, developed and developing countries alike. As the development and adoption of trade-related green policies gains momentum globally, this outlier status is likely to become an acute source of vulnerability for South African producers (and, in turn, labour). The combination of relative labour intensity and potential for foreign currency earnings through the export of food and agriculture-related products such as those discussed above ought to make these activities' long-term growth and sustainability a critical priority for policymakers.

Figure 5: Key suppliers of agriculture, forestry and fishing products to the EU (28) with carbon intensity, 2015



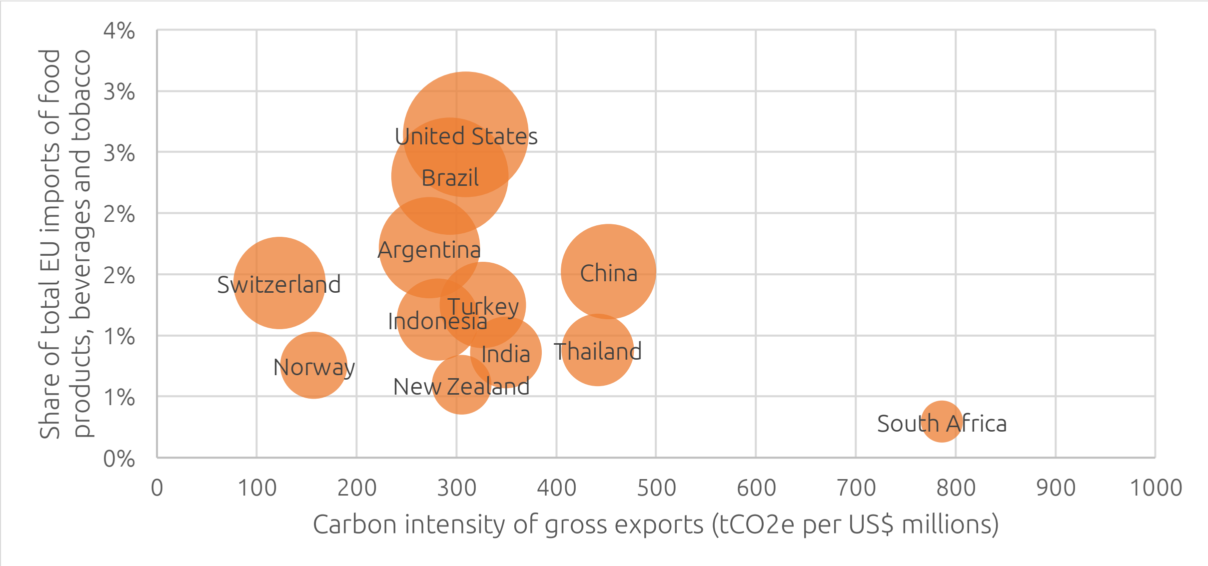
Source: Adapted from Montmasson-Clair (2020) based on OECD data

Notes: Some countries (Ukraine and Côte d'Ivoire) were omitted from the top 10 because there was no carbon intensity data. Imports from EU countries are excluded. The carbon intensity of gross exports indicator shows the intensity of CO_2 emissions, tonne CO_2 per Million USD, in gross exports of exporting country c sector i to the importing partner country p. The emissions can come from any domestic or foreign sector upstream in the production chain.

While the food- and agriculture-related products discussed above do not fall under the initial scope of the envisioned CBAM, several other EU initiatives suggest that there is a need for countries like SA to avoid complacency in reducing the carbon intensity of its production in these areas. The Farm to Fork (F2F) strategy, another pillar of the EGD, was launched in May 2020 to reduce the environmental impact of the EU's food system. While the main focus of F2F at this stage is on domestic production – key priorities relating to the reduction of pesticide, fertiliser and antibiotics usage in farming, mitigation of nutrient loss, and increasing the proportion of agricultural land used for organic production – there are also elements likely to affect exporters to the EU (CBI, 2021). These include stricter requirements regarding labelling and the provision of information regarding levels of carbon embodied in imports to the EU, the EU-wide harmonisation of "voluntary green claims" and an associated labelling framework, and a range of other measures likely to emerge from the negotiation of a new Common Agricultural Policy (CAP), which will enter into force in 2023 (European Commission, 2021e).[18]

A number of the nine key objectives of the new CAP appear likely to affect developing country exporters over time as the imperatives to "ensure a fair income to farmers" and "increase competitiveness" combine with the costs EU agricultural producers will need to take on to more effectively "contribute to climate change mitigation" (European Commission, 2021f). As with the broader EGD, the underlying logic for trade-related climate measures in agriculture hinges on carbon leakage.

Figure 6: Key suppliers of food products, beverages and tobacco to the EU (28) with carbon intensity, 2015



Source: Adapted from Montmasson-Clair (2020) based on OECD data

Notes: Imports from EU countries are excluded. South Africa did not make up the top 10 suppliers of this group of products. The carbon intensity of gross exports indicator shows the intensity of CO_2 emissions, tonne CO_2 per Million USD, in gross exports of exporting country c sector i to the importing partner country p. The emissions can come from any domestic or foreign sector upstream in the production chain.

For South Africa, one of the more pressing concerns will be the use of pesticides and specifically the tightening of maximum residual levels (MRL) for pesticides in food. Already, some pesticides used locally are not authorised for use in the European Union or are subject to much stricter standards. In 2020, the European Food Safety Authority adjusted maximum levels for certain pesticides and excluded several pesticides (Wood, 2021).

[18] A proposal for a legislative framework for sustainability in food is expected to come out in 2023 and it is expected to cover, among other things, use of chemical pesticides; reduction of excess nutrients; and front-of-pack nutrition and sustainability labelling.

Furthermore, while the initial scope of the proposed CBAM does not include food and agricultural products, there are some indications that some of SA's key exports could be subject to carbon border taxes in future. Since 2009, the EU has published and maintained "an official list of sectors and sub-sectors considered to be at a significant risk of carbon leakage" as defined in the directive establishing the EU's Emissions Trading Scheme (European Commission, 2021g; 2003: 20). This list has included the manufacture of wine, sugar and wool products, all of which rank among SA's top 50 exports (European Commission, 2009; 2014; 2019a).

A further area of concern for exporters is around packaging. The European Commission has adopted a new circular economy action plan (CEAP) in 2020 which targets how products are designed, promotes circular economy processes, and encourages sustainable consumption. In line with the plan, a revision of the Packaging and Packaging Waste Directive (a major piece of legislation in the sector) is planned to set out requirements for packaging to reduce waste and increase reuse and recycling.[19] Furthermore, there are increasing private standards around packaging driven by changing consumer preferences and expectations around regulations. In July 2021, a list of ten single-use plastics banned in the EU was released, including food containers made of expanded polystyrene. Increasing regulations around packaging will affect South Africa’s exporters, with companies having to shift to sustainable packaging in response to increasing regulation and consumer awareness.

In addition to official EU policy and legislation, private sector climate mitigation and sustainability initiatives are also likely to generate costs and barriers for developing country producers seeking to export to the EU. A few examples relevant for the SA exports discussed above include the Sustainable Nut Initiative (with a focus on traceability and environmental risk assessments for private sector participants in the value chain)(SNI, 2021); the Sustainability Initiative on Fruit and Vegetables (climate change mitigation standards, as well as integrating smallholder producers into global supply chains, living wage and gender equality advocacy and aiming to "[make] smallholder farmers a new asset class" for private investors) (IDH, 2021); and, the European Fruit Juice Association coordinating European private sector participants through a Sustainable Juice Covenant aiming to achieve its target of 100% sustainably sourced juices, purees, and concentrates by 2030 (Sustainable Juice Covenant, 2021).

The food sector will have to innovate to address mitigation, sustainability and food safety. For small farmers and processors particularly, the raft of expanding measures reinforces and raises barriers to entry that farmers and processors face in trying to access markets like the EU. Furthermore, within a globally concentrated food sector, while large incumbents appear to be taking sustainability concerns into account increasingly, it is in their interest to do so in ways that bolster their positions and to shift the cost onto smaller players in the value chain (Mondliwa & Roberts, 2021). Research shows that multinationals' environmental standards add a “sustainability-driven supplier squeeze” onto producers in developing countries (Ponte, 2019). The growing importance of eco-labelling thus reinforces the power of large food businesses while squeezing smaller players and farmers in the value chain.[20] More sustainable market outcomes must be pursued through policies that consider large multinational food

[19] https://www.europen-packaging.eu/policy-area/european-green-deal/

[20] Another criticism is that evidence that eco-labels have a positive environmental impact is mixed (Potter, et al., 2021).

companies' power and advocate for broader participation by farmers and smaller producers through rules to reshape markets (Mondliwa & Roberts, 2021).

Bigger players are better placed for adaptation and have already begun to adapt in many ways.[21] There is a need for reforms to improve state-support programmes and extension programmes to support smaller players in the market to transition. Furthermore, if managed quickly, the move towards sustainability could provide an opportunity for farmers and processors to gain a competitive edge.

d. Mining – minerals , pearls, precious stones and precious metals

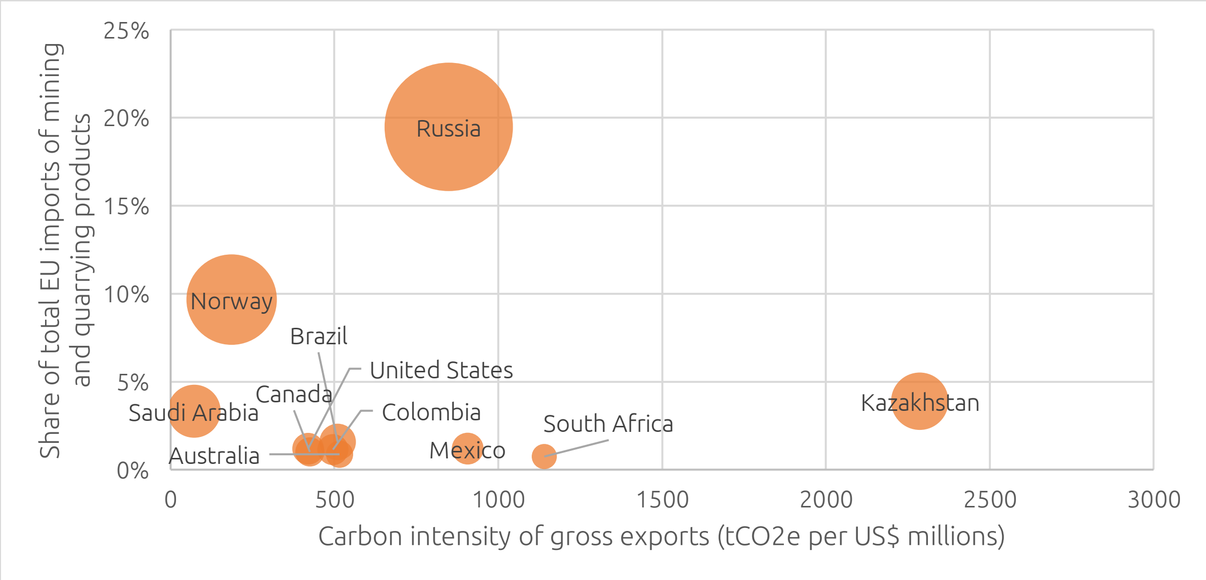
The impacts of climate change policies on the minerals, precious stones and precious metals sectors in South Africa is dependent both on global climate policies to mitigate climate change as well as policies relating to transitioning towards a more sustainable economy. While the former will put pressure on some South African exports, the latter will result in an increased demand for certain products. The South African mining sector is one of the biggest energy consumers in the country, particularly electricity (Ratshomo & Nembahe, 2019).[22]

In terms of its relative carbon intensity and importance as a supplier of mining and quarrying products to the EU, South Africa ranks in the top 10 (if EU suppliers and countries with missing data are excluded). South Africa supplies approximately one percent of the EU's mining and quarrying products imports. However, South Africa's relative carbon intensity embodied in its exports is second-highest behind only Kazakhstan (Figure 7).

[21] For instance, Nestle in its East and Southern Africa Region operations is testing emissions reductions and water saving using proprietary technology from the Emissions Capture Company (ECCO) while South African Breweries aims to completely switch to renewable energy by 2025 – all seven of its SA breweries have started generating electricity using solar, and one is also making use of bio-gas facilities (https://www.foodbusinessafrica.com/nestle-unveils-africas-first-ai-powered-technology-reducing-carbon-emissions-recycles-wastewater/ and https://www.foodbusinessafrica.com/south-africa-breweries-switches-to-renewable-energy-in-production-of-castle-lite/).

[22] Along with the manufacturing sector, mining accounts for significant end-use energy demand in the country. These include ferrous and non-ferrous metals processing, mining, pulp and paper, and the petrochemical sector (Department of Mineral Resources and Energy, 2005).

Figure 7: Key suppliers of mining and quarrying products to the EU (28) with carbon intensity, 2015



Source: Adapted from Montmasson-Clair (2020) based on OECD data

Notes: Some countries (Algeria, Nigeria, Iraq, Azerbaijan, Angola, Libya, Qatar, Egypt) were omitted from the top 10 because there was no carbon intensity data. Imports from EU countries are excluded. The carbon intensity of gross exports indicator shows the intensity of CO_2 emissions, tonne CO_2 per Million USD, in gross exports of exporting country c sector i to the importing partner country p. The emissions can come from any domestic or foreign sector upstream in the production chain.

EU policy documents do not make mention of the direct imposition of the CBAM on the minerals sector. However, there is some discussion about an expansion of the CBAM's scope of emissions that could see raw materials falling under a much broader full carbon footprint scope more popularly termed 'cradle to grave'[23]. Moreover, there have been discussions among EU policymakers about shifting to more sustainable mineral and precious metals extraction (for example, green mining), and the mining environment will likely see more pressure towards sustainable practices going forward.

However, there does not seem to be any specific risk to South African exports from the EGD. There will likely be an increase in demand for some minerals due to sectors being promoted under the green economy. Many sectors being promoted under the green economy, including those related to renewable energy (bioenergy, hydrogen, water, wind and sun), better storage and less loss of energy (batteries and energy transport), reduction in the use of fossil energy (electrification of vehicles, lighter materials) and advanced, smart technology (Geological Survey of Norway, 2016) will increase demand for raw materials. As a result, minerals and precious metals will likely see a marked increase in their demand in line with the

[23] 'Cradle to grave' includes all GHG emissions relating to the mining of raw materials, all emissions from the production of materials and components needed for manufacture of the product, the emissions caused by the production process, including emissions from providing the necessary energy, emissions from the transport of raw materials and interim products to the site of the production process and of the product to the consumer, emissions caused during the use phase and emissions related to the disposal / end-of-life phase of the product (European Commission, 2021a).

growing trends and transitions towards greener and circular economic models.[24] A World Bank report emphasises that the production of minerals (notably graphite, lithium and cobalt) could increase by as much as 500% by 2050 to meet the demand for clean energy technologies (World Bank, 2020). Platinum, too, has recorded notable growth as a direct result of stricter vehicle emissions rules across Asia and Europe.[25] In addition, platinum's demand will grow further given its essential role in the burgeoning hydrogen economy, more specifically in the production of fuel cells.

As far as South Africa is concerned, platinum will likely be negatively affected as the demand for catalytic converters decreases strongly with the rollout of electric vehicles, but will likely benefit from an expansion in battery-storage demand (Wood, 2021). Iron ore and zirconium may face risks from energy-intensive sectors. Metals like titanium, chromium, rhodium and iridium are likely to experience increased demand from new green technologies. While traditional uses of manganese may decline, demand may increase because of battery storage (Wood, 2021).

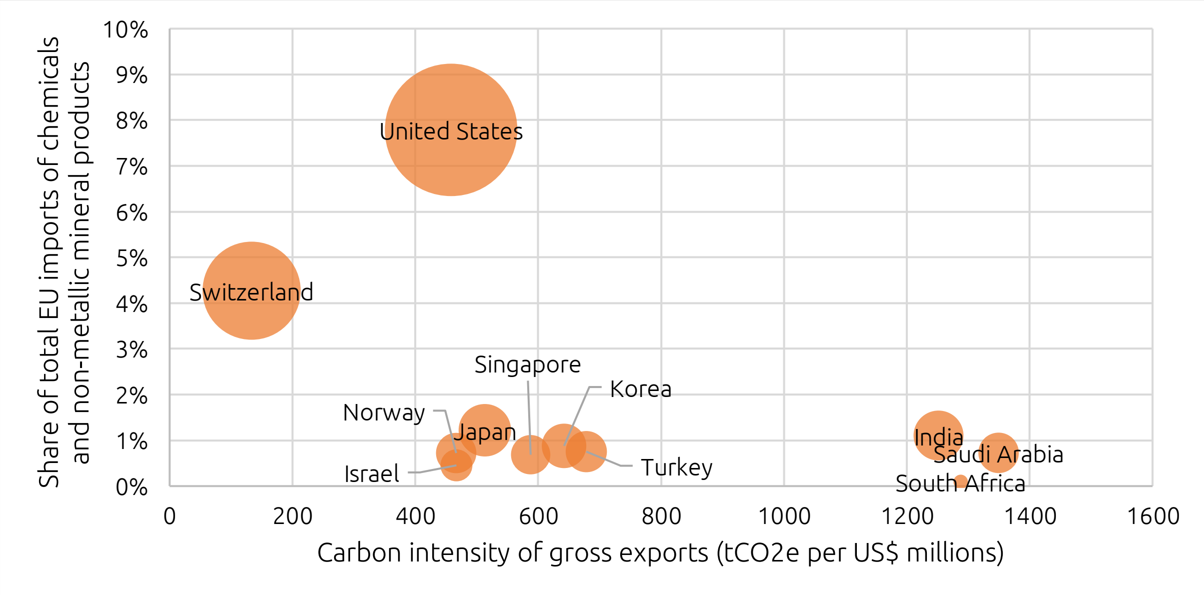
e. Chemical and fertilisers

Most of the chemicals exported by South Africa are by-products of either primary petroleum refining or mining, and thus production is often disconnected from demand. South Africa's exports of chemicals and plastics to the EU are in a group of basic chemicals which have a wide variety of uses, and because of this, this sector is known as a root industry. The EU represents a significant market for South Africa's chemicals sector, with some of the notable products being sulphates (92.4%), reaction initiators (60.4%), acyclic hydrocarbons (21%), new pneumatic tyres (19.4%), and polymers of propylene (16.9%). In the context of international trade to the EU, South Africa ranks as one of the highest emitters of carbon relative to its small share of EU imports of chemicals (Figure 8).

[24] The boost in demand for minerals is a hallmark of development historically, with each new industrial breakthrough and innovation culminating in the use of new and expanded use of existing minerals (Figure 1). The use of these new and ever-expansive arrays of minerals and materials has facilitated new technological developments and innovations across multiple industries. The green economy is seemingly following this path, and its success necessitates the continued use of mined minerals (Geological Survey of Norway, 2016).

[25] https://miningglobal.com/sustainability-1/platinum-receives-boost-green-economy

Figure 8: Key suppliers of chemicals and non-metallic mineral products to the EU (28) with carbon intensity, 2015



Source: Adapted from Montmasson-Clair (2020) based on OECD data

Notes: Some countries (China) were omitted from the top 10 because there was no carbon intensity data. Imports from EU countries are excluded. South Africa did not make up the top 10 suppliers of this group of products. The carbon intensity of gross exports indicator shows the intensity of CO_2 emissions, tonne CO_2 per Million USD, in gross exports of exporting country c sector i to the importing partner country p. The emissions can come from any domestic or foreign sector upstream in the production chain.

Trade to the EU will be affected by standards governing chemicals exports, specifically the EU's Chemicals Strategy published in 2020. The strategy falls under the EGD and will have far-reaching implications for the chemicals sector, specifically on restrictions on harmful chemicals that may pose a risk when used in combination with others ('cocktail effect'). While this will likely impact a range of retail chemicals like cosmetics and cleaning goods, it is still not clear which chemicals will be impacted. The chemicals that are a risk to the environment are most at risk, including sulphates (primarily used in agriculture), acyclic hydrocarbons (use varies by type), sodium dichromate (primarily used in ferrochrome production), and butyl acrylate (primarily used in paint manufacture). Since these are already subject to compliance regulations, the sector may be well-placed to deal with potential changes (Montmasson-Clair, 2021).

While inorganic fertilisers are identified among the products affected by CBAM, South Africa's exports of inorganic fertilisers to the EU are not high, and therefore exposure to the CBAM will be marginal (Monaisa, 2021)). The CBAM may include polypropylene, which will affect South Africa.

4. Cross-cutting issues

This section focus on two critical cross-cutting issues, namely green hydrogen opportunities for industrial growth and the role of finance.

Green hydrogen: The energy transition debates in South Africa have mainly focused on electricity generation, but will need to be expanded to the use of petroleum products and gas in other sectors. South Africa has excellent renewable energy resources (wind and solar) making it ideal for renewable energy generation. Parallel to this process, there is an opportunity to produce green hydrogen to replace petroleum products in sector. For this opportunity to be realised, it will be necessary to link the energy transition to reinvestment within sector in energy-intensive sectors like metals and basic chemicals, as well as those which use coal, fuel oil, or gas such as cement, glass and paper & pulp.

Finance: The threat of climate change and looming policy changes in European policy presents numerous systemic risks and implications for South Africa's industrial policy. Without action, the South African economy risks falling behind and becoming uncompetitive in key industrial export sectors to the EU. Nevertheless, despite the risks, there also exist opportunities to mitigate the impacts of climate change on South Africa's industrial and trade landscapes. A long-term vision must centre around forming a sustainable economic trajectory that incorporates all sectors of the economy in the actions taken to alleviate and minimise climate change risks. The speed and magnitude of actions taken to reduce carbon emissions will determine how much these impacts can be mitigated over the coming decades (CAP, 2019). The financial sector ought to play a key role in mitigating transition risks and, at the same time, speeding up the process of achieving carbon neutrality and reorientating South Africa's industrial base toward greener production.

4.1. Green hydrogen opportunities for industrial growth

Hydrogen has a range of applications in traditionally carbon-intensive industrial processes, including oil refinement, the production of high-value chemicals and the production of iron and steel products (Patel, 2020). Hydrogen can be produced via several processes, with the predominant methods being highly carbon-intensive due to both the use of fossil fuels as feedstock and the emission of carbon dioxide as a by-product. A shorthand has emerged to describe the hydrogen produced by these different processes. Hydrogen produced with fossil fuels is referred to as brown (if coal is the feedstock and gasification the method), grey (if natural gas is the feedstock and reformation the method), blue (if natural gas and reformation are used alongside carbon capture and storage technologies) or green (Deign, 2020). The latter is applicable if electrolysis is the method used and the electricity used in the process has been generated by renewable energy sources (Patel, 2020).

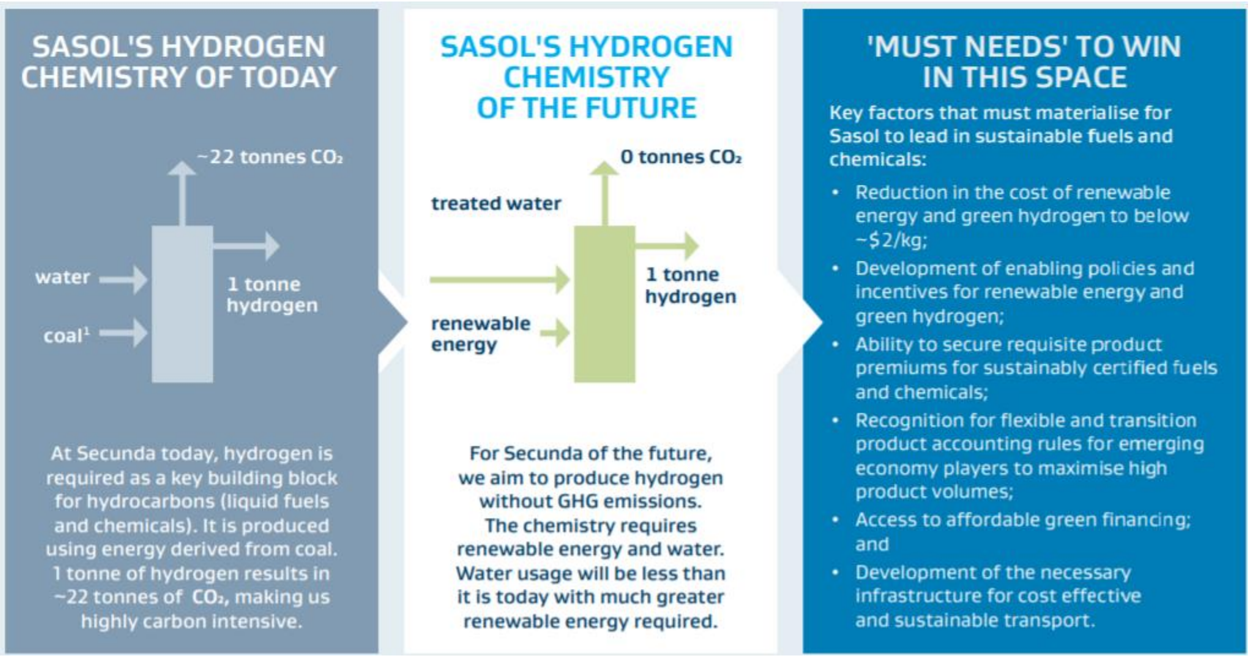
Global demand is dominated by chemicals production – mostly ammonia and methanol - at around 50% and refineries at 44%, with steelmaking making up the bulk of the remainder at 5.5% (IEA, 2021). As of 2020, hydrogen supply remained dominated by fossil fuel-powered methods (79%), with natural gas the primary feedstock (60%) (IEA, 2021). The use of hydrogen in newer applications remains limited, with technologies for applying hydrogen to electric vehicles and electricity generation still at the early stages of commercial deployment; transport applications take up only 0.02% of total demand (IEA, 2021).

Green hydrogen production, storage and transportation remain costly, presenting several technical challenges that require major upfront financial commitments (IEA, 2019; Deign, 2020; dtic, 2021a). In addition, the race to develop green hydrogen technologies and lead green hydrogen exports is highly competitive, dominated thus far by lead firms in countries that already have sophisticated and well-resourced hydrogen research and development capabilities (Deign, 2019; Material Economics, 2020; CSIS, 2021).

Debates within South Africa on the transition towards a green economy have primarily focused on electricity generation. However, these debates only account for half the story as an additional crucial step in the green transition necessitates replacing fossil fuels with green energy sources. South Africa boasts one of the most conducive geographies for generating renewable energy sources such as solar and wind. Owing to its geography, South Africa may be relatively well-placed to integrate the production of green hydrogen, its deployment for various industrial and other uses, and exports to overseas users into its strategy for decarbonisation and climate change mitigation. As summarised by Patel (2020: 4), "South Africa's rich endowment of ideal weather conditions for solar and wind power generation, technological capabilities around the Fischer-Tropsch (FT) process, and access to platinum resources place the country at an advantage for developing the hydrogen value chain and being a key supplier into the global hydrogen market." Given the requisite investments, abundant renewable energy resources combined with relatively rapidly expanding production capacity ought to enable competitive production through the electrolysis method.

Realising a transition towards green hydrogen-powered industry will require significant re-investment in much of South Africa's existing capital stock. This re-investment drive necessitates a set of sectors collectively leading the way, such as the energy-intensive metals and basic chemicals sectors and those which use coal, fuel oil, or gas such as cement, glass and paper & pulp. There already exist examples of industrial-scale applications of hydrogen in South Africa. For example, Sasol's origination of and expertise in the FT process combines hydrogen with carbon to produce synthetic fuels and other high-value chemicals (Patel, 2020). Sasol's vertically-integrated operations already produce hydrogen for use as feedstock in the FT process, and its Secunda plant is "the world's largest producer of grey hydrogen from coal-based feedstocks" (Sasol, 2021: 7). As discussed above, this method is highly carbon-intensive and a key driver of Sasol's extremely high volume of GHG emissions. The company has already identified "a siseable reduction opportunity" and a "significant value creation proposition" in the replacement of grey with green hydrogen in its supply chain – it proposes that the combination of renewable energy resources with its existing large-scale plants will place it in a highly competitive position in the production of synthetic fuels and high-value chemicals from green hydrogen (Sasol, 2021: 12).

Figure 9: Summary of green hydrogen strategy for Sasol's Secunda plant



Source: Sasol Climate Change Report (2021: 12)

As reflected in Figure 9 above, Sasol indicates that a successful transition from grey to green hydrogen as the basis of its decarbonisation strategy will hinge on a range of policy and market-related developments. On the policy front, successful upscaling of renewable energy production, "enabling policies and incentives", and the availability of critical infrastructure are "must needs"; the ability to secure premiums for "sustainably certified" products and access to green financing are critical requirements from product and financial markets.

Other large firms are also exploring the integration of green hydrogen into their decarbonisation strategies – Anglo American plans to develop and introduce hydrogen-powered electric mine haul vehicles for use at its Mokgalakwena platinum mine, fueled by green hydrogen produced by a 3.5MW electrolyser to be built on-site (Anglo American, 2022). However, as with Sasol, investment and implementation appear to be heavily dependent on policies, incentives and market developments that de-risk green hydrogen strategies for large players.

The South African Steel and Metal Fabrication Master Plan 1.0 recognises the importance of transitioning the steel and metal fabrication to greener production methods by 2050 (achieving carbon neutrality). There are several options for reducing the carbon intensity of steel production, including increasing the efficiency of existing production methods, recycling of steel, and carbon capture and storage (CCS) technologies. There is also potential for relative decarbonisation through green hydrogen in steel production. However, ArcelorMittal, which acquired the assets of former parastatal steelmaker Iscor in 2005, derives a relatively small proportion of its revenue from South Africa and, perhaps for this reason, has focused its efforts to produce "green steel" using green hydrogen in its European operations (ArcelorMittal, 2020). ArcelorMittal's Climate Action Report for 2021 reflects that it doubts that policy in South Africa will meet its five conditions for accelerated decarbonisation by 2025; these include incentives for the production and consumption of "zero carbon-emissions steel", financial support for long-term investments, access to sufficient and affordable renewable energy and a "fair competitive landscape" (ArcelorMittal, 2021a). The Q&A session held with ArcelorMittal South Africa investors in May 2021 also reflects vigorous lobbying regarding these conditions, particularly concerning additional protection from imports, a contentious issue in the South African context (ArcelorMittal, 2021b; Phakathi, 2021).

4.2. Climate change and industrial finance

a. Overview of broad industrial finance and climate change issues

The global financial sector faces a direct threat from climate change but is also a force for change. The risks to the financial sector stem from effects on the the banking and insurance sectors (Lagarde, 2020), and delaying effective responses to tackling climate change which will only serve to weaken any future efforts at mitigating climate exposure (Grippa, et al., 2019). Governments and other public and private institutions are envisioned as playing essential roles through regulation, taxation, and early and coordinated action in tackling climate change. Additionally, many short-term risks could become long-term catastrophes spanning from food insecurity to economic malaise, especially given that many of the financial stability risks from climate change are, on average, concentrated in sectors, geographies, and firms with these risks widely varying given already substantial path-dependency risks (ECB, 2021). A sizeable deficiency in financial and policy response to climate change will only serve to exacerbate the already negative patterns of environmental damage and, in the process, set in motion harsher reactionary policies and responses from economies driving the green transition.

To meet the challenges of climate change head-on, financial sectors, public and private, must evaluate its internal processes, policies, products, and services (WWF, 2005). The requisite response from the financial sector should be two-fold. On the one hand, the financial sector must prepare for the effects of climate change on its operations. On the other hand, the financial sector must recognise its ability to significantly mitigate the economic, environmental, and social risks through offering carbon-neutral-focused products, services, and incentives (ECB, 2021).

Effective and deliberate policy actions and choices combined with expanded access to patient capital can facilitate a smooth transition to renewable energies, processes, technologies, and products improving the competitive dynamics of transitioning firms and sectors (OECD, 2021). The choice and design of policies and incentives aimed at climate change mitigation will play a determining role in the transition pathway of the South African economy in the face of stringent EU regulations.

South Africa can benchmark policies and financial incentives from international examples such as the EU. Some of these include the increasing issuance of green bonds (National Treasury, 2020) and the promotion of export credit agencies. A recent, and as yet untested, example is South Africa's adoption of a Green Finance Taxonomy (GFT) (National Treasury, 2022). EU regulators recently agreed on its "Taxonomy Compass" for sustainable finance in response to widespread misunderstanding and disagreement about categorising green investments. This taxonomy is a classification system that establishes a list of environmentally sustainable economic activities that, if successful, will aid the EU in its efforts towards implementing its green deal (European Commission, 2022). It is hoped that this taxonomy will serve as a common language for banks, insurance, government departments, and development finance institutions to better align the financial system with environmental, social, and governmental goals in policymaking (Wehrmann & Wettengel, 2022). There is still considerable debate as to whether the EU's taxonomy is stringent enough to change investment patterns to the extent required to meet its climate targets, with much of the debate centred around the green credentials of investments in gas and nuclear power. Similar debates on South Africa's approach to gas and nuclear power will be critical; this is already reflected in the first edition of the GFT, where the role of gas as a "transition fuel" and its possible inclusion in future editions is mooted (National Treasury, 2022: 157).

b. South Africa's industrial financial landscape

South Africa's industrial financing and policy ecosystems are well-entrenched in the economy; however, long-standing, systemic gaps remain. South Africa's financial ecosystem was designed and developed in the 1880s to support the growing mining sector before expanding to support the broader minerals energy complex (MEC, Lowitt, 2021). Despite being relatively well-developed, South Africa's financing ecosystem is designed in such a way as to fund and replicate the dominant MEC and support existing large enterprises employing established and tested technology, with low-risk profiles and predictable financial returns, despite volatility in the past decade. Because of this, material gaps exist whereby smaller-scale, early-stage, higher-risk projects using less well-known technologies are underfunded.

This systemic failure to provide industrial finance for these overlooked parts of the economy is due to a combination of reluctance on the part of private equity firms to invest in early-stage projects, the limited fiscal space in which government currently operates, and the lack of grants and concessional funding issued by South Africa's development finance institutions (DFIs) because of a lack of underwriting from national government leading these institutions to conduct their developmental financing agendas on a for-profit basis (National Treasury, 2020; Lowitt, 2021). DFIs are forced to follow this for-profit model with profound implications for South Africa's structural transformation and comprehensive developmental agenda (Goga, et al., 2019).

These gaps are grouped into four categories: policy-related, structural, skills and capacity, and fund design (TIPS, 2020). These categories produce barriers to green financing with implications for South Africa's green transition. For example, there is a misalignment at the policy level between the country's green economy vision, industrial policy, and the prevailing structure of the financial system. The implication is that South Africa's financial system is geared towards financing an economy that is a technology follower rather than a technology leader in contrast to the visions of the economy's industrial and green policies.

Another crucial barrier to green financing is the lack of requisite skills and capacity constraints in green project implementation partners, commercial banks, and project developers. These shortages and constraints hinder access to domestic commercial finance providers, equity finance, and commercial debt. The last problem is linked to green economy funds' design that creates barriers such as a limited focus on low-carbon projects, high transaction costs for commercial finance, weak and poorly structured concessional funding, and other legislative barriers (TIPS, 2020; National Treasury, 2020). Overall, given the scope and scale of funding required to ease the transition risks associated with the green economy, South Africa's public funds are insufficient for financing climate-related initiatives and projects.

Consequently, the persistence of these systemic gaps will continue to disadvantage South Africa's transition towards a green, carbon-neutral economy if unaddressed. The risks present impediments to South Africa's transition towards a green economy and industrial policy agenda suited to assisting South African sectors prepare, mitigate, and adapt their production systems to the various risks of climate change. Failure to address these systemic risks adequately will weaken South African industry and leave it vulnerable to future policies from international trade and investment partners.

Critically, South Africa still lacks an all-encompassing national policy for transition to a greener and more sustainable economy (National Treasury, 2020) despite several attempts, since the early 2000s, to adopt a broad range of national and sectoral policies aimed at decarbonising the economy while at the same time trying to deliver on broader developmental objectives (Cassim, et al., 2021). For example, as early as 2004, South Africa launched its National Climate Response Strategy with various iterations, additions, and amendments to laws and regulatory frameworks. These iterations culminated in the recently released National Climate Change Response Policy (NCCRP). The NCCRP is a comprehensive plan that sets a long-time horizon (up to 2050) for addressing, mitigating, and adapting to climate change (Department of Environmental Affairs, 2021). The NCCRP focuses on multiple areas from carbon pricing and water to biodiversity, agriculture, and human settlements. More crucially, however, the NCCRP openly calls for closing green financing gaps by including the broader financial sector in shaping South Africa's climate and green finance architecture (Cassim, et al., 2021).

The national government must play a crucial and leading role in supporting climate change investment, mitigation, and adaptation to solve these issues. The public sector must take a leading role in driving investments for green technologies and climate change mitigating policies (Cassim, et al., 2021). DFIs and blended finance must be leveraged as essential sources of green industrial finance in South Africa. While there are instruments in the industrial finance sector to finance the green transition, including the co-managed Green Fund and the Development Bank of Southern Africa's DSBSA Green Bond Framework[26], the private sector currently dominates the local green finance landscape, providing over 50% of South Africa's climate finance between 2017 and 2018. This is followed by the public sector (35%) and blended finance (8%). Within the public sector finance, the South African government accounted for more than 55% (or R12 billion) of the finance provided by the public sector (Cassim, et al., 2021).

In contrast, DFIs' contributions to green finance amounted to R5.5 billion (25%) of all public finance flows, with much of this finance going toward clean energy projects. Furthermore, the instruments and incentives employed by the South African financial sector towards green economy projects are overwhelmingly focused on debt and equity finance (about 70%) with grants, budgetary expenditure, and concessional financing accounting for the other 30% in 2017 and 2018 (Cassim, et al., 2021). The end-use of this financing was for mostly climate mitigation activities (81%), with climate adaptation activities accounting for only 7%.

Overall, a comprehensive review of South Africa's green financing and incentive ecosystem is required to align it with a targeted and sectoral green industrial policy. Furthermore, there is scope for more strategic uses of blended finance to expand South Africa's green finance ecosystem and mobilise additional financing from international development finance institutions. In addition to this, several policy levers can be utilised to ensure that the South African government's industrial policy and green economy visions are supported by a conducive and effective developmental financing ecosystem. Some policies could include

[26] These financial instruments aim to provide financing to green economy-related projects (TIPS, 2020)

improved public-private coordination on climate spending and investment; increased support for and use of innovative financial tools, instruments, and incentives; and guidelines and tools to enable reporting monitoring, and evaluation (National Treasury, 2020; Cassim, et al., 2021).

A shift in the lending portfolios of South African DFIs away from coal-powered and dirty sectors toward green and clean sectors, are crucial given their exposure to physical and transition risks from climate change (IDC, 2021). In addition, a review of the enabling frameworks governing DFI funding must be undertaken to ensure DFIs are incentivized away from from financing unsustainable activities, hindering climate mitigation, adaptation, and resilience efforts. Currently, contradictions within government published industrial and growth policies are simultaneously encouraging South African DFIs, such as the IDC, to finance investment in green infrastructure and the manufacture of green industry components while also encouraging the financing of unsustainable infrastructure and value chains (Centre for Environmental Rights, 2021). The IDC should leverage its significant stakes in the identified priority sectors and firms like ArcelorMittal to accelerate research and development into greener technologies and reduce these firms' reliance on climate change-enducing processes.

5. Policy implications and conclusion

5.1. Reviewing the key issues

Climate policies related to decarbonisation are impacting the trade and competitiveness of countries' exports. The EGD and related policies are the most extensive set of policies relating to decarbonisation. Through its "Fit for 55" Strategy announced in 2021, the EU aims to reduce emissions in the EU by a minimum of 55% by 2030 relative to emissions in 1990. While most of the measures in the EGD and related policies are aimed at markets within the EU, some are likely to affect its trading partners as well. These impacts on trading partners will occur through changing regulations and policies, the evolving competitiveness of competing technologies, shifting consumer preferences, and impacts through value chains because of changing competitiveness of end products.

Indications are that policies and initiatives related to decarbonisation from the EU, and the introduction of similar types of policies from other developing countries will be ramped up in the coming years. The most direct trade-related EGD measure is the Carbon Border Adjustment Mechanism which will impose an additional price on imports of certain goods from countries where mitigation measures related to decarbonisation are not as strong as in the EU. For the transitional period from 2023-2025, CBAM will apply to the iron and steel, cement, fertiliser, aluminium, and electricity sectors. Other key policies include the move to electric vehicles which will effectively end new petrol and diesel sales by 2035 and a range of policies in the agri-food sector aiming to reduce the environmental impact of the EU's food systems, including eco-labelling.

As far as the CBAM is concerned, countries that will be most affected are those exporting products covered under the CBAM and have a high carbon emission intensity. Furthermore, aside from the carbon levy costs, there will be costs related to the administrative burden of calculating and reporting on carbon emissions, while companies will also bear the cost of changing production systems to reduce emissions. In the longer term, if the CBAM is extended to cover the full value chain, including indirect emissions (like emissions related to energy use), the costs will be even more substantial. For the food sector, among others, labelling and information requirements will impose costs related to collecting, verifying, and reporting on information, together with on-going changes in demand towards eco-friendly and more sustainable products.

The costs for developing countries from this array of climate policies are expected to be substantial. Developing countries are expected to bear mitigation and reporting costs on top of the costs related to adaptation to climate change, even though the climate challenges experienced on the planet have largely been because of the industrialisation of countries in the global North. South Africa will bear these costs because, not only is it expected to get hotter and drier in some areas of South Africa, but South Africa is heavily dependent on coal-based energy. Therefore, the country faces the challenge of adapting to climate change while decarbonising the energy sector and taking mitigation and sustainability steps in other key sectors like metals, automotives and food to protect its trade competitiveness.

The nature of the various trade-related climate mitigation measures being developed by EU policymakers is concerning for those sectors for which the EU is a major destination for South African exports. Of the seven most prominent South African exporting sectors to the EU highlighted in this paper, we have identified basic metals and fabricated metal products; transport equipment, automotive & auto parts and components; vegetable and fruit products; and prepared foodstuffs, beverages, spirits, and tobacco as priority sectors.

Firstly, these sectors and sub-sectors are at risk from immediate EU green policies and initiatives such as the CBAM, "Fit for 55", and the F2F strategy. Secondly, for these specific priority sectors, the EU is an essential market regarding the share of exports and value it demands. Lastly, these sectors also have relatively high degrees of carbon intensity in their respective value chains. These indicators show that these priority sectors face immediate and significant risks from EU climate policies. Therefore, these sectors require priority- and joint intervention on the part of the government and the private sector to mitigate the negative impacts stemming from EU climate change policies. Viewing South Africa's transition towards a green industrial landscape as a problem requiring jointly public and private interventions is necessary for lessening South African sectors' exposure to carbon mitigation policies and other barriers to entry for South African export firms.

While a number of sectors have been labelled in this paper as "non-priority", some of these still represent future pressure points for South Africa's export basket given their relatively high export values to the EU and the carbon intensity of their production systems. These risks could manifest in response to expansions in the sectoral scope of the CBAM and other EU and international policies associated with climate mitigation. Despite these potential future risks, these non-priority sectors also offer significant opportunities to improve South Africa's industrial resilience to climate change mitigation policies.

The high level of aggregation with which this paper views the various risks and vulnerabilities associated with trade-related climate mitigation policies does not lend itself to the formulation of targeted industrial policy responses. For this reason, we acknowledge a need for greater depth of investigation into the respective value chains in which the priority sectors are located. Adopting a value chain approach to the issues related to climate mitigation policies would afford policymakers a more precise lens with which to view these problems in the South African industrial context controlling for size differentials, existing technological and industrial infrastructures, and upstream carbon intensity. Understanding carbon intensity at a more granular level is key, including more detailed reflections of the direct and indirect emissions originating from production of the products marked for inclusion in various green economy and climate change policy documents.

An additional factor that warrants attention for South African policymakers is the lack of domestic green technological capabilities, exacerbated by the skewed structure and concentration present in many of the priority and non-priority sectors in South Africa. Compared to established MNCs, South African manufacturers are at higher risk given their less-developed technological and industrial infrastructures. This pressure is exacerbated by the need for many MNCs to cut their supplier base to decarbonise their production drastically. Therefore, larger South African firms and MNCs with the financial resources to invest in climate mitigating technologies and infrastructure will undoubtedly lead the way at the expense of smaller South African firms precipitating a continued divergence in industrial and technological capabilities and capacity. This continued divergence in technological and industrial capabilities will further reduce the resilience of sectors to future climate mitigation policies, internationally and domestically.

Improving the responsiveness and resilience of South African industry to climate change will require support from the financial sector. However, there are many challenges and systemic gaps within the financial sector, ranging from a continued imbalance in support for upstream versus downstream sectors combined with limited state fiscal space and the reluctance of private capital to invest in early-stage and risky ventures. For South African sectors to develop greater resilience to climate change's direct and indirect threats, the national government and DFIs must play a leading facilitating role in supporting climate change mitigation. Success in this regard requires a comprehensive review of South Africa's green financing and incentive ecosystem to align it with targeted green industrial policies.

In addition, several structural weaknesses may also contribute to South Africa's struggles to mitigate climate change, and need to be addressed in critical value chains. Long-standing issues here include a weak supply of labour skilled in science, technology, engineering, and mathematics; inadequate and unproductive financing of research and development; and a lack of support for small firms' technological and operational readiness to contribute to their respective value chains effectively. Considering these weaknesses, it will become crucial for firms to develop the capacity to adopt new technologies to enable trade.

5.2. Opportunities in South Africa's way forward

Decarbonisation also presents opportunities to drive South Africa's industrial renewal. South Africa's transition towards renewable energy provides an opportunity to link energy policy to industrial policies that can support the emergence of new production capabilities in wind and solar value chains. Such capabilities, in turn, may provide the basis for reindustrialisation and sustainable growth and thus for a socially viable energy transition. One of the key challenges in driving a climate-compatible structural transformation growth strategy will be the state's ability to delink fractions of capital inextricably tied up in high CO_2 emitting sectors from those only contingently reliant on carbon-intensive energy and production methods as a result of South Africa's economic history.

The transition towards greener production methods and outcomes in the South African economy will also require a concerted and coordinated effort from both the state and the private sector. The ability to exploit the potential sectoral opportunities will necessitate the emergence and success of transition champions to facilitate an sector-wide adaptation to the threats posed by climate change and the necessary big push required to kick-start South Africa's industrial revival and transition towards a greener economy. This demand-side push from these identified priority sectors may help to lend momentum to necessary changes in South Africa's energy mix, allowing it to take advantage of competitive advantages in solar, wind and hydrogen power generation.

Furthermore, while the energy transition debates have mainly focused thus far on electricity generation, measures are also required within sectors to decarbonise. South Africa has the potential to produce renewable energy competitively from a range of resources, and with sufficient investment and planning will be relatively well-placed to reduce industrial-scale fossil fuel usage and green its industrial base. For this to bear out requires linking the energy transition to reinvestment in sectors like metals, basic chemicals, and those that use coal, fuel oil or gas such as cement, glass, and paper & pulp. Furthermore, the various regulatory regimes that govern different energy resources in South Africa remain insufficiently coordinated, and are subject to a great deal of pressure from conflicting and entrenched interests. Unless resolved decisively, these conflicts will impede attempts to transition towards a greener economy.

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7. Appendices

Appendix A: South Africa's top 50 exports and major trading partners by sector

SA Top 50 Exported Products	Export value (2020; R'billion)	Export Value CAGR (2011-2020)	Country share of SA exports of product (2020)				
			EU (excl. UK)	UK	USA	Japan	China
Basic metals							
HST7202: Ferro-alloys	R44.1	3.1%	14.9%	0.1%	8.4%	5.0%	34.7%
HST7601: Unwrought aluminium	R16.7	6.2%	36.9%	5.4%	20.7%	6.7%	1.2%
HST7219: Flat-rolled products of stainless steel, of a width of >= 600 mm, hot-rolled or cold-rolled ...	R6.6	2.4%	49.2%	3.6%	2.6%	0.0%	2.6%
HST7606: Plates, sheets and strip, of aluminium, of a thickness of > 0,2 mm (excluding expanded plates, ...	R5.1	1.7%	41.3%	13.0%	26.9%	0.0%	0.7%
HST7308: Structures and parts of structures "e.g., bridges and bridge-sections, lock-gates, towers, ...	R4.9	2.9%	1.9%	0.5%	0.8%	0.0%	0.0%
HST7402: Copper, unrefined; copper anodes for electrolytic refining	R4.7	38.8%	1.2%	0.0%	0.0%	0.0%	94.5%
HST7502: Unwrought nickel	R4.7	18.3%	33.5%	1.0%	12.2%	9.5%	12.1%
Machinery & equipment							
HST8474: Machinery for sorting, screening, separating, washing, crushing, grinding, mixing or kneading ...	R5.3	4.0%	5.0%	0.5%	3.4%	0.0%	0.4%
HST8431: Parts suitable for use solely or principally with the machinery of heading 8425 to 8430, n.e.s.	R5.3	6.8%	7.5%	1.7%	4.1%	0.2%	0.5%
HST8413: Pumps for liquids, whether or not fitted with a measuring device (excluding ceramic pumps and ...	R4.6	7.4%	5.2%	0.4%	3.0%	0.0%	0.3%
HST8517: Telephone sets, incl. telephones for cellular networks or for other wireless networks; other ...	R3.8	11.1%	18.5%	1.4%	2.4%	0.0%	6.4%
Mining - mineral products and pearls, precious stones and precious metals							
HST2601: Iron ores and concentrates, incl. roasted iron pyrites	R99.8	4.9%	15.4%	0.9%	0.1%	4.8%	59.6%
HST2701: Coal; briquettes, ovoids and similar solid fuels manufactured from coal	R63.9	1.9%	1.1%	0.0%	0.9%	0.1%	0.7%
HST2602: Manganese ores and concentrates, incl. ferruginous manganese ores and concentrates, with a ...	R40.4	18.5%	3.5%	0.0%	0.4%	2.6%	67.1%
HST2710: Petroleum oils and oils obtained from bituminous minerals (excluding crude); preparations containing ...	R29.9	3.8%	0.9%	0.0%	0.0%	0.2%	0.1%
HST2610: Chromium ores and concentrates	R25.1	9.4%	2.2%	0.1%	0.9%	0.3%	61.1%
HST2616: Precious-metal ores and concentrates	R15.6	32.4%	95.1%	2.6%	0.0%	0.0%	0.9%
HST2716: Electrical energy	R10.6	15.9%	0.0%	0.0%	0.0%	0.0%	0.0%
HST2614: Titanium ores and concentrates	R7.9	8.6%	30.7%	0.0%	33.9%	11.3%	4.7%
HST2615: Niobium, tantalum, vanadium or zirconium ores and concentrates	R6.6	4.5%	30.5%	0.7%	3.4%	1.6%	51.8%
HST2603: Copper ores and concentrates	R4.7	0.4%	1.0%	0.0%	0.0%	0.0%	20.1%
HST2618: Granulated slag "slag sand" from the manufacture of iron or steel	R3.5	45.5%	11.6%	0.0%	80.0%	1.8%	1.6%
HST7110: Platinum, incl. palladium, rhodium, iridium, osmium and ruthenium, unwrought or in semi-manufactured	R175.1	9.2%	9.5%	19.1%	30.7%	21.6%	1.2%
HST7108: Gold, incl. gold plated with platinum, unwrought or not further worked than semi-manufactured ...	R110.6	4.5%	0.0%	0.0%	0.0%	0.0%	0.0%
HST7102: Diamonds, whether or not worked, but not mounted or set (excluding unmounted stones for pick-up ...	R22.4	4.1%	30.1%	0.0%	2.4%	0.0%	0.0%
HST7118: Coin, incl. legal tender (excluding medals, jewellery made from coins, collectors' items of ...	R10.7	125.8%	93.2%	0.1%	3.5%	0.0%	0.0%
HST7112: Waste and scrap of precious metal or of metal clad with precious metal; other waste and scrap ...	R5.0	5.6%	90.9%	4.3%	0.9%	2.2%	0.0%

Food and agricultural products							
HST2204: Wine of fresh grapes, incl. fortified wines; grape must, partly fermented and of an actual ...	R10.2	6.4%	38.6%	20.7%	6.5%	1.4%	2.9%
HST1701: Cane or beet sugar and chemically pure sucrose, in solid form	R6.0	11.4%	12.9%	4.4%	6.1%	2.3%	4.1%
HST2009: Fruit juices, incl. grape must, and vegetable juices, unfermented, not containing added spirit, ...	R4.1	6.8%	26.7%	0.3%	9.4%	6.2%	0.4%
HST0805: Citrus fruit, fresh or dried	R27.9	16.9%	33.1%	9.6%	5.3%	0.9%	5.6%
HST0806: Grapes, fresh or dried	R10.5	13.5%	47.6%	20.9%	2.0%	0.1%	1.8%
HST0808: Apples, pears and quinces, fresh	R9.8	12.3%	14.5%	13.8%	0.2%	0.0%	1.0%
HST1005: Maize or corn	R9.2	3.8%	1.9%	0.0%	0.0%	5.0%	0.2%
HST0802: Other nuts, fresh or dried, whether or not shelled or peeled (excluding coconuts, Brazil nuts ...	R6.1	22.1%	15.9%	1.0%	14.3%	2.6%	35.7%
HST5101: Wool, neither carded nor combed	R4.2	8.1%	20.9%	0.0%	0.2%	0.0%	76.2%
Transport equipment, automotives & auto parts and components							
HST8421: Centrifuges, incl. centrifugal dryers (excluding those for isotope separation); filtering or ...	R29.0	3.8%	60.2%	7.5%	11.5%	1.1%	0.3%
HST8703: Motor cars and other motor vehicles principally designed for the transport of persons, incl. ...	R75.2	9.2%	61.6%	4.4%	12.1%	6.3%	0.0%
HST8704: Motor vehicles for the transport of goods, incl. chassis with engine and cab	R45.2	12.7%	48.6%	15.5%	0.1%	0.1%	0.0%
HST8708: Parts and accessories for tractors, motor vehicles for the transport of ten or more persons, ...	R8.6	0.5%	30.9%	2.2%	5.7%	1.1%	0.6%
Products of the chemical or allied industries							
HST3902: Polymers of propylene or of other olefins, in primary forms	R5.7	6.1%	16.9%	2.6%	0.1%	0.0%	7.7%
HST4011: New pneumatic tyres, of rubber	R3.6	2.2%	19.4%	3.5%	6.3%	3.8%	1.8%
HST3815: Reaction initiators, reaction accelerators and catalytic preparations, n.e.s. (excluding rubber ...	R10.8	42.7%	60.4%	3.8%	19.5%	0.4%	11.4%
HST2901: Acyclic hydrocarbons	R6.7	7.7%	21.0%	0.0%	22.0%	4.1%	0.6%
HST2833: Sulphates; alums; peroxosulphates "persulphates"	R5.4	35.6%	92.4%	0.0%	0.0%	0.0%	1.8%
HST3808: Insecticides, rodenticides, fungicides, herbicides, anti-sprouting products and plant-growth ...	R5.1	14.0%	2.3%	1.5%	0.8%	0.0%	0.7%
HST3004: Medicaments consisting of mixed or unmixed products for therapeutic or prophylactic uses, put ...	R4.5	6.9%	9.8%	1.2%	6.5%	0.0%	0.0%
HST3304: Beauty or make-up preparations and preparations for the care of the skin, incl. sunscreen or ...	R4.4	13.5%	13.0%	6.6%	9.1%	5.7%	1.3%
Pulp of wood, paper							
HST4702: Chemical wood pulp, dissolving grades	R11.1	7.9%	7.1%	3.4%	2.9%	1.3%	34.1%
Total	**100%**						
Share of top 50 exports in total exports	***74.6%***						

Source: Data on carbon intensity collected from OECD Stats (https://stats.oecd.org/#). Data on trade gathered from TradeMap (https://www.trademap.org/).

Notes: 1. Centrifuges have been moved from machinery and equipment to transport equipment; 2. Unclassified commodities (HST9999) amounting to 4.6 billion rands of exports have been omitted from the table; 3. Share of exports (2020) is calculated as South Africa's exports to country X as a proportion of South Africa's total exports to the world; 4. Authors are solely responsible for calculations