CHAPTER 3

Technology-intensive supply chains and industries: Resetting African markets and businesses for mobility and scale

As stated in chapter 1 of this report, companies are increasingly seeking to diversify their supply chains to reduce their exposure to global shocks and disruptions, such as the COVID-19 pandemic or the war in Ukraine. Such a perspective for supply chain diversification provides opportunities for economies in Africa to position themselves as geographic alternatives. Some industries are more exposed to supply chain shocks than others – this is closely related to their global value chain activity. Figure 19 illustrates that supply chain linkages, measured by imported foreign value added embedded in exports, showing that several areas – computers and electronics, the automotive industry, electrical equipment, machinery and equipment, and chemicals and pharmaceutical products – provide deep supply chain integration.

In countries of the Organisation for Economic Co-operation and Development, refined petroleum products and basic metals depend the most on imported value added. The high trade intensity in these sectors offers scope for regional and global specialization in the production of the various components. The largest growth in supply chain activity is observed for motor vehicles, where foreign value added increased almost fivefold between 2000 and 2018 (on average across non-member countries of the Organisation for Economic Co-operation and Development) (see figure 19).

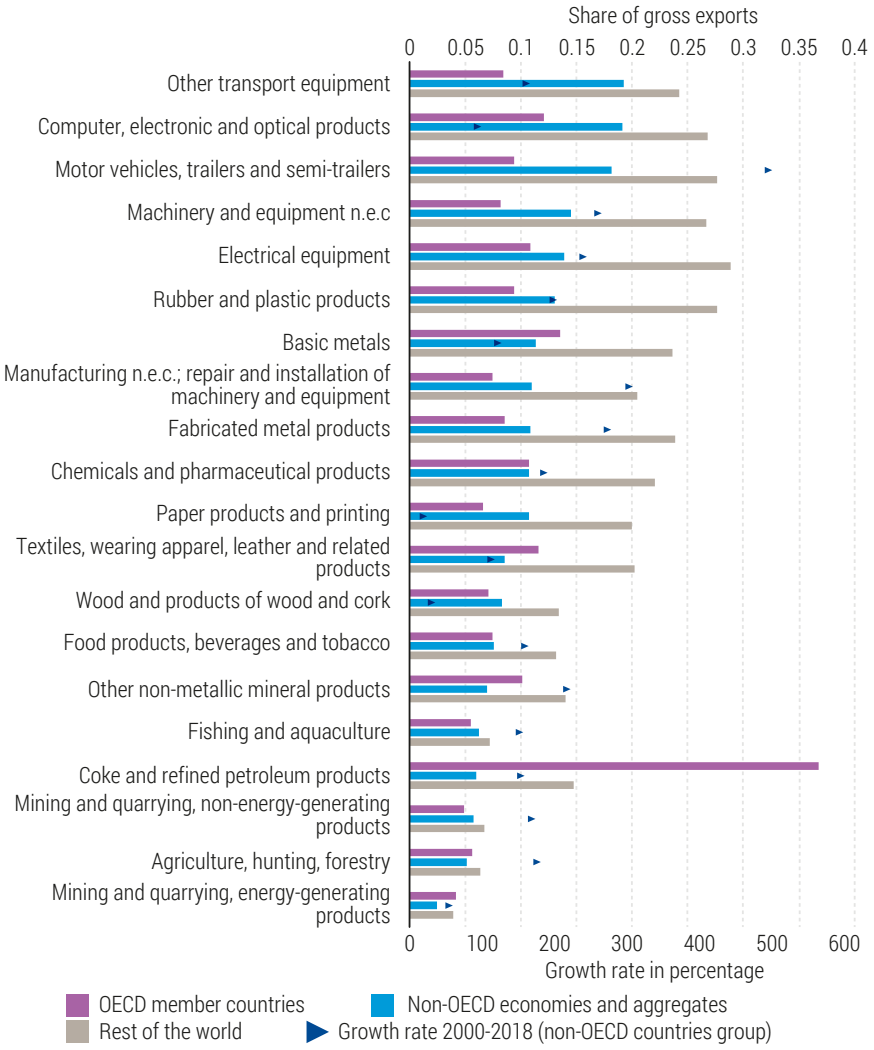
The strong supply chain activity of these medium- and high-technology manufacturing areas suggests some opportunities for production in manufacturing subsectors that propel growth and development. Recent studies support this assertion by showing that technology-intensive manufacturing can be less emissions intensive than low-technology manufacturing (Altenburg and Assman, 2017; Avenyo and Tregenna, 2022; Zhang, 2012), therefore implying its suitability for sustainable resource-based industrialization. In addition, the evolving scenario of digitizing and greening supply chains, as discussed in chapter 2, provides a window of opportunity for African countries to reposition and integrate into the medium and downstream segments of several supply chains. Specifically, the natural capital of Africa – including opportunity for abundant renewable energy generation and endowments of rare earth metals and critical minerals – can play a pivotal role in attracting investments into productive capacities and promoting the development of domestic and regional linkages.

This chapter discusses the possible paths for the integration of Africa into medium- and high-technology intensive supply chains by using its natural endowments. Global supply chain integration can pave the way for industrialization and sustainable development in the region. Further, the chapter examines the automotive and electronics industries, with special emphasis on mobile telephone supply chains and renewable energy technology (prospects of solar panels). It also explores the medical device and pharmaceutical supply chains. It is vital to understand the relevance and sustainability of the mining industry as a driver of these high-technology supply chains.

Apart from vertical linkages to the supply chain, the chapter will highlight the importance of horizontal integration to leverage increasing demand in Africa and reduce its vulnerability to external shocks. Given its limited manufacturing base and the benefits it stands to gain from greater value addition to its abundant resources, the greater part of the discussion focuses on production and procurement. Nevertheless, aspects of distribution, transport and logistics are considered elements of supply chain integration that can attract investment in production capacities.

Figure 19

Foreign value added embedded in exports by domestic industry and country group



Source: UNCTAD calculations, based on data from the trade in value added database (Organisation for Economic Co-operation and Development and World Trade Organization).
Abbreviations: n.e.c., not elsewhere classified; OECD, Organisation for Economic Co-operation and Development.

3.1 Automotive industry: Leveraging increasing vehicle demand for regional supply chain localization

The automotive industry is one of the most dynamic and complex supply chains and as a result, highly vulnerable to supply chain disruptions. The automotive industry is undergoing far-reaching changes and challenges that can also present opportunities for African countries, owing to supply chain disruptions associated with the COVID-19 pandemic (see chapter 2, box 2), as well as technological advancements, such as connected, autonomous, shared and electric vehicles. For instance, data from the International Organization of Motor Vehicle Manufacturers indicate that the pandemic caused a 16 per cent decline in global vehicle production due to lockdown measures that affected not only assembly but production and shipping of necessary components. Although Africa experienced the sharpest decline (28 per cent) between 2019 and 2020, it also recovered more strongly with an increase of 16 per cent in 2021, compared with the world average of 3 per cent. The robust recovery is also indicative of the recent demand and supply growth of the automotive industry.

In Africa, several factors will provide the momentum to achieve a deeper integration in the automotive supply chain: the abundance of critical metals required for this technology-intensive supply chain, young and fast-growing consumer markets and recent disruptions in the automotive supply chain (see chapter 2). Recent trends in the African automotive industry and the strategic position of African countries in the regional supply chain will be discussed further in this section.

3.1.1 Promising trends for the integration of Africa into the automotive supply chain

Although the registration and sale of new vehicles in Africa is low (1.14 million in 2021), compared with Asia (42.66 million), Europe (16.87 million) and the Americas (22.00 million), projections show that vehicle demand in Africa could reach 10 million vehicles a year by 2030 (Black and McLennan, 2016). Similarly, demand for second-hand vehicles, which dominate many markets in Africa, has also increased. In 2021, Africa accounted for about 40 per cent of the world's used vehicles imports, which represent close to 85 per cent of the total vehicle fleet in Africa (see www.mordorintelligence.com/industry-reports/middle-east-and-africa-used-car-market).

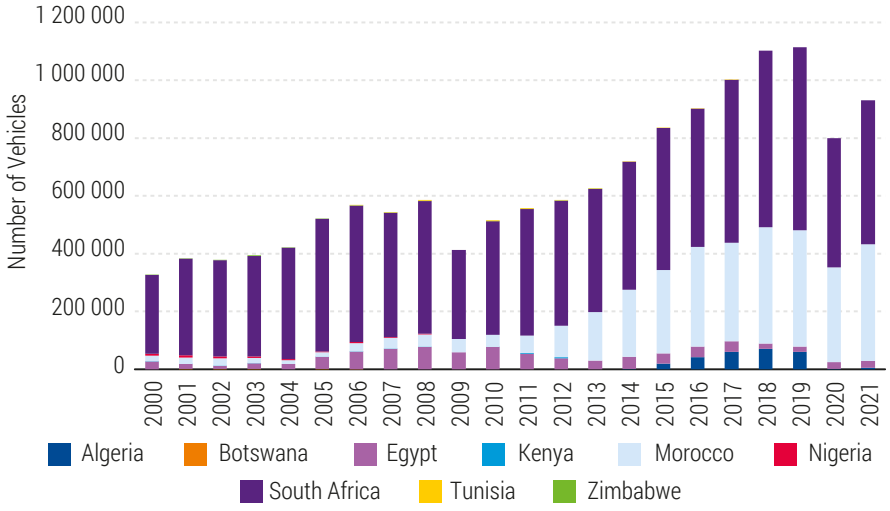
Despite global challenges and concentration in the sector, the production of vehicles is flourishing on the continent. According to International Organization of Motor Vehicle Manufacturers statistics, production increased from 328,749 units in 2000 to

931,056 units in 2021 (see www.oica.net). However, the automotive sector in Africa is still in its early stages, accounting for only 1.2 per cent of global output. Total production units in other regions range from 46.7 million in Asia and the Pacific, to 16.3 million in Europe and 16.2 million in the Americas.

In 2019, the production of vehicles in Africa was dominated by South Africa (631,921 units) and Morocco (403,218 units), followed by Algeria (60,012 units) and Egypt (18,500 units) (figure 20).[16] In Morocco, a sharp increase in vehicle production, from 42,066 in 2010 to 403,007 in 2021, was driven by large investments by original equipment manufacturers from Europe.[17] The geographical location of Morocco, its stable political and macroeconomic environment, investment in infrastructure and a national framework to support the automotive industry were factors that made these investments attractive (see box 6).

Figure 20

Vehicle production trends in Africa, 2000–2021



Source: UNCTAD calculations, based on International Organization of Motor Vehicle Manufacturers statistics (www.oica.net/production-statistics/).

Note: Units of vehicles produced in Botswana, Kenya, Tunisia and Zimbabwe were relatively small compared to other reported countries, at less than 3,000 units of vehicles per year during the covered period 2000-2021.

[16] In Algeria, output virtually came to a halt in 2020 due to plant closures resulting from new regulations and a corruption controversy (Agarwal et al., 2022).

[17] In the automotive industry, original equipment manufacturers are the original producers and suppliers of devices or components used in the manufacture of vehicles.

The case of Nigeria, however, differs from that of Morocco. Nigeria used to have a vibrant automotive industry in the 1970s and 1980s, with a production of 149,000 units per annum. Six automobile manufacturers were present on the local market (Leyland, Mercedes-Benz, National Trucks, Peugeot, Steyr and Volkswagen). However, macroeconomic challenges stemming from the 1981 global oil price shock, subsequent recessions and local currency depreciations, led to substantial reductions in the industry's output. To improve on the 2013 National Automotive Industry Development Plan, Nigeria recently announced the adoption of a new plan covering the period 2023–2033. In 2023, Nigeria attracted investment in the automotive industry through a joint venture between Dangote Industries (Nigeria) and Sinotruck (China), raising assembly capacity to 10,000 units (Business Insider Africa, 2023).

Box 6

Morocco: An exemplary domestic automotive industry

Since 1957, the automotive industry in Morocco has evolved from the assembly of vehicles (*Société marocaine de constructions automobiles*) to their production. In 2021, 403,007 units were manufactured, with exports valued at $8.3 billion, $3.4 billion of which were final vehicle exports. Approximately 220,000 jobs were created in the sector, and a burgeoning components network of more than 230 tier 1 and 2 suppliers was set up. This represents a local integration rate of 60 per cent. The country is now positioned as a production platform with the entry of several groups, for example, German Motor Distributors, Renault, Snop (parts and components supplier), Stellantis Sumitomo Electric Wiring Systems (technical array of systems and components) and Yazaki (the world's largest manufacturer of wiring harnesses).

Manufacturing is moving towards more complex components with high value added, such as engine manufacturing, engineering, and research and development. Morocco also produces about 40,000–50,000 electric vehicles per year. However, since the domestic registration of new vehicles is low (175,435 units in 2021; see www.oica.net), the assembly of vehicles is oriented towards the European market. For example, Renault, which has the largest assembly plant with a capacity of 400,000 units, exports most of its production. The Citroën *Ami*, made in Kenitra, Morocco, was the most widely sold vehicle in Spain in 2022. In December 2022, X-Electric Vehicle of China, known commonly as XEV, announced plans to produce electric cars in Morocco for the Italian market.

Various factors have enabled Morocco to attract multinational companies and support local content: investment in infrastructure (domestic and international connectivity); the creation of

six special economic zones, in which investors receive tax exemptions and other incentives; and its proximity to Europe. Domestic industrial policies and plans, such as the Industrial Acceleration Plan 2014–2020, have fostered the automotive industry ecosystem and have seen the advent of industrial parks and the automotive cities of Kenitra and Tangier, Morocco. The integration of Morocco into the global economy, facilitated by the signing of various free trade agreements, has also made the country a lucrative investment location. In addition, engineering and research and development capacities have grown with the establishment of a regional technical centre by Stellantis and the first automobile testing centre in Africa, which will allow Morocco to be autonomous in terms of the validation and homologation of parts and vehicles. Systematic investment in education and skill development, digitization and supplier development programmes has also enabled the emergence of Moroccan know-how in the manufacturing of parts and components.

Morocco aims to produce one million cars per year by 2025 and achieve a local integration rate of 80 per cent. In 2020, it already had an installed annual capacity of 700,000 vehicles. The aforementioned government initiatives and plans are designed to enhance local integration, scale up industrial activities, upgrade operations across the value chain, improve levels of technology and knowledge transfer, and diversify export markets. Addressing these challenges could also help increase the participation of small and medium-sized domestic enterprises in the assembly phase, which remains limited. To maintain growth and foster supply chain sustainability, vehicle export destinations should be diversified, and the automotive industry in Morocco should target the African parts market that is dominated by second-hand vehicles. In November 2022, Stellantis announced a $300 million investment in its manufacturing facility to double productive capacity to 400,000 units and serve the Middle East and Africa market.

Source: UNCTAD, based on Auktor 2022; *Automotive News Europe*, 2022; bladi.net, 2023; Economic Commission for Africa, 2018; Hahn and Vidican-Auktor, 2017; Japan International Cooperation Agency and Boston Consulting Group, 2022; Kasraoui, 2022; Khattabi, 2023; Naji, 2020.

Other African countries, such as Angola, Ethiopia, Ghana, Kenya, Lesotho, Mozambique and Namibia, have relatively small-scale assembly operations, mostly semi-knock-down kits with minimal value added. Semi-knock-down kit assembly can be done in low volumes but entails minor assembly with virtually no value addition or employment. The absence of a thriving parts and components industry on the continent is a main challenge to reaping more inclusive benefits in terms of employment creation and the

participation of more African countries in the supply chain. However, there is potential to build new capabilities through targeted investment. According to projections for 2025, vehicle bodies will represent the largest global automotive market at $190 billion, followed by electronics ($154 billion), and wheels and tyres ($144 billion) (Deloitte, 2021). Increasing the production of these parts and components provides a major opportunity for African countries to take advantage of and transform available raw materials, such as aluminium, copper and rubber.

Exports of vehicles from Africa to the world have also risen steadily since 2003. Between 2018 and 2020, the two leading African exporters of vehicles were South Africa ($9.2 billion) and Morocco ($3.4 billion).

While Europe is the main destination of vehicle exports from Africa for the transport of persons, mainly driven by exports from Morocco, other types of vehicles, especially vehicles for the transport of goods, such as trucks and tractors, boast a bigger share of intra-Africa exports (30 per cent and 97 per cent, respectively). The majority of intra-African exports of vehicles are trucks (57 per cent), followed by passenger cars (25 per cent). Owing to the potential of the African Continental Free Trade Area to boost trade within the continent, it is likely that there will be a growing demand for regional production and the supply of tractors, buses and vehicles for the transport of goods.

While production facilities of the final vehicle product are generally located in close proximity to the customer, owing to logistical factors such as transport costs, the manufacturing and supply of vehicle parts and components have become more global. Nevertheless, the dependence of the automotive industry on the efficient supply of parts and components often motivates tier 1 (automotive parts and components) suppliers to set up their locations close to large assembling operations, particularly because of high transportation costs. Further up the supply chain, tier 2 (non-automotive parts and components) and tier 3 (raw and semi-raw materials) supplies are also inputs to a range of other industries and hence, less dependent on a particular original equipment manufacturer in the supply chain.

3.1.2 The largest benefits for Africa lie in regional supply chains: A supply chain mapping approach

This section applies a value chain mapping exercise to potentially identify the positions of individual countries in regional supply chains (box 7). The focus on such chains is

motivated by the momentum of the African Continental Free Trade Area and the need to achieve greater local and regional value addition. This is important not only to promote industrial growth on the continent but also to meet rules of origin requirements in the various continental trade agreements. The section is also devoted to opportunities in the electric vehicle supply chain.

Box 7

Methodology for identifying regional supply chain opportunities

To position African countries in the global and regional automotive supply chain and to identify feasible opportunities for upgrading, the chapter applies an approach using a mix of sources and existing literature (see sources below).

The methodology uses an input–output table from Canada for the year 2020, as its disaggregation into 234 subsectors allows a detailed identification of potential forward and backward linkages. After matching with the codes of the International Standard Industrial Classification and the Harmonized Commodity Description and Coding System (HS), relevant activities and products are identified along the supply chain.

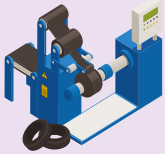
Identified products are classified under tier 1 (automotive parts and systems), tier 2 (non-automotive parts and system) and tier 3 (semi- and raw materials) suppliers. The mapping of these codes by tier, supporting services and technological equipment is shown in the next figure. Yet, the matching is not perfect, as not all identified inputs are necessarily used in the automotive supply chain, especially in tiers 2 and 3. For instance, all iron and steel subgroups are presented, although not all steel grades can be used by assemblers. Desktop research completes the identification of additional inputs and raw materials used especially in electric vehicle manufacturing. In total, 93 product groups are identified at the HS six-digit level and 28 product groups at the four-digit level, 15 service categories at the International Standard Industrial Classification four-digit level and nine HS product groups as necessary industrial equipment/technology.

It is necessary to identify potential product diversification opportunities by supplementing the input–output approach with the product space method (for an application of the automotive industry in South Africa, see Bam et al., 2021 and for the steel industry, Bam and De Bruyne, 2019). The proposed analysis in this report is the first to apply the input–output product space method to the whole continent. Feasible product diversification opportunities at the HS six-digit level are identified, based on findings from UNCTAD (2022d).

Mapping of automotive parts and components, supporting services and equipment

TIER 1

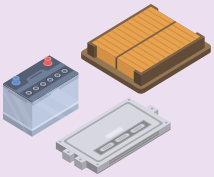
Automotive parts and systems



- Tyres
- Motors, engines and pumps
- Chassis and vehicle bodies
- Electronic parts
- Air/gas equipment and fillters
- Seats and interior parts

TIER 2

Non-automotive grade parts



- Batteries
- Wiring
- Semiconductors
- Textile fabrics and hides
- Glass and mirrors
- Plastics and rubber
- Lamps
- Paints and varnishes
- Filter blocks
- Aluminium parts
- Gaskets and joints
- Bearings, screws and bolts

TIER 3

Raw and semi-raw materials

- Aluminium, Iron and copper ore
- Cotton, raw silk, hides and skins
- Plastics in primary forms
- Unrefined/unwrought metals
- Natural and synthetic rubber
- Primary form/semi-finished metals
- Copper and aluminum plates
- Natural sands

Materials used also in electrical vehicles:

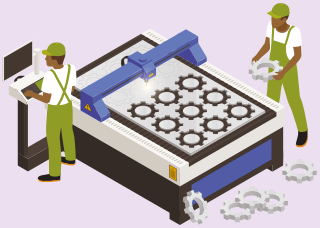
- Natural graphite
- Cobalt, Manganese and Nikel ores and concentrates
- Alkali or alkaline-earth metals
- Copper ore

Supporting Services

- Wholesale (equipment, materials and waste or scrap)
- Transportation
- Financial and related services
- Sales, maintenance and repair
- Legal services (IP, contracts, etc.)
- Administrative services
- Logistics
- Utilities and communications

Supporting equipment

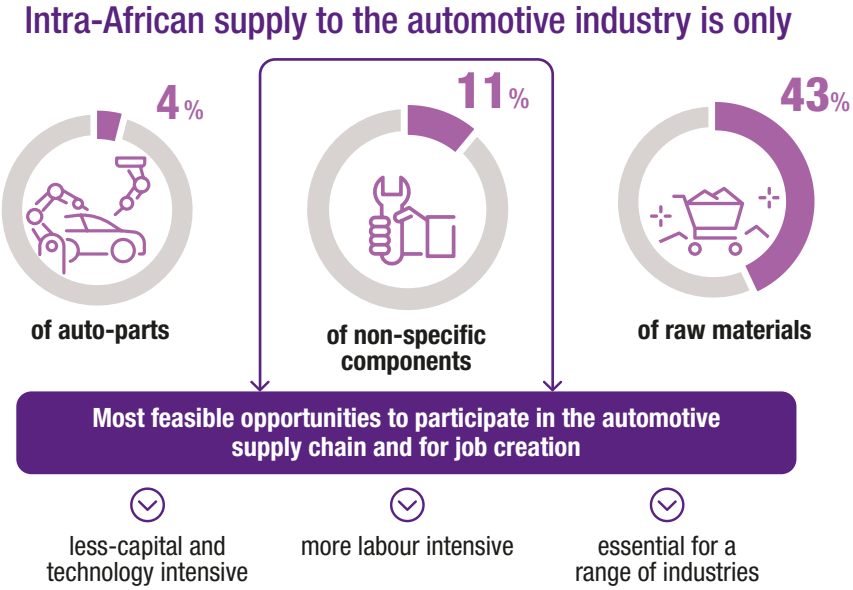
- Die-stamping machines
- Lifting and handling machinery
- Machinery for treating metal
- Hand tools
- Industrial robots
- Metal-rolling mills



Sources: UNCTAD, with input from Bam et al., 2021.

Export data at the HS 1992 six-digit level for 2018–2020 are obtained from the United Nations Comtrade database. Due to data limitations in recent years, only 43 African countries were included (data were not available for 2018–2020 for the following countries: Algeria, Chad, Djibouti, Eritrea, Equatorial Guinea, Gabon, Guinea, Guinea-Bissau, Liberia, Somalia and South Sudan).

Sources: UNCTAD, based on Bam et al., 2021; Bam and De Bruyne, 2019; El Mataoui et al., 2019; International Trade Centre, 2022; UNCTAD, 2022d.



Although almost all of the 43 African countries for which recent export data were available appear to have some export capacity in either tiers 1, 2 or 3, the share of intra-African inputs to the automotive industry is limited, especially in tiers 1 and 2. As shown in table 4, African imports account for only 4 per cent of total imports of automotive parts and systems owing to the limited productive capacity in Africa; this is largely driven by upper-middle income countries.[18] Most of these products are

[18] To align the analysis with that of chapter 2, African countries are classified by income as per the World Bank classification.

Table 4

Import supply to Africa, by region and tier category, 2018–2020 average exports

	Tier 1		Tier 2		Traditional tier 3		Tier 3 (including electric vehicle materials)	
	Value in million dollars	Share (percentage)	Value in million dollars	Share (percentage)	Value in million dollars	Share (percentage)	Value in million dollars	Share (percentage)
Africa	**887.37**	***4***	**817.13**	***11***	**5,684.09**	***38***	**7,171.99**	***43***
Low-income countries	49.68	*0*	34.02	*0*	4,127.55	*28*	4,890.86	*29*
Lower-middle-income countries	144.56	*1*	316.25	*4*	429.84	*3*	956.08	*6*
Upper-middle-income countries	693.11	*3*	466.84	*6*	1,126.70	*8*	1,325.047	*8*
Americas	**1,401.15**	***6***	**222.64**	***3***	**1,395.75**	***9***	**1,622.11**	***10***
Asia	**10,911.06**	***47***	**3,973.35**	***53***	**4,244.77**	***29***	**4,248.99**	***25***
Europe	**9,266.04**	***40***	**2,500.51**	***33***	**3,450.76**	***23***	**3,592.95**	***22***
Oceania	**46.79**	***0***	**18.73**	***0***	**28.98**	***0***	**28.98**	***0***

Source: UNCTAD calculations, based on data from the United Nations Comtrade database.

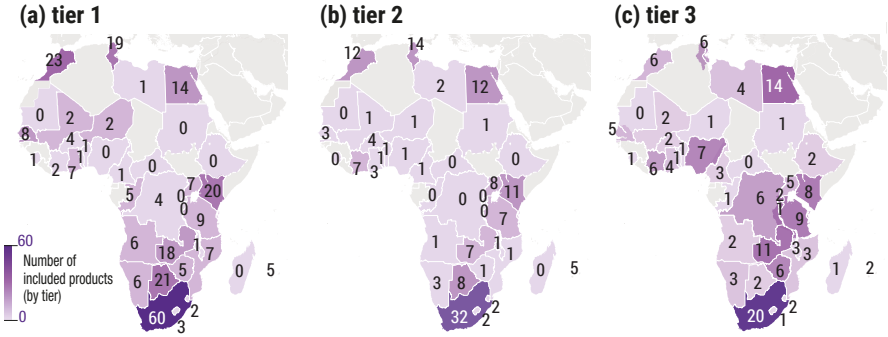
exported by South Africa, especially to member countries of the Southern African Development Community, where the bulk of components exports are destined for the aftersales market (that is, repair and maintenance of cars), including for instance, tyres, engine parts and transmission shafts (African Union Commission and Organisation for Economic Co-operation and Development, 2022). In tier 2, the share of import supply of African countries to other African countries is 11 per cent, and low-middle-income African countries also have a larger share. Finally, Africa is the largest supplier of raw materials that are required for vehicle production. Based on the report's research findings (box 7), 38 per cent of tier-3 imports are from Africa. This share increases to 43 per cent when considering new materials (electric vehicle materials) used to make electric vehicles. Africa holds about 19 per cent of the global metal reserves required for building electric vehicles.

Figure 21 maps the number of products, with a minimum value of $100,000, that African countries exported to the continent between 2018 and 2020. It illustrates the dominant role of South Africa, especially in tier 1. About 75 per cent of the countries covered (31 out of 43) exported at least one product in tier 1 (figure 21(a)).[19] Thirty

[19] In reality, the number of countries exporting a certain product based on actual production is probably much lower. However, re-exports as part of export are poorly reported, which poses a key limitation on the chapter's export data-based analysis.

Figure 21

Number of countries currently supplying inputs, including new electric vehicle materials, to African markets: (a) tier 1, (b) tier 2 and (c) tier 3, 2018–2020 average



Source: UNCTAD, based on data from the United Nations Comtrade database.
Note: Tier 1 includes 63 product groups; tier 2, 34 product groups; and tier 3, 26 product groups.

The boundaries and names shown and the designations used on these maps do not imply official endorsement or acceptance by the United Nations.

African countries exported at least one product in tier 2 (figure 21(b)), and 36 African countries exported at least one product in tier 3 (figure 21(c)). The identification of feasible export diversification opportunities suggests that through targeted investment in capabilities, African countries can fill recent gaps in the regional supply chain. For instance, the report's analysis (box 7) shows that Uganda, which currently exports eight products in tier 2, could diversify into 25 other products in tier 2, given that tier 2 products require similar capabilities and could be realized through relatively small jumps in the product space.

Parts and components are not only relevant for final vehicle assembly but increasingly for the aftersales market. In Ghana, for example, the aftersales market has an estimated revenue of $500–$575 million per year, which is approximately twice as much as revenue stemming from new vehicles sales. The supply of parts, in particular, tyres, but also batteries, brake pads and filters, accounts for about 60–65 per cent of the aftersales market in Ghana, while the costs of repair services contribute about 25–30 per cent. About 70–80 per cent of the aftersales market in that country is run by informal small and medium-sized enterprises. Given the constraints faced by the informal sector, such as limited access to finance and higher costs of importing parts and components, tackling such barriers could trigger greater expansion in the automotive industry in Ghana.

Similarly, in Nigeria, the aftersales market is estimated at $1.5 billion (2020) of which tyres contribute the largest part (Japan International Cooperation Agency and Boston Consulting Group, 2022).

Despite the abundance of rubber in Africa, more than 85 per cent of tyres are still being imported from China, thus suggesting little existing local capacity for rubber processing and tyre export. For instance, in Côte d'Ivoire, the largest supplier of natural rubber in Africa, rubber output was estimated at 1.1 million tons in 2021, a 16 per cent increase from 2020, while the country's processing capacity was estimated at only 664,000 tons. Despite planned investment in rubber-processing plants (for example, by Saph), local processing and capacity remains low, compared with the output of natural rubber (Reuters, 2021). Considering the example of car seats, intra-African export mapping prepared for this report shows that Africa can provide almost all the inputs necessary to produce car seats. Leather, for example, could be made by Kenya, Namibia and the Niger; textiles fabrics, by Botswana, Côte d'Ivoire and Eswatini; bolts and screws, by Côte d'Ivoire, Egypt, Kenya, Mauritius, Morocco, Senegal, the United Republic of Tanzania and Zambia; and propylene polymers, by Burkina Faso, Côte d'Ivoire, Egypt, Eswatini, Kenya, Morocco, the Niger, Nigeria and Senegal. On the whole, however, inputs continue to be largely imported from other countries (International Trade Centre, 2022).

Given the increasing adoption of automation and technology, such as artificial intelligence, machine learning and additive manufacturing, in the automotive production and supply chain processes, the potential impact of the automotive industry on employment creation in Africa is worth exploring in more detail. According to statistics from the data portal of the United Nations Industrial Development Organization (see https://stat.unido.org), Morocco experienced an increase of 147 per cent in the number of people employed in the manufacture of motor vehicles between 2000 and 2016, as well as a growing share of industrial employment, from 2 per cent to 4 per cent during the same period. Similarly, between 2000 and 2019, the number of employees in South Africa rose by 14 per cent, and the share of total industrial employment increased from 8 per cent in 2010 to 9.7 per cent in 2019. Input–output table analysis suggests that assembly manufacturing contributes only 1 per cent to total value added of the sector's output. The majority is contributed by automotive parts and components (for example, metal stamping contributes 11 per cent value addition; engine manufacturing, 9 per cent; and seat manufacturing, 7 per cent). In addition, non-automotive sectors that contribute high value addition are plastic manufacturing, financial services and transport services. While it is difficult to estimate the multiplier effects for African countries, this analysis gives an idea of the additional employment

created in more labour-intensive sectors, such as seat manufacturing, including the leather and textile industry. In South Africa, for example, final assembly employment grew slightly from 28,100 people in 2010 to 30,000 people in 2017 and 33,000 people in 2022, owing principally to technological progress and the increased use of robots. Employment figures in the automotive component manufacturing sector increased form 65,000 people in 2010 and 80,000 in 2017 to 83,000 in 2022 (Mashilo, 2019; National Association of Automobile Manufacturers of South Africa, 2023). In addition, employment along the entire auto supply chain in South Africa is estimated at more than one million people, implying a multiplier effect of 14 jobs upstream and downstream in the supply chain (National Association of Automobile Manufacturers of South Africa, 2023).

In focus: How the electric vehicle trend leads to new opportunities for African countries

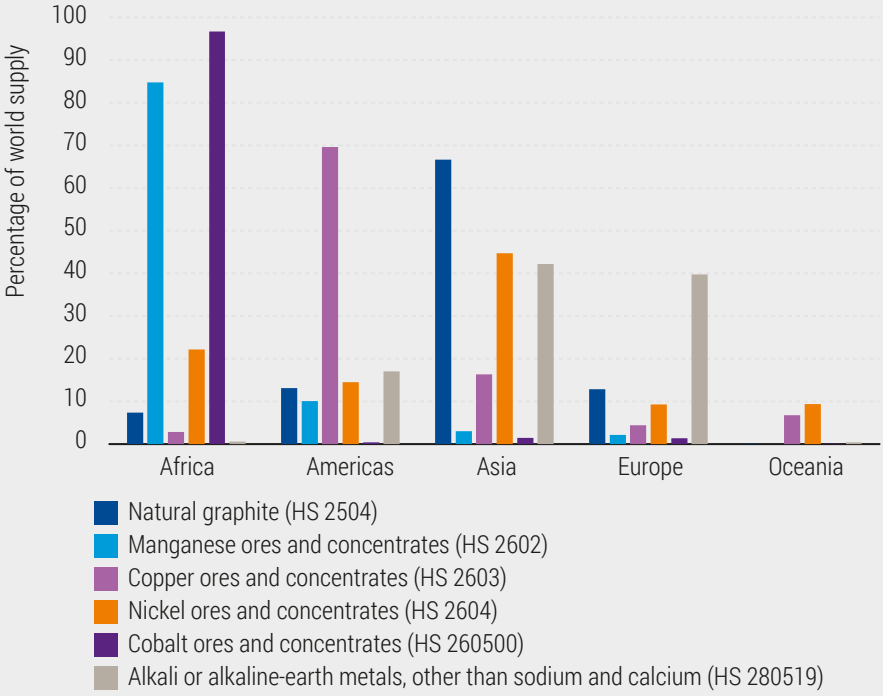
To achieve the climate goals, the share of electric vehicles, alongside the electrification of buses, freight trucks and commercial vehicles, must reach 40 per cent by 2030 (International Energy Agency, 2022). In 2020, electric car sales worldwide climbed by 40 per cent to about 3 million, attaining a market share of over 4 per cent. According to the International Energy Agency (2022a), an electric car requires about six times the mineral inputs of a conventional car: One electric car requires 53 kg of copper, 13.3 kg of cobalt, 8.9 kg of lithium, 39.9 kg of nickel, 24.5 kg of manganese, 66.3 kg of graphite and 0.5 kg of rare earth metals. By contrast, a conventional car requires 22.3 kg of copper and 11.2 kg of manganese. In a sustainable development scenario, demand for these minerals will rise (International Energy Agency, 2022a).[20] At the time of writing, nine African countries hold a significant share of world exports in these critical materials.[21] Africa accounts for 97 per cent of world cobalt exports, and 84 per cent of world manganese exports (see figure 22).

[20] The International Energy Agency (2022a) estimates that the demand for minerals will increase sharply between 2020 and 2040. The demand for nickel will multiply 41 times to 3,300 kilotons; for cobalt, 21 times; for lithium, 43 times; for copper, 28 times, reaching about 3,000 kilotons for new electric vehicle sales; and for graphite, 25 times (from 140 kilotons in 2020 to over 3,500 kilotons in 2040).

[21] These countries are Botswana (copper), the Democratic Republic of the Congo (manganese, copper, cobalt), Egypt (natural graphite), Morocco (manganese), Mozambique (natural graphite), South Africa (manganese, copper), the United Republic of Tanzania (natural graphite), Zambia (manganese, copper, cobalt) and Zimbabwe (nickel).

Figure 22

Share of critical electric vehicle materials in world exports, by region, 2018–2022 average



Source: UNCTAD calculations, based on data from the United Nations Comtrade database.
Note: HS code 280519 (alkali or alkaline-earth metals) includes lithium.

African countries abounding in electric vehicle minerals are exploring opportunities on how best to exploit their resources to attract downstream investment in battery production. South Africa launched a programme to develop a lithium battery value chain in 2011, focusing on cell and battery manufacturing, testing and validation and recycling. South Africa holds vast resources of some of the minerals that go into that supply chain, including manganese, cobalt, iron ore, nickel and titanium, and it has lithium reserves (Mordor Intelligence, 2022; Trade

and Industrial Policy Strategies, 2021).[22] To date, however, there is little value addition and transformation of minerals to battery grade in the country. Only manganese and aluminium are refined to battery grade, while nickel and lithium are in the pipeline. Downstream of the supply chain, some battery manufacturing activities depend on imported battery cells (Trade and Industrial Policy Strategies, 2021).

Paradoxically, proximity to the mineral source is only a minor factor in the location of downstream industries, since processed metals are relatively easy and inexpensive to transport (Trade and Industrial Policy Strategies, 2021). However, transport cost is still relevant for products closer to the raw extraction stage, especially in its raw form. For instance, to reduce the weight of exports, Zambia has succeeded in developing copper smelting and refining copper from concentrates to cathodes. Conversely, there is only a small manufacturing sector that uses this copper, despite the emerging demand for the mineral in battery production.

With regard to the demand side in battery production, all vehicle assemblers in Africa are multinational companies with their own core technology and research and development at headquarters or other plants outside the continent. Despite the encouraging trend in electric vehicle demand, the demand in Africa for electric vehicles is simply not sufficient to make new battery cell production plans competitive without securing demand from the major companies. It is estimated that by 2040, at current production capacity and demand, only 20 per cent of vehicles in Africa will be electric vehicles (Conzade et al., 2022). Necessary investment in battery or electric vehicle production plants is also costly and requires private–private and public–private partnerships. Electric vehicle producers could serve more aptly as alternative capital providers to accelerate projects, while gaining supply security.

Given the fast-developing battery supply chain in terms of technology advancements and research and development spending, African countries need to actively make deals with car companies and producers of car batteries to acquire technology and knowledge and engage local processing and go beyond the supplying of raw materials. Moreover, national incentives and regional cooperation should allow local African car companies to source first and provide local companies with the competitive advantage of localization or local content.[23] As they access such market advantages domestically and gain skills and technologies

[22] Minerals used in the cell and battery supply chain include lithium, cobalt, manganese, nickel, graphite, bauxite, copper, iron, phosphate rock and titanium.

[23] Local companies can have a competitive advantage if they are granted preferential access to local resources. Such measures can take the form of a specific percentage of mining products that must be used or transformed locally. However, investment in infrastructure is needed to reduce local transportation costs and promote the provision of services that facilitate local market linkages (Korinek and Ramdoo, 2017).

from their relationships with leading multinational companies, local African companies will also be in a better position to encourage battery assembly. This entails the improvement of battery management systems, which include a range of parts and components, such as chargers, battery packaging and harnessing. Enlarging development capacity in recycling or supplying the circular economy is also necessary. Recycling will be a key feature of automakers and electric vehicle battery manufacturing operations by transforming current supply chains into a circular economy. This will enable firms to reuse the critical raw materials in electric vehicle batteries at low cost, which will be important for automakers as electric vehicle adoption grows exponentially throughout the world over the next decade or so (see section 3.5.2).

3.1.3 Realizing industry potential by achieving scale and mobility

Despite the growing exports of parts and components in some African countries, the intra-African supply of tier 1 and tier 2 components remains small. The minimum production capacity of an automotive assembly plant is estimated at 80,000 vehicles per year, requiring an investment of $200 million (Natsuda and Thoburn, 2021). Hence, to reach greater scale and mobility in the automotive industry, it is necessary to institute favourable policies and incentives to localize supply chains, including parts and components, distribution and aftersales goods and services.

Promoting national demand for locally produced vehicles and parts and components

First, new vehicle-financing mechanisms should be developed. Current financing options come with high interest rates and strict repayment terms. In Ghana, for example, interest rates can be as high as 30 per cent, resulting in only 5 per cent of new car sales being financed by banks (*Automotive News Europe, 2020*). The Government announced a vehicle-financing scheme in 2023, an initiative that would allow more Africans to purchase new, locally manufactured cars (Ghana News Agency, 2023).

Second, the regulation of used-car imports and minimum standard requirements on imported parts and components aimed at promoting the aftersales market should be harmonized further. The lack of harmonization of standards makes it difficult for parts and components suppliers to produce at sufficiently large scale. There are about 1,432 international automotive standards worldwide. The African Organization for Standardization expects that some 250 standards relating to basic components

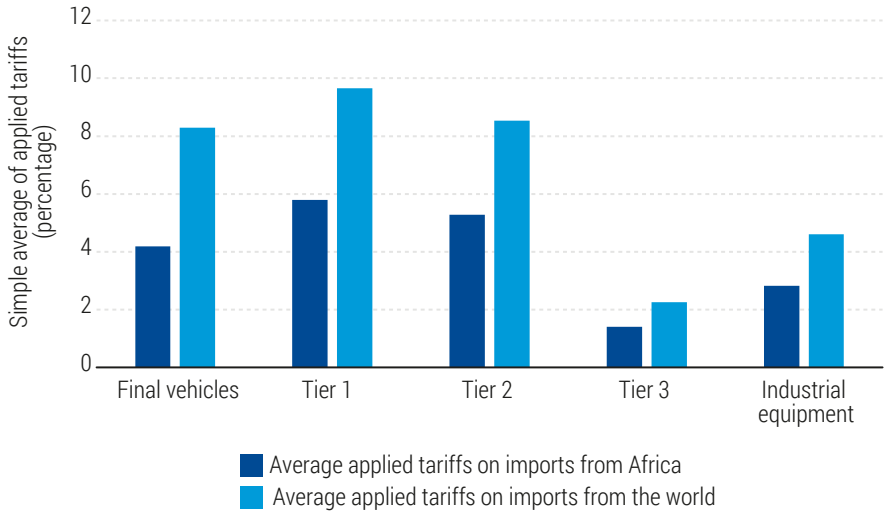
and replacement parts will need to be harmonized in Africa to keep vehicles safe and operational (African Export–Import Bank, 2021).

Third, regional integration efforts should favour locally produced vehicles and components. As shown in figure 23, tariffs on imports from Africa are currently more advantageous than imports from outside the continent. However, to benefit from tariff advantages under the African Continental Free Trade Area (see International Trade Centre and UNCTAD, 2021 and UNCTAD, 2021b), rules of origin must be certified. Rules of origin are an important instrument to promote regional value addition. The African Continental Free Trade Area rules of origin are being negotiated on a sector-by-sector basis, resulting in product-specific origin rules (Agarwal et al., 2022; Trade Law Centre, 2021). As of January 2023, negotiations relating to the automotive sector had not yet been concluded.

Fourth, the regional supply chain can be leveraged to reduce overall costs. For that, intraregional supply chain efficiency can be enhanced through better regional logistical coordination facilitated by custom harmonization, single-window arrangements and simplified regional sourcing of parts and components.

Figure 23

Tariff advantage for sourcing inputs from Africa



Source: UNCTAD calculations, based on the World Integrated Trade Solution database.
Note: Final vehicles include HS 8701–8705; tiers 1, 2 and 3 and industrial equipment discussed in box 7.

Realizing scale through the identification of niche areas and clustering production

Clearly, not all African countries have the same opportunities, depending on their initial capabilities and their location. For instance, countries and close neighbours can use existing assembly hubs to target the production of heavier and model-specific parts, such as engines, transmissions, seats and other car interior parts. Countries farther away, which is true for most African countries, can still benefit from the automotive industry through the production of lighter, less complex and more labour-intensive components to take advantage of economies of scale and low labour costs (for example, tyres and wire harnesses). The niche areas in countries and regions should be identified through detailed research in the future, fostered through bilateral and multilateral cooperation.

Due to high operating costs, lack of electricity and infrastructure, African countries find it difficult to compete with imports from China and India. To overcome this challenge, clustering production through special economic zones and industrial parks can be a viable option. For instance, under an agreement between the Democratic Republic of the Congo and Zambia to build a battery supply chain, the creation of a special economic zone for batteries was officially confirmed in March 2023 (United Nations, Economic Commission for Africa, 2023).

Attracting investment and facilitating financing options

Foreign investments are necessary for companies to acquire the technological capabilities required to manufacture more sophisticated automotive components (Wuttke, 2022). The experiences of Morocco (box 6) and Thailand (see box 8) highlight the importance of original equipment manufacturers and parts and component manufacturers in the growth of local industry. Strong domestic demand (Thailand), favourable locations (Morocco), infrastructure investments (Morocco and Thailand) and supportive trade and industrial policies, such as local content requirements and tax incentives, are key incentives to investment in the automotive supply chain. Other performance requirements to increase local benefits for the economy include requirements relating to local training, joint ventures, technology transfer and exports. Such requirements, for instance to transfer technology or research and development findings, should, however, be coupled with national efforts to build national innovation systems that include the promotion of education and training to be effective. For instance, export-related performance requirements have been widely used in various countries, for example, Chile (diversification of resource-based exports), in Costa Rica (example of a leading manufacturer of microprocessors and chipsets attracting exports of medical devices), Malaysia (electronic components industry), South Africa (automotive industry) and Mexico and Thailand (export-focused investment in the automotive industry) (UNCTAD, 2003; UNCTAD, 2022d; World Economic Forum, 2016).

Other localization policies include requirements relating to the transfer of knowledge and technology to local firms and employment and skills creation. Yet, according to UNCTAD research, the driving force behind export performance is supply capacity; and those requirements alone would suffice to build domestic production capabilities and localize more parts of the supply chain (UNCTAD, 2003; UNCTAD, 2005).

To avoid national strategies that would impede economies of scale and necessary investments, a regionally harmonized policy aimed at attracting large-scale investment in both assembly and parts and components and facilitating public procurement would be advantageous.

Access to financing remains one of the key challenges of African companies as they strive to integrate supply chains. Therefore, to support financing of industrial players in the automotive supply chain, African Export–Import Bank and the African Association of Automotive Manufacturers have entered into a memorandum of understanding in which the African Export–Import Bank has committed to providing $1 billion (African Continental Free Trade Area, 2023). Possible areas of intervention include direct financing, project financing, guarantees and equity financing. Additional financing instruments, such as supply chain financing, is discussed further in chapter 4.

Box 8

Automotive industrial policies: Lessons from Thailand in the context of the Association of Southeast Asian Nations

In 2019, 4.2 million vehicles were manufactured in countries of the Association of Southeast Asian Nations. Thailand produced about 2 million units; Indonesia, 1.2 million units; and Malaysia, 700,000 units. Most of the vehicles are sold in the countries of origin, except for Thailand, which exports 52 per cent of production, 14 per cent of which is exported to countries in the region. The Philippines and Viet Nam have some small-scale production and contribute substantially to component supply, for which there is strong demand within the countries of the Association of Southeast Asian Nations. Thailand has emerged as the main automotive hub of the region, ranking as the third-largest exporter of automotive products in Asia after Japan and the Republic of Korea. Countries in the region have supported that growth. For example, in 2014, 82 per cent of households owned a car. Under the Industrial Promotion Act (1960), Thailand established the first vehicle assembly firm in 1961. High tariffs and restrictions on imports of completely built units, as well as fiscal incentives, promoted import substitution. Once local assembly was set up,

localization policies, such as local content requirements, targeted an increase in local content ratios. Since then, there has been a gradual shift to greater localization of auto parts production. In 1991, the first research and development centre in the country was founded.

The success of the automotive industry in Thailand can be attributed to firm-level costs and market advantages. The local auto industry benefited from large-scale export-oriented investments, which were facilitated by a favourable physical environment, substantial infrastructure investments and supportive trade and industrial policies. Further, Thailand had used local content requirements widely as an industrial policy to promote local sourcing before joining the World Trade Organization. As local content requirements are not allowed under article 2.1 of the Agreement on Trade-related Investment Measures of the World Trade Organization, they were abolished after Thailand joined the Organization. The liberalization of inputs through the abolition of local content requirements has even increased local content, combined with the relaxation of restrictions on the foreign entry of input suppliers. Even if Thailand does not have its own brand, the country added value to the production process by localizing research and development activities through multinational original equipment manufacturers. Thailand is indeed an important example of a country that uses existing supply chain facilities to achieve further value addition for domestic industries.

While Thailand has benefited from investments from Japan, the creation of a full regional supply chain still remains difficult, as other members of the Association of Southeast Asian Nations (Indonesia and Malaysia) are also developing their local car brands. Yet, regional integration under the Association has supported the industry's growth. The Industrial Cooperation Scheme (1996) of the Association grants preferential tariff rates if two companies set up an industrial cooperation arrangement. The products included under that arrangement must have at least 40 per cent content from countries of the Association. It is considered by some authors that this policy (although only used by Toyota and its major supplier Denso in Thailand), coupled with regional integration and increased regional demand, leveraged additional foreign investments and helped create a regional market that was large enough to achieve economies of scale. In Thailand, the automotive industry is supplied at small but increasing scale through imports of wiring harnesses and seat covers from Cambodia, the Lao People's Democratic Republic and Myanmar. Although the experience of building a regional supply chain of components is encouraging, it took decades of efforts and growth before culminating in a regional production of 3 million units per year.

Source: UNCTAD, based on Barnes et al., 2017; Ing and Losari, 2022; Japan International Cooperation Agency and Boston Consulting Group, 2022; Markowitz and Black, 2019; Natsuda and Thoburn, 2021.

3.2 Electronics: Favourable prospects for mobile telephones supply chains

The electronics industry is an interesting case, owing to the pivotal role of information and communications technology and digital technologies in industrialization (United Nations Industrial Development Organization, 2019). Between 2019 and 2021, the consumer electronics industry attracted 20 greenfield investment projects to the continent. According to the fDi Markets database, the largest investment was announced by Bosch ($70 million), concerning plans to build a home appliance factory in Egypt. Recent decisions by industry leaders to diversify their supply chains in response to major disruptions can be promising for the growing mobile telephone market in Africa. For example, Apple and its key tier 1 supplier, Foxconn, decided to make a major investment in India in 2023 (*Financial Times,* 2023).

3.2.1 Promising demand and supply trends in the mobile telephone sector

Africa has a diverse mobile telephone market. Mobile cellular subscriptions are far in excess of 100 per 100 inhabitants in 13 out of 44 countries considered, namely Botswana, Cabo Verde, Côte d'Ivoire, Gabon, the Gambia, Ghana, Kenya, Mali, Mauritius, Namibia, Senegal, Seychelles and South Africa. Twenty countries have subscription rates per 100 inhabitants below the African average of 82.3, while 12 others have less than 50 subscriptions per 100 inhabitants (International Telecommunication Union, 2021).

Africa has seen tremendous growth in the mobile telephone industry in recent years, with a rising demand for affordable and reliable smartphones. Stiff competition on the continent is taking place in the middle-range smartphone and budget-telephone brackets (on average below $200). The leading competitor is Transsion, a Chinese-led group that started in Africa in 2006 and focuses on emerging markets outside China. Its brand Tecno is the single biggest smartphone seller in Africa. For instance, since 2011, every telephone Transsion sells in Ethiopia has been assembled at its facilities in the suburbs of Addis Ababa (Dahir, 2018).

Several African companies have emerged, offering a range of products that cater to the needs of consumers in different countries. For example, in South Africa, Onyx was launched in 2017 as a start-up. Onyx imports its components from overseas and builds its smartphones from the circuit board on up in South Africa (Scott, 2017). In the

Republic of the Congo, a local startup, VMK, opened a plant in Brazzaville in 2015 to produce smartphones, including its Elikia brand (van Zyl, 2013). In 2018, Mara Group, a pan-African multisectoral business services company opened a smartphone factory in Rwanda. These encouraging trends provide a strong case for relocating parts of the electronics supply chain to Africa and producing locally components of mobile telephones that are largely imported from outside the continent (World Economic Forum, 2019). In 2021, the mobile technology company Africell and Industry Five, a global smart manufacturing vendor, collaborated to develop assembling facilities for mobile telephones in the Democratic Republic of the Congo. The factory in Kinshasa is equipped with modular and mobile workstations, and workers are trained to reach quality standards and handle proprietary handsets. In addition, workers are assisted by state-of-the art robots. Performance testing and quality checks are also to be carried out at the facility (Barton, 2021; Boyadzhieva, 2021).

3.2.2 Leveraging horizontal and vertical linkages to localize supply chains

The mobile telephone global supply chain – from product conception to after-use – includes the following segments: input materials, hardware manufacturing, software development, sales and marketing, mobile service and use, and after-use (Lee et al., 2013). Indeed, the supply chain combines hardware and software, and it has spread worldwide as the integration of developing countries has deepened.

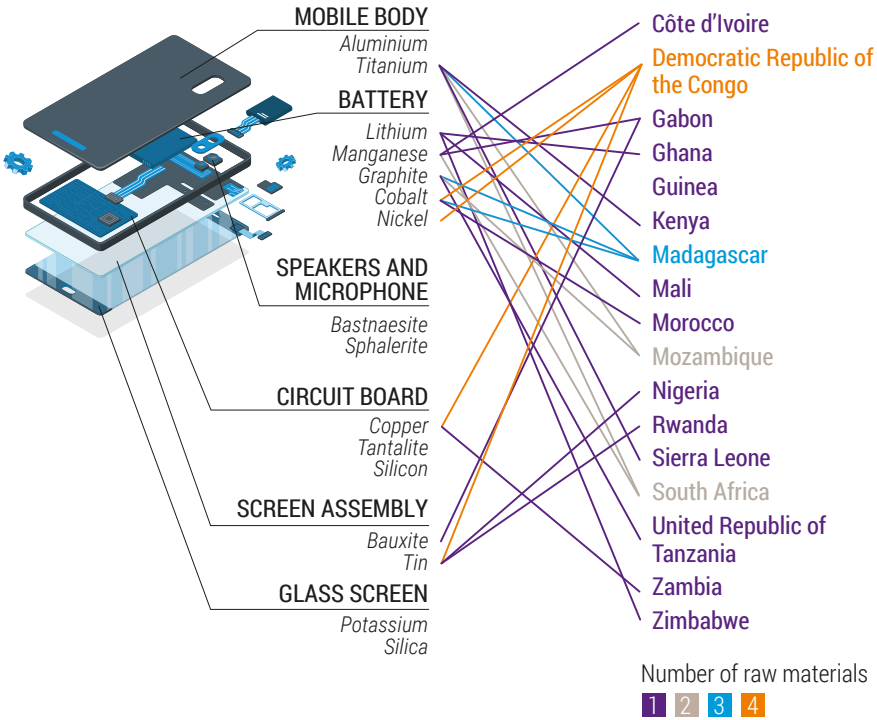
With regard to the first step in the supply chain, sourcing raw material, the composition of telephones varies, depending on the brand. Figure 24 provides a breakdown of the raw materials used to make mobile telephones in African countries.

Overall cobalt demand from the lithium-ion industry is expected to grow 1.5 times between 2021 and 2030. Nickel, used in cathodes, should see demand rise to about 1.4 million metric tons by 2030, five times that of 2021. Annual copper demand from the industry is estimated to reach 3.9 million tons by 2030, and aluminium, 3.1 million tons. In addition, the market size for both metals is projected to grow sixfold during that period (Bloomberg Finance, 2021; Daly, 2021).

In the next steps in the supply chain, manufacturers transform the raw material into a usable material or component. Component suppliers are numerous and will often specialize in particular parts that may be used by many different brands. A smartphone, for example, can contain components from more than 200 suppliers. Components include circuit boards, antennae, liquid crystal displays, microphones, speakers,

Figure 24

Raw materials used in the manufacture of mobile telephones



Sources: UNCTAD, based on data from United States Geological Survey.

batteries and cameras (Webb, 2022). Once the components have been sourced from manufacturers, they are taken to a factory for assembly. To make lithium-ion batteries for mobile telephones, sulphates for cobalt, nickel and manganese are combined to form precursor cathode-active materials (precursors). These are then combined with graphite, an anode material, to form battery cells. Owing to the abundance of cobalt, nickel and manganese, the production of precursors provides a good manufacturing opportunity for the Democratic Republic of the Congo and for building a regional supply chain (Bloomberg Finance, 2021; UNCTAD, 2022c).

In focus: Opportunities for regional supply chains in precursor development

According to Bloomberg Finance (2021), annual lithium-battery demand is expected to grow rapidly, topping 4.5 terawatt hours annually by 2035. Meeting this demand requires unprecedented but achievable increases in metals, precursor and cell production. In April 2021, a leading battery manufacturer, Contemporary Amperex Technology, announced it would acquire a 25 per cent stake in China Molybdenum in the Kisanfu mine in the Democratic Republic of the Congo. The Democratic Republic of the Congo, which produced about 70 per cent of global cobalt supply in 2020, unveiled plans to produce battery precursors (Daly, 2021). The production of cathode precursors (nickel-manganese-cobalt oxide), a main ingredient in the manufacture of battery components, can contribute to the country's higher value capture in the battery industry and integration into the electric vehicle supply chain. The investment in the country's infrastructure to support industrialization totals $58 billion (roads, ports and electrical infrastructure) (Argus Media, 2022; Eyewitness News, 2021). According to a feasibility study requested by the United Nations, Economic Commission for Africa, building a 10,000-ton precursor facility in the Democratic Republic of the Congo could cost $39 million, which is three times cheaper than what it would cost for a similar plant in the United States. The precursor plant would need to procure nickel from the Ambatovy mine in Madagascar and then ship it through the United Republic of Tanzania or Mozambique into the country. It is assumed that manganese will be procured from Gabon and transported into the Democratic Republic of the Congo. The Democratic Republic of the Congo has manganese deposits that could benefit from the potential demand stemming from the precursor plant, should it be established (Bloomberg Finance, 2021).

The potential of the Democratic Republic of the Congo for cathode precursor development could also contribute to increased mobile phone production capacities in the country by enabling companies to develop further stages upstream in the electronics supply chain. There are already some positive signs. For example, in 2021, Africell undertook a record-breaking network expansion in the country, extending infrastructure and launching telecommunications services in several new provinces. At the same time, Industry Five began diversifying facilities in the Democratic Republic of the Congo to focus on tablets, laptops, high-performance servers and data storage solutions. The company expects to generate up to 5,000 skilled technical jobs in the country by 2026 (Barton, 2021; Boyadzhieva, 2021).

The Agreement Establishing the African Continental Free Trade Area and other existing subregional free trade agreements offer opportunities for regional value and supply chains development for battery minerals and electric vehicles. For instance, the Regional Mining Vision of the Southern African Development Community proposes a mechanism to redistribute benefits

across countries, for example, a common fund that pays the additional cost of transporting inputs from countries with weak transport infrastructure to where the activity is taking place (Natural Resource Governance Institute, 2022). By locating domestic strategies as part of regional industrial development plans, African countries could exert more bargaining power and realize greater cluster and scale economies.

3.3 Renewable energy technology: Prospects for solar panels supply chains

3.3.1 Importance of solar photovoltaic supply chains

The International Renewable Energy Agency and African Development Bank (2022) estimate the solar photovoltaic potential of Africa at 7,900 gigawatts, underscoring the continent's unique untapped potential for solar generation. Yet, despite the continent's enormous potential to generate energy from renewable sources and its urgent need to bring modern energy services to the millions of people still lacking access to electricity – about 43 per cent of the total population – only 2 per cent ($60 billion) of the $2.8 trillion invested in renewable energy worldwide between 2000 and 2020 went to Africa (International Renewable Energy Agency and African Development Bank, 2022). According to the African Union (2022), there remains an annual financing gap of $90 billion for the region to meet energy-access and transition goals. However, during this period, renewables investment in Africa grew at an average growth rate of 96 per cent per year, compared with 15 per cent in Asia–Oceania (excluding China and India) and 7 per cent globally (International Renewable Energy Agency and African Development Bank (2022). Between 2019 and 2021, 134 greenfield investment projects in Africa were announced, 86 of which were made in solar energy, representing a total value of $10.8 billion. Of these investments, 98 per cent were made in solar energy for the supply of electricity, the rest, in maintenance and services, and sales and marketing. According to the fDi Markets database, most of these investments were announced by France and Norway as the source countries. The bulk of investments in renewables was driven by structured procurement programmes, such as the Renewable Energy Independent Power Producer Procurement Programme in South Africa (South Africa, 2023). In 2020, 57 per cent of total installed solar generation capacity in Africa (10,431 megawatts) was

generated by South Africa, followed by Egypt (16 per cent) and Morocco (7 per cent) (International Renewable Energy Agency and African Development Bank, 2022).

Traditionally reliant on hydropower, Africa is increasingly turning to solar photovoltaics to bolster energy security and support rapid economic growth in a sustainable manner. Economies of scale and continuous innovation throughout the supply chain have enabled steep reductions in manufacturing costs at every step of the production process. As a result, module prices declined by more than 80 per cent over the last decade, making solar photovoltaics the most affordable electricity-generation technology in many parts of the world. With regard to solar energy production, most African countries have a competitive advantage, given their high horizontal irradiance levels (International Renewable Energy Agency, 2016). Solar thermal investments, mainly in concentrated solar power, were made in Morocco and South Africa, primarily between 2012 and 2018. For instance, the Noor-Ouarzazate concentrated solar power complex in Morocco is the world's largest (World Bank, 2016).

Nevertheless, Morocco heavily depends on foreign sources for over 97 per cent of its energy. Harnessing energy from the sun will free Morocco from the volatility of import costs and create the potential for green energy exports to neighbouring countries. An ambitious national energy strategy, issued by the Government of Morocco in 2009, drove a strong expansion of wind and solar energies over the following decade. By 2020, solar photovoltaic capacity in Morocco had increased sixteenfold, albeit from a low base, and wind, sixfold (Alami, 2021).

In addition, the Government of Morocco encouraged private sector investments by implementing a number of measures: increasing the installed capacity threshold of hydro projects, enabling renewable electricity producers to access electricity networks (low, medium, high and very high voltage) and allowing the sale of excess electricity from renewable sources to the national electricity and water utilities office of Morocco for facilities connected to high and very high voltage networks (World Bank, 2018). Morocco plans to increase renewables capacity to reach 52 per cent by 2030. This ambitious goal requires massive investment in solar power (solar panels and batteries) (International Energy Agency, 2019). Although several sources of critical minerals are available in the country for the manufacture of solar power components, these minerals continue to be largely imported.

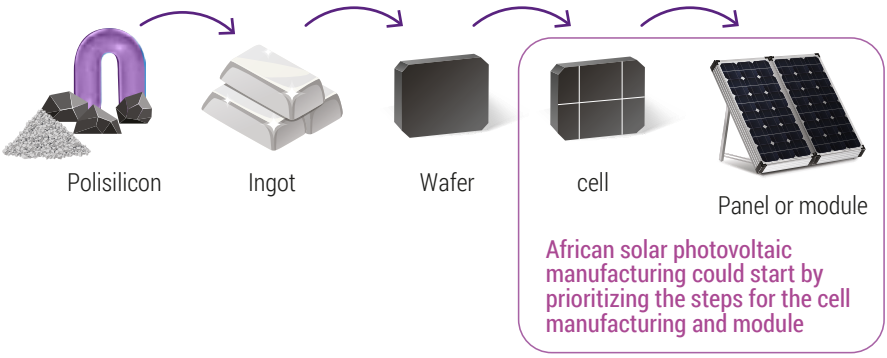
3.3.2 Diversification opportunities through the solar panel supply chain

Figure 25 illustrates the main stages in the manufacturing process for solar photovoltaic systems, including crystalline silicon and cadmium telluride systems, although they require different materials. In recent years, a major geographical shift has occurred in solar photovoltaic manufacturing capacity and production. Top solar panel manufacturers include Canadian Solar (Canada), First Solar (United States), Hanwha Q Cells (Republic of Korea), Jinko Solar (China), Sun Power (United States) and Trina Solar (China) (UNCTAD, 2023). China further strengthened its leading position as a manufacturer of wafers, cells and modules between 2010 and 2021, while its share of global polysilicon production capacity almost tripled. Today, the country's share in all manufacturing stages exceeds 80 per cent, more than double its 36 per cent share in global photovoltaic deployment.

The manufacture of the physical components of solar panels and solar storage relies on the combination of a variety of metals, metalloids, non-metallic minerals and polymers, with material needs differing across technologies and segments. Critical minerals and rare earth metals needed to make these components are aluminium, cadmium, copper, gallium, indium, lead, molybdenum, nickel, silicon, silver, selenium, tellurium, tin and zinc. These minerals are deployed at different stages of the solar photovoltaic value chain. International Energy Agency (2022b) estimates suggest that raw materials make up 35–50 per cent of the total cost of a solar photovoltaic module at 2021 prices.

Figure 25

Key stages of solar photovoltaic manufacturing



Source: UNCTAD.
Note: Production of solar photovoltaics is limited in Africa, with some initial opportunities materializing in Egypt, Morocco and South Africa, which are also countries with the strongest demand pull.

Capital requirements are a key consideration when companies consider investing in solar photovoltaic manufacturing and when policymakers design incentives to support businesses. High investment requirements for certain segments of the supply chain, in particular polysilicon, ingots and wafers, may increase risk and reduce project bankability (International Energy Agency, 2022b). According to recently commissioned plant and equipment price data, polysilicon plants and ingot and wafer factories require significantly more capital expenditure than cell- and module-manufacturing facilities (International Energy Agency, 2022b). For instance, owing to the considerable infrastructure investment requirements, estimated at $200–$400 million, greenfield polysilicon plants are not usually bankable for capacities of less than 10,000 megatons (about 3 gigawatts) (International Energy Agency, 2022b). Again, economies of scale are necessary to attract investment. According to the International Renewable Energy Agency (2016), the rapid growth in demand for solar home systems in the African market is being driven by lower system costs and innovative new business models. Yet, systems in Africa, typically under 100 watts, are tiny compared with their counterparts in the developed countries and require batteries and charge controllers to ensure stable output.

The concentrated solar power supply chain is even more complex, requiring a range of manufacturing steps. Here, the solar field represents the biggest value share of a concentrated solar power plant, largely due to labour costs rather than equipment costs, offering great local content potential. With regard to components, for example, ball joints, bearings and cables, most inputs are not specialized and are also used by other industries. This lends opportunities to already established companies for the lateral diversification of customers, and the joint demand for these components by several industries can make investments in productive capacities more lucrative. Assembly of the solar field, which must be performed at the site, especially offers potential for local manufacturing and installation services (box 9). With regard to more critical components, such as mirrors or heat exchangers, joint ventures with international market players are necessary to successfully adapt already existing production lines to meet needs and to achieve the necessary quality standards. Such adaptations require an initial investment in equipment and skilled workers. To justify this investment, a long and stable project pipeline is necessary.

Similarly to the early development of the automotive industry in Africa, which began with the assembly stage, African solar photovoltaic manufacturing could start by prioritizing the steps for the cell manufacturing and module assembly. This is feasible, owing to the less technological and chemical complexity of these processes, input–import and product-export opportunities, labour availability and existing solar panel assembly. Polysilicon and wafer production could be considered when other manufacturing steps

scale up, as production of these components is complex and requires high energy availability. In addition, for latecomers to the industry, opportunities further down the supply chain, such as project development, procurement and construction, should be considered (UNCTAD, 2023; box 9).

Box 9

Kenya: Participation of domestic companies in solar panel supply chains

Kenya has made great strides in securing access to electricity. According to World Bank world development indicators, the share of population with access to electricity increased from 19.2 per cent in 2010 to 71.4 per cent in 2020. Yet, this still lags behind the Government's goal, outlined in a national electrification strategy, to achieve universal access to electricity by 2022. Apart from the dominant energy sources (geothermal, representing 36 per cent of total energy sources, and hydropower, 36 per cent), solar power contributes 6 per cent to renewable energy capacity in Kenya. It therefore has promising potential to accelerate access to electricity, owing to its high horizontal irradiation levels.

Growth in the solar panel market provides a vast opportunity for the economy through private sector development and job creation. However, much of the market is held by internationally owned companies. A study by the United Nations Environment Programme assesses how the solar market can be better leveraged by domestic companies through supply chain linkages. Most domestic companies operate in services, offering project-development services, consultancy and after-sales services. A few companies also focus on product sale and distribution, often using informal sales and distribution channels, such as churches, local retail stores or supermarket chains. The participation of domestic companies is particularly high in the installation of commercial and industrial rooftop systems and mini-grids, as this market requires an in-depth engagement with customers and local skills, such as language and cultural knowledge.

Future expansion in industrial parks promises to grow business opportunities for domestic companies and employment in the solar panel supply chain. According to the United Nations, Economic Commission for Africa, for every megawatt of mini-grid capacity developed, approximately 800 full-time-equivalent job-years are created in Kenya. To maximize the benefits from increased investment for domestic employment and supply chain participation, the Government, as part of the Kenya Vision 2030 development plan, aims to promote local manufacturing through the Energy (Local Content) Regulations, 2014. However, skills development must be promoted. On one hand, this can be done through mentoring programmes

between large experienced and new domestic companies, and on the other, through organized training. For instance, Renewable Energy Solutions for Africa has established a microgrid academy with local partners to develop skills needed for the sector. Further, vocational training and university curricula in energy offer courses in business, finance and technology.

Source: UNCTAD, based on United Nations, Economic Commission for Africa, 2020a; International Renewable Energy Agency and African Development Bank, 2022; United Nations Development Programme, 2017; United Nations Environment Programme, 2021; World Bank, 2019c.

3.4 Building resilience and improving public health by strengthening supply chains in pharmaceuticals and medical devices

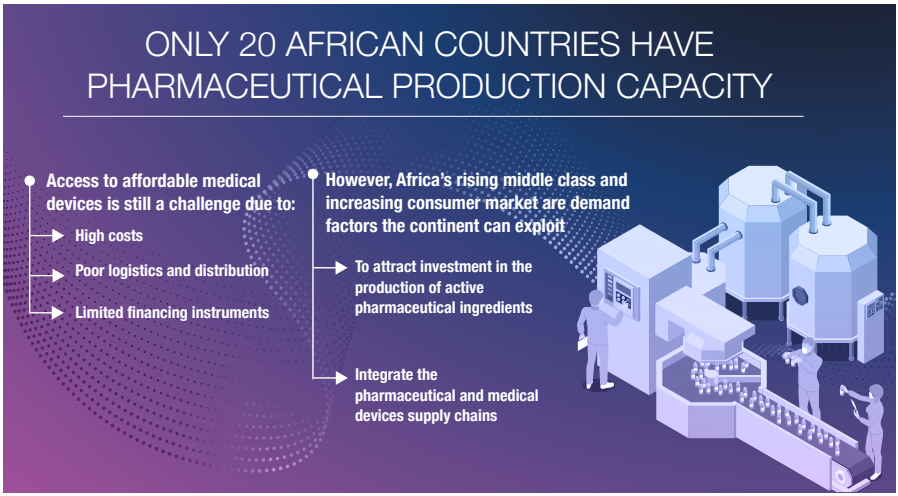
3.4.1 Promising trends in relocating health-care supply chains

As mentioned in chapter 1, medical devices and pharmaceuticals are among the top five supply chains most exposed to shocks and disruptions. Such exposure poses a considerable risk to African countries, which are heavily dependent on the import of pharmaceuticals goods and medical devices. However, the rising middle class and increasing consumer demand, as discussed in chapter 2, are assets the continent can exploit to attract horizontal investment, for example, by lead companies, and to diversify global supply chains in the pharmaceutical and medical device sectors.

In 2021, greenfield investments of $19 billion dollars were recorded in the global pharmaceutical industry, with an increase of 26 per cent over 2020 (UNCTAD, 2022d). In Africa, 28 greenfield investment projects were recorded between 2019 and 2021, mostly in the manufacturing of pharmaceutical products and related processes. The largest project recipients were Kenya ($108 million), Ethiopia ($98 million), Lesotho ($79 million), Morocco ($65 million), and Uganda ($64 million). For instance, a $47 million investment in Ethiopia by a firm based in India, Africure Pharmaceuticals, aimed to build manufacturing plants to better serve regional demand, while circumventing lengthy and costly shipping (Gupta, 2022). Similarly, an Egyptian-based company announced plans to invest $30 million to build a factory in the United Republic of Tanzania. In comparison, fewer investment projects (nine) were announced for the medical device sector between 2019 and 2021, including a $130 million investment in the United Republic of

Tanzania by a producer of medical devices from the Republic of Korea, providing access to a lucrative pharmaceutical market (fDi Markets database).

Despite these investments and the abundance of key materials that go into the manufacturing of medical products and devices, the pharmaceutical industry in Africa remains highly dependent on the import of pharmaceutical products. Between 2018 and 2020, the number of imported pharmaceuticals, accounting for 4 per cent of total imports, has risen steadily since 2006, to $13.6 billion. Most of these imports originated in India (20 per cent) and France (16 per cent); 4.5 per cent of these products were imported from Africa due to limited productive capacity. Imports are expected to increase further by 79 per cent by 2026 (International Trade Centre, 2022). Although total exports grew from $695 million in 2008–2010 to about $1.06 billion in 2018–2020, the billowing trade deficit in the pharmaceutical sector, which increased from minus $2.3 billion in 2000 to minus $12.5 billion in 2020, points to the need to set up more production facilities of pharmaceuticals in Africa to facilitate access to medicine.



According to 2021 figures, only 20 African countries have pharmaceutical production capacity; less than half (eight) produce about 80 per cent of total local output. The top eight producers and exporters are South Africa, Egypt, Kenya, Morocco, Tunisia, Mauritius, Ghana, and Uganda. Production focuses mostly on generic products, which represent about 70 per cent of total local production value (African Development Bank, 2022a). However, a large part of today's health challenges come from non-communicable

diseases, such as cardiovascular diseases, cancer and diabetes, cancer and diabetes, which may not respond effectively to generic products. For instance, unlike generic medicines, insulin, which is used to treat diabetes, is a biological product, for which creating an exact copy requires a complex, high-knowledge-intensive manufacturing process, generating unique challenges to supply chain development and resilience (Perrin et al., 2017). In addition, non-communicable diseases necessitate regular health examinations and medical devices for diagnosis and monitoring. However, while global trade in medical devices[24] more than tripled between 2000 and 2020, limited access to diagnostic equipment, especially in rural areas, is still a major constraint to public health. According to data from the United Nations Comtrade database, the trade deficit in the medical device sector amounted to minus $2.6 billion in 2018–2020, compared with minus $1.3 billion in 2008–2010, despite a slight increase in exports from $237 million in 2008–2010 to $404 million in 2018–2020. Based on growing GDP and population figures and increasing demand for medical devices, the negative trade balance is expected to rise further.

3.4.2 The non-communicable disease supply chain: A special case

Deaths from non-communicable diseases are on the rise in Africa, owing to weaknesses in prevention, diagnosis and care. For instance, data from the International Diabetes Federation show that the prevalence of diabetes in Africa has been increasing rapidly (see https://diabetesatlas.org/data/en/). In 2021, 44 million adults (20–70 years old) in 53 African countries were living with diabetes; this figure is expected to increase by 34 per cent to 59 million in 2030 and by 109 per cent to 91 million in 2045. Access to affordable insulin is limited, due to high prices and poor infrastructure (logistics and distribution). In addition, syringes and needles are needed, and patients require medical devices to monitor glucose levels regularly. According to the World Health Organization, only 46 per cent of people living with diabetes in Africa know their status. The end consumer, be it an institution or a patient, requires the technology, medicine and equipment to treat diabetes (World Health Organization, 2022). Therefore, two distinct supply chains are of relevance: First, the insulin supply chain in Egypt, and second, the supply chain of medical devices. The following section discusses the position of Egypt in the supply chain to deliver insulin to hospitals and patients, as well the procurement of necessary materials and production relating to medical devices.

[24] This section focuses on medium- and high-technology medical devices and provides an analysis of trends and supply chains of HS group 9018, instruments and appliances used in medical, surgical, dental or veterinary sciences.

In focus: Case study of the insulin supply chain in Egypt

Egypt has significantly boosted its export capacity in pharmaceuticals by 300 per cent since 2006, according to data from the United Nations Comtrade database. It is one of the biggest pharmaceutical importers and exporters on the continent, contributing to 17 per cent of total pharmaceutical imports and 24 per cent of total pharmaceutical exports. Based on estimates by the International Diabetes Federation (2021), Egypt has one of the highest estimated projections for the prevalence of diabetes, with 22 per cent of its adult population (20–79 years) at risk of being affected by diabetes in 2030. Access to quality diabetes care is thus an urgent consideration.

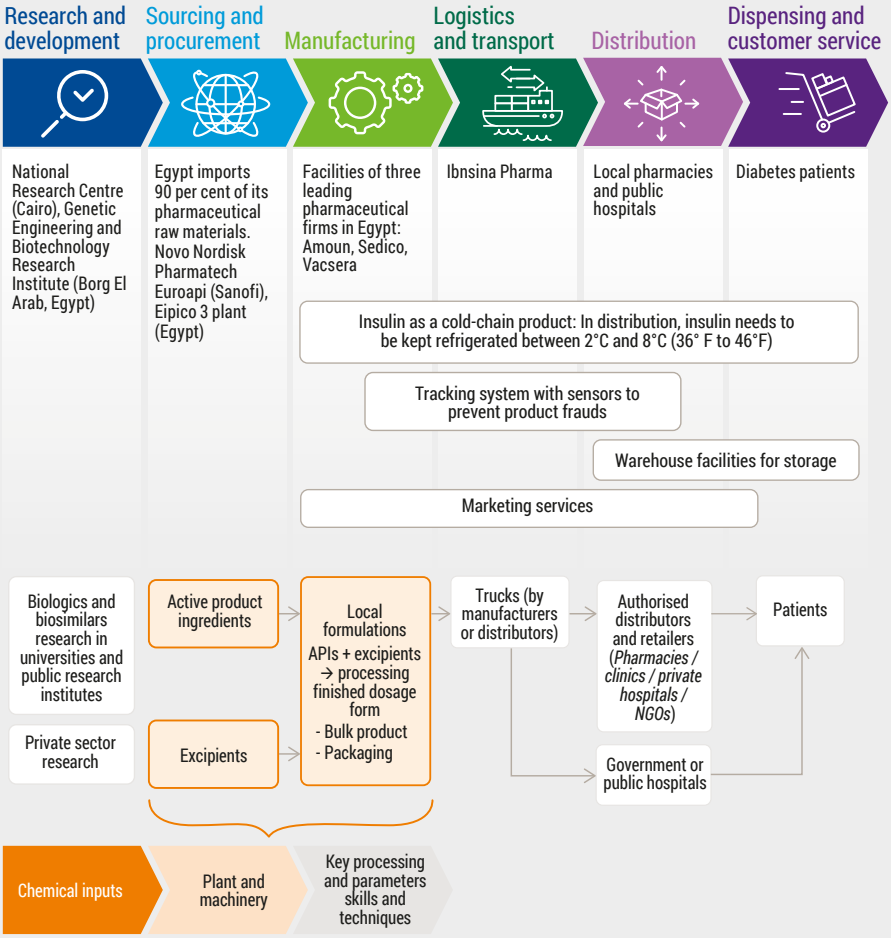
Insulin production is complex and highly concentrated globally. The three leading multinational insulin manufacturers, Novo Nordisk, Sanofi and Eli Lilly, controlled over 90 per cent of the insulin market in 2016. Until 2002, over 90 per cent of total insulin needs in Egypt were imported from Novo Nordisk (Abdelgafar et al., 2004). When the country suddenly faced an acute insulin shortage crisis in 2002, it cooperated with international partners from China and Europe. Vacsera rapidly started to produce recombinant human insulin locally, resulting in a two-year supply of insulin, substantial cost savings for the Government of Egypt and independence from foreign monopoly. Nevertheless, Egypt still imports about $103 million of insulin per year. Reported exports amount to $1.1 million, mainly to Iraq, the Sudan and Yemen.

With regard to the supply chain of insulin in Egypt (figure 26), pharmaceutical localization has occurred mainly at the manufacturing stage, with Amoun, Sedico and Vacsera as lead manufacturers. Logistics and distribution are also localized, largely through Ibnsina Pharma, the fastest growing pharmaceutical distributor in the country. Limited backward linkages to the manufacture of active pharmaceutical ingredients pose a challenge to the development of a competitive pharmaceutical industry. Egypt still imports 90 per cent of its pharmaceutical raw materials (Agiba, 2022; UNCTAD, 1999), mainly from China, India and the United States, which implies long transport routes. Overall, considering the growing importance of sophisticated biotechnology in pharmaceutical manufacturing, lowering cost through economies of scale, improved technology and stronger industrial production infrastructure are key to attracting the multinational companies to establish local production sites (Agiba, 2022; UNCTAD, 1999).

Certain upstream inputs, such as the active pharmaceutical ingredients of insulin that are biotechnologically processed, require deep sophistication and technological intensity in their production. Yet the trade deficit of Egypt in the production of active pharmaceutical ingredients is large (based on data from the United Nations Comtrade database). This suggests that even active pharmaceutical ingredients used in the manufacture of more common generic drugs,

Figure 26

Insulin supply chain in Egypt



Source: UNCTAD.

APIs: Active product ingredients
NGOs: Non-governmental organizations

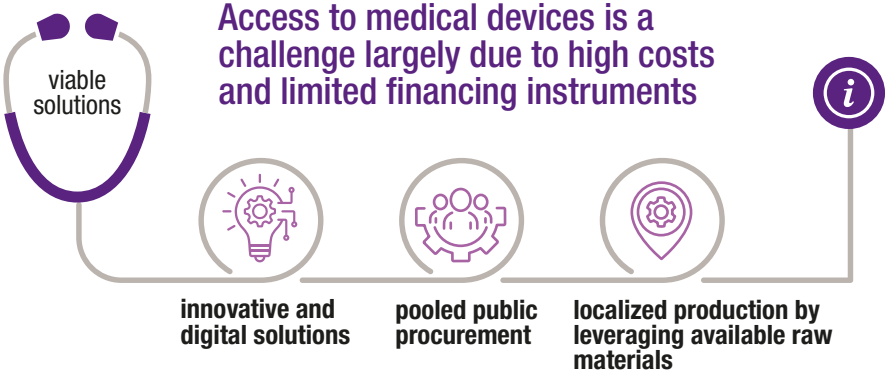
and which require lower technology, are not manufactured locally. To overcome the constraint of limited production of active pharmaceutical ingredients, Egypt has encouraged local companies to establish new facilities for sourcing raw materials (Business Today Egypt, 2021; Egypt, 2021a). Examples include Pharco B International for Chemicals, a subsidiary of Pharco, a domestic firm, which has been producing active pharmaceutical ingredients and raw materials since 2016 (Agiba, 2022; World Economic Forum, 2022).

More recently, Egyptian International Pharmaceuticals Industries, the largest pharmaceutical company in Egypt by units and fifth largest by value, in collaboration with the Egyptian pharma group Acdima, invested $103 million to build a biological and biosimilar production plant. It would be the first such facility in Egypt and is expected to commence production at the end of 2023 (Agiba, 2022; Garcia, 2022). According to data from the United Nations Comtrade database, imports of active pharmaceutical ingredients declined by 21 per cent between 2019 and 2021, partly due to increased capacity to manufacture such ingredients as part of the long-term national strategic plan for pharmaceutical localization.

With regard to research and development in the supply chain (figure 26), Egypt has been less successful in building local capacity. According to the World Bank Enterprise Surveys (various years), Egypt has introduced fewer new products, services, or improved processes in pharmaceutical manufacturing and spent less on research and development, compared with China and India, for instance. As the pharmaceutical industry is a high-knowledge-intensive sector, particularly for the manufacturing of biologics and biosimilars, which requires more advanced biotechnological processing, it is necessary for Egypt to increase research spending and innovation to further develop its long-term competitiveness in the pharmaceutical sector and reinforce its supply chain flexibility and resilience.

3.4.3 Strengthening the position of Africa in the medical device supply chain

Between 2018 and 2020, imports of medical devices were valued at $6 billion (data from the United Nations Comtrade database). With a high prevalence of diabetes, the continent imported $1.8 billion of electro-diagnostic apparatus and $295 million worth of syringes, where imports from African countries accounted for only 0.45 per cent and 3.5 per cent, respectively. Yet, access to medical devices is still a challenge, largely due to high costs and limited financing instruments. Further, the COVID-19-related shortages in medical equipment, including medical devices, have made Africa vulnerable to these external shocks.



As the largest exporters of medical devices in Africa, Tunisia ($193 million in 2018–2020), South Africa ($119 million), Egypt ($35.8 million) and Mauritius ($32.2 million) can readily serve as potential hubs (data from the United Nations Comtrade database). Such potential can be leveraged through the implementation of technologies and innovative solutions, especially in rural areas (see box 10). On the other hand, to be competitive in a technology- and digitization-driven industry such as this, the digital capability of firms must be high (United Nations Industrial Development Organization, 2019). Despite digital transformation on the continent, the region's capabilities to absorb new technologies are small, due to the lack of skilled labour, efficient logistics and infrastructure. Yet, African countries can integrate the medical supply chain through a combination of vertical or horizontal linkages and thus leverage the regional supply chain.

Box 10

Innovation in medical device solutions

An encouraging example of how innovation and technology in medical supplies can enhance health care in rural areas in Africa is the cardiopad device, designed by a Cameroonian engineer. Since its launch in 2016, sales of the device have been rising steadily. It enables cardiac screening, and the results are sent remotely to specialists for analysis without patients needing to travel to urban centres. Public procurement by the Ministry of Public Health of Cameroon played an important role in boosting interest and demand.

Another example is the first solar-powered hearing-aid unit, manufactured by Deaftronics, based in Botswana. There are only a few audiology centres in the country where patients can

test levels of hearing impairment or obtain a suitable hearing aid. Unlike conventional hearing aids, the device developed by Deaftronics eliminates the need for expensive batteries that are often not available. In addition, the solar rechargeable solar device is accessible to rural and poorer parts of the population.

Women's entrepreneurship also plays an essential role in innovative solutions. For instance, Medsaf, a company led by women, offers a medication supply chain management solution for hospitals and pharmacies based on blockchain technology.

Sources: UNCTAD, based on Hendricks, 2015; Mbodiam, 2021; Roland Berger, 2018.

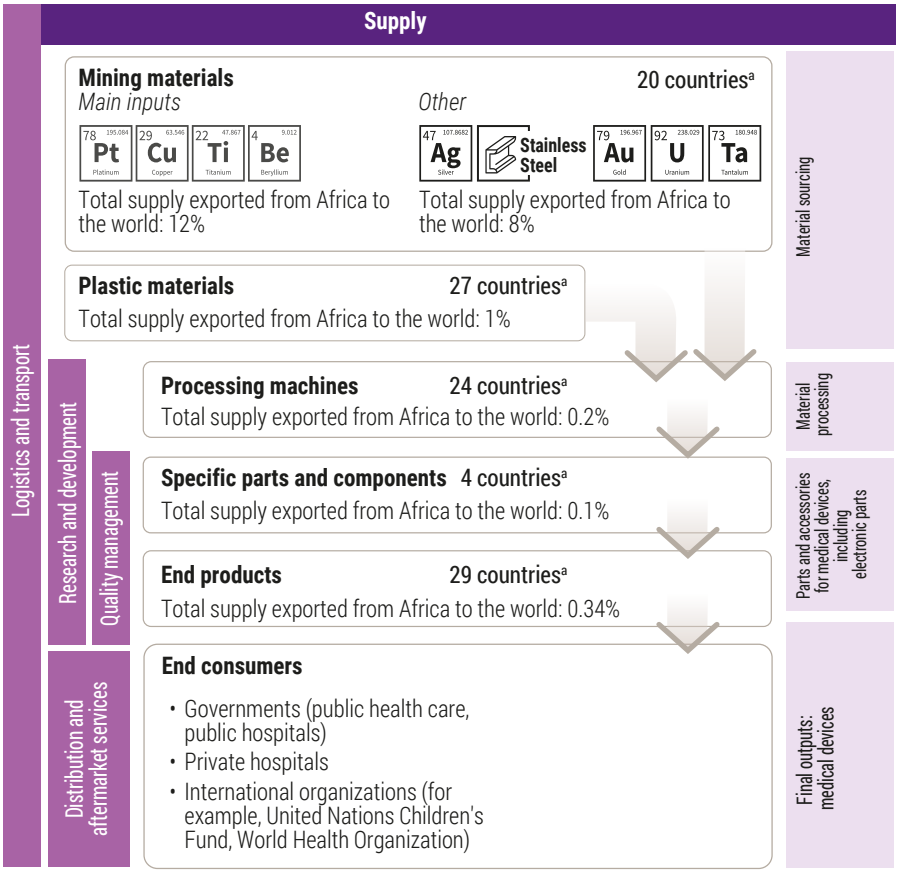
Figure 27 illustrates the different stages of the supply chain: sourcing and processing mining and plastics materials; procuring additional parts and components, such as semi-conductors; assembly of the final products; and distribution.[25] Similarly to the automotive industry, medical devices are part of producer-driven supply chains, and global trade is led by vertically integrated lead firms with worldwide production facilities. Owing to the high safety standards and quality requirements of medical devices, many principal firms maintain some production of critical components in house, which explains the remaining dominance of traditional exporters. Africa accounts for 12 per cent of global exports of key mining materials, emphasizing their importance for future growth of the industry and for increasing the resilience of lead firms. The most important minerals and metals include titanium as the pillar of many medical applications, especially in devices to control heart function, where nine African countries have a substantial export supply (Arima, 2022).

South Africa is the world's largest titanium exporter, representing 35 per cent of global reserves of the mineral, followed by Mozambique (12 per cent) and Kenya (10 per cent). Yet, imports to Africa in 2018–2020 came primarily from Ukraine (55 per cent), followed by Mozambique (29 per cent) and Senegal (16 per cent) (based on data from the United Nations Comtrade database). South Africa accounts for only 5 per cent of imports

[25] The analysis presented here is one the first that attempts to identify supply chains in the medical device sector. This section follows a similar methodology to that described in section 3.1 (box 7). First, based on Canadian input–output tables, key economic activities in the manufacturing of medical supplies are identified; second, additional supply chain direction and linkages, especially with regard to the sourcing of raw materials, are identified through desktop research, for example, Hendriwardani and Ramdoo, 2022 (see www.pekoprecision.com/blog/medical-device-manufacturing-critical-processes/); third, inputs and activities are matched with trade in products (at the HS six- or four-digit level).

Figure 27

Medical devices supply chain and number of African countries with export supply to the world, by supply chain category



Source: UNCTAD.

Notes: Product codes with number of countries in parentheses are included in each supply chain category as follows: Mining materials: 2603 (12), 7110 (4), 261400 (9), 811211 (0); other: 7218 (6), 7402 (6), 7403 (21), 7901 (8), 261210 (2), 261590 (10), 710691 (8), 710692 (7), 710812 (26), 710813 (18); plastic materials: 3901 (16), 3902 (20), 3903 (7), 3904 (10), 3907 (16); processing machines: 8302 (12), 8466 (12), 847710 (10), 847759 (5), 847780 (10), 848079 (7); specific parts and components: 903300 (3), 854150 (2), 854390 (4); end products: 901811 (3), 901812 (4), 901813 (3), 901814 (1), 901819 (6), 901820 (2), 901831 (6), 901832 (3), 901839 (7), 9018416(1), 901849 (3), 901850 (4), 901890 (24).

[a] Number of African countries that export at least one product or product group at the HS four- or six-digit level to the world, at a value of $100,000.

to Africa, despite its leading role in the world market. A similar case is observed for platinum metals, where South Africa is the top exporting country, representing 21 per cent of world exports but it exports these metals mainly outside Africa, principally to the United States, the United Kingdom and Germany. The leading importers of platinum from Africa are the United States (32 per cent), Zimbabwe (31 per cent) and Germany (29 per cent).

Increasing intra-African trade can be a good starting point to leverage the comparative advantage of Africa in metal supply for use in the medical device supply chain. The African Continental Free Trade Area can play an important part in facilitating this. For instance, the tariff applied to unwrought platinum imports from South Africa to Tunisia amounts to 15 per cent of the value of the metal shipped; to Kenya, 25 per cent but 0 per cent to Germany and the United States. This poses a clear competitive disadvantage for African countries aiming to produce medical devices. However, African Continental Free Trade Area tariff liberalization targets can be a solution. Many African countries have a competitive advantage in supplying key inputs to the production of medical devices. To strengthen these supply chain linkages, tariff and non-tariff barriers must be tackled and stronger collaboration encouraged to access the inputs.

Based on data from the United Nations Comtrade database, African countries play a limited role further along in the global supply chain (figure 27). However, some African countries show some export capacity in plastic materials, an important input for the manufacture of medical devices.[26] Hence, African countries could serve regional inputs but plastic processing capabilities must be improved. Manufacturers are increasingly turning to technologies, such as artificial intelligence, robotics and three-dimensional printing, to improve the affordability of medical devices. For instance, injection-mould manufacturing is key to producing plastic parts for use in such devices.[27] This stage of the supply chain is concentrated in China, which supplies 46 per cent of global exports in mining and metal processing machines (data from the United Nations Comtrade database).

[26] According to data from the United Nations Comtrade database, 27 African countries already export one type of plastic material to the world for a value of at least $100,000. These countries are Angola, Botswana, Burkina Faso, Cameroon, Côte d'Ivoire, Egypt, Eswatini, Ethiopia, Ghana, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritius, Morocco, Mozambique, Namibia, the Niger, Nigeria, Senegal, South Africa, Tunisia, Uganda, the United Republic of Tanzania, Zambia and Zimbabwe.

[27] For low volumes, three dimensional-printing is an alternative to work around injection-moulding parts but this technology is also limited on the continent.

However, regulatory and digital solutions can help boost processing capabilities and facilitate access to medical device supply chains. Regulation of medical devices varies widely across countries in Africa and can be lengthy and lack transparency, often delaying access to medical products and devices. Harmonization towards internationally recognized registration or certification programmes (Saidi and Douglas, 2019) and the possibility to apply digital solutions for procurement, production, quality control, distribution, logistics and traceability should be explored. Innovative and technology-based solutions already play an important role in facilitating public health-care supply chains in Africa. Some examples include Mdaas Global, which provides a network of physical and virtual diagnostic and primary care facilities; Infiuss Health, the first remote clinical research platform in Africa; Koniku, a technology company working in visual processing, data processing and pattern recognition; and Instantrad, an as-a-service teleradiology platform (see https://healthcap.co/portfolio/). Box 11 illustrates the importance of partnerships in facilitating research and development and technology, as well as public procurement.

Box 11

Building research and development capacity and enhanced technology transfer through partnerships

More than in other high-technology industries, patents and trademarks play a crucial role in the competitiveness of the pharmaceutical industry. The low levels of patenting activity by countries in Africa is indicative of the need to develop and strengthen health innovation systems in the region. This can be done through policies that support health research systems and a local incentive structure that focuses research on local health challenges.

There are various global health innovation and entrepreneurship initiatives under way. These include an initiative launched by UNCTAD, aimed at sparking the post-COVID-19 resurgence of the micro, small and medium-sized enterprise sector (2020–2022). Other such initiatives are a global digital health strategy (2020–2025) and a special toolkit, the Mobile Health Assessment and Planning-for-Scale Toolkit, developed by the World Health Organization. Other means of strengthening health innovation systems would include the development of local scientific and biomedical research capacities and local manufacturing capabilities. For example, in South Africa, funding is being provided for research and development through a technology and human resources for industry programme. Targeted special economic zones with a focus on

the health sector can also enhance knowledge and technology transfer. Medical cities have, for instance, been promoted by investment promotion agencies in Rwanda.

Emulation has become more difficult, owing to increasing protection of intellectual property rights through the 1994 Agreement on Trade-related Aspects of Intellectual Property Rights. The African Pharmaceutical Technology Foundation, established in 2022, is expected to support the practical implementation of trade-related intellectual property rights in Africa. It is supposed to act as an intermediator to advance the sharing of intellectual property-protected technologies, know-how and patented processes. In 2020, India and South Africa submitted a proposal for a waiver of four forms of intellectual property of the Agreement (patents, copyrights, industrial design and undisclosed information) for COVID-19-related vaccines, treatments and diagnostics. By May 2021, the waiver proposal had gained 65 official co-sponsors. However, only patents have been included in the waiver for vaccines. Hence, the final adoption fell short of what was in the original proposal.

Although national enforcement of intellectual property rights is important to promote innovation, the provisions concerning special and differentiated treatment are not linked to objective measures for technological or productive capacities. An UNCTAD study recommends that manufacturers in technologically weak and less-diversified countries should be allowed to imitate the production of more technologically advanced economies.

Some patent holders also grant voluntary licences to local manufacturers through contractual arrangements or mechanisms such as the Medicines Patent Pool. It is common practice, however, to restrict the location where the product can be sold. For instance, in Egypt, partnerships between multinational companies and local companies have allowed exchanges for technology transfer and intellectual property, while producing locally for the Egyptian market. For example, Sun Pharma of India opened its first manufacturing site in Egypt in 2017; Gypto Pharma, a domestic company, worked with Otsuka of Japan; and Eli Lilly collaborated with the Egytian firm, Eva Pharma. The Government of Egypt encourages local pharmaceutical production and aims to become self-sufficient in pharmaceuticals by 2030, as part of its national sustainable development strategy, Egypt Vision 2030, launched in 2016.

Sources: UNCTAD, based on African Development Bank, 2022b; Agiba, 2022; Egypt, 2016; Egypt, 2021b; Iqvia, 2022; Lilly, 2022; Motari et al., 2021; UNCTAD, 2021c; UNCTAD, 2022f; UNCTAD, 2023; World Trade Organization, 2020b; World Trade Organization, 2021; Youssef, 2021.

3.5 Making resource-based supply chain integration work for sustainable development

3.5.1 Local content requirements in the mining supply chain

Despite the vast mineral wealth of Africa and the significant foreign investment that the sector has attracted throughout the years, many resource-rich African countries have not been able to translate their resource wealth into sustainable economic, social and environmental development. In an effort to reverse this trend and ensure that capital-intensive large-scale mining becomes an engine of inclusive and sustained development, many resource-rich Governments have established policies and measures that can catalyse lateral linkages between large-scale mining and local productive industrial development. Developing an African supplier base in the mining industry has perhaps the most potential among all the benefits countries can derive from mining. Suppliers provide goods and services to mining companies. This can range from products such as pick-up trucks, tyres, drills, conveyor belts and specific replacement parts, to services, such as catering, surveying and human resource management. Efficient local suppliers lead to lower costs for mining companies. Mining companies need to import fewer goods, and local expertise solves local problems. By procuring more from the local market and establishing a wide network of local suppliers, the mining industry also has stronger ties to their host countries, reducing disputes and discontent (Kemp et al., 2011; Ross et al., 2012). Governments that are aware of the industrial value represented by critical minerals and the opportunities to develop domestic production capabilities to yield cluster and scale economies, instituted measures to incentivize local procurement and local content production (see the example of South Africa, box 12).

However, in most African countries, much procurement value is spent on imported goods and resold by domestic suppliers, without creating additional employment, transferring business knowledge to other economic sectors (Korinek and Ramdoo, 2017). The case of the mining value chain in Zambia (Lombe, 2020) is illustrative in that regard, with foreign suppliers accounting for 96 per cent of goods and services[28] supplied to the mines. Domestic suppliers in Zambia contribute about 1 per cent to total supplies for mines,

[28] About 98 per cent of core services (drilling services, underground development, instrumentation services) and 95 per cent of core goods (explosives, mill balls and rods, chemicals); 95 per cent of non-core services (security, customs handling, cleaning, transportation) and 87 per cent of non-core goods (safety and office equipment, nuts and bolts, light fittings).

mainly in catering, security services and office maintenance. Despite industry supplier development programmes at the firm level, these have not successfully included many domestic companies. The reasons can be mainly attributed to limitations, such as a lack of access to long-term capital, restricted access to production technologies, high costs of production inputs and a lack of full quality control of production, as well as a lack of legislative provisions favouring domestic production and sourcing (Lombe, 2020). Current incentives reward mining firms for importing goods rather than encouraging domestic manufactures. In the past, more focus was placed on capturing tax benefits but local participation in the mining value chain through infrastructure about mines would provide larger gains. Structured support requires incentives for imports of raw materials and equipment, access to technology and structured finance, and technical mentorship.

Box 12

South Africa: The mining equipment sector

South Africa plays a central role in the trade of processed platinum and primary aluminium and uranium across the continent. This suggests the central role of South Africa in leading these regional value chains. Mining equipment production and services are today's most relevant and technologically advanced segments of the broader special-purpose machinery industry in South Africa. Specifically, the mining machinery and equipment sector represents the largest contributor to employment, turnover and exports of the special purpose-machinery industry, and it also stands out with respect to total plant, property, equipment and intangible assets, expenditures in research and development, royalties and patent rights, and staff training.

Proximity to the mining sites and demand for customized and niche technology solutions well suited for the peculiar geological conditions of South Africa have been important drivers of learning and, thus, of global competitiveness for local companies that, over the years, have developed production and service operations across major extractive industries and countries, actively engaging in the technological race in the global mining value chain. However, although a number of these companies are large by local standards, they are still significantly smaller than the leading multinational corporations operating in South Africa, and their expertise and competencies are particularly advanced and at the global frontier only in specific product segments, such as deep-level mining and related areas.

With the amendment of the Mining Charter in 2010, the Government of South Africa introduced a black economic empowerment programme, requiring that black ownership of mining companies

reach 30 per cent and that the companies purchase 80 per cent of their services, 50 per cent of their consumable goods and 40 per cent of their capital goods from entities participating in the programme.

Since 2013, however, the global competitiveness of South Africa in the mining equipment sector has been on the decline, owing to a combination of factors. These factors include domestic bottlenecks, such as the shrinking domestic mining industry, and global threats, such as the increasing foreign competition faced by local players. The country has experienced a drop in its export shares of mining machinery and equipment to traditional markets in the aftermath of the global financial and economic crisis and it is losing its appeal for leading multinational corporations as a preferred and strategic location in which to undertake research, product development, engineering and production activities.

Local content requirements policies have played an important role in the mining policy of South Africa to increase the participation of local actors; however, in some cases, they have also introduced unnecessary rigidities, such as a more limited choice of inputs or potentially higher costs of inputs, which have prevented alternative pathways to increasing domestic value addition. The local procurement and content policy framework could be reformed along two main directions: first, by introducing specific categories of procurement reserved for local suppliers, based on a thorough assessment of goods and services to target; second, by linking local procurement and content requirements with export promotion where companies would be allowed to import more of the products they need, to the extent that they also increase the local content value of the exported products.

Source: UNCTAD, based on Andreoni and Torreggiani, 2020; Andreoni et al., 2021.

To unlock the potential of capital-intensive large-scale mining for inclusive and sustained development, Governments in Africa have started adopting local content policies to harness business opportunities for domestic enterprises by developing local supply chains and facilitating the creation of backward linkages in the mining sector, for example, generating value addition in domestic supply sectors, creating local employment opportunities or transferring technology. In many resource-rich countries, Governments adopt local procurement policies to foster greater participation of domestic industries in the mining supply chain. International Institute for Sustainable Development and Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (2019) define local procurement as the purchase of goods and services

from domestic suppliers. A supplier is considered local when it originates from, is registered or incorporated in, and conducts business in the country where the mining project or site is physically located.

The definition and practice of "local" can vary across countries. However, in the absence of a clear definition and applicable regulations, this can result in a situation where mining companies end up sourcing imported goods from companies in the local area and therefore report on having met their local procurement targets. Although in such a situation a proportion of value addition is performed within the country, it does not create meaningful economic benefits for the host country. Local employment is not necessarily created, domestic manufacturing industry is not promoted, and the growth of local suppliers is not adequately supported. It is therefore vital for mineral-rich countries in Africa to put in place sound local procurement policies based on clear local sourcing and local ownership criteria.

To date, 17 African countries have local content regulations in place, namely Angola, Botswana, Burkina Faso, Cameroon, Côte d'Ivoire, the Democratic Republic of the Congo, Ghana, Guinea, Mali, Mozambique, Namibia, the Niger, Sierra Leone, South Africa, the United Republic of Tanzania, Zambia and Zimbabwe. Of these, only nine – Cameroon, the Democratic Republic of the Congo, Guinea, Mozambique, Namibia, the Niger, Sierra Leone, the United Republic of Tanzania and Zambia – have introduced negotiated local content requirements in their mining regulations (Fofaria, 2020). While the implementation of local content measures will require regulatory and monitoring capabilities to ensure compliance by investors and foreign firms, their success will also depend on domestic capabilities – adequate infrastructure, strong institutions, a supportive local business environment and a skilled labour force.

Although local content requirements are established through domestic policies, their scope can extend beyond national borders and contribute to the development of regional supply chains (International Institute for Sustainable Development and Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development, 2019). Promoting local content from a regional perspective will also contribute to expanding local suppliers' access to wider regional markets and thus create larger business and economic gains for domestic firms. In Africa, opportunities for regional markets and more efficient rules of origin under the African Continental Free Trade Area, combined with the commitment of the Africa Mining Vision to promote economic linkages in the mining sector, can help optimize regional content in local procurement rules and foster regional supply chains on the continent. The Africa Mining

Vision (box 13) was formulated in 2009 by African Heads of State as a pathway for catalysing more sustainable backward (upstream industries) and forward (downstream industries) linkages in the mining sector that will help establish more competitive local suppliers and manufacturing industries (Ackah-Baidoo, 2020). The continued commitment of resource-rich countries to such a vision will serve as a springboard for the materialization of local content to support the growth of African industries and their integration in regional and global supply chains.

Box 13

Africa Mining Vision

In 2009, the African Union put forward the Africa Mining Vision to ensure that Africa utilizes its mineral resources strategically for broad-based, inclusive industrial development. This vision identifies several areas of intervention where improvements can be made:

- Quality of geological data.
- Contract negotiation capacity.
- Capacity for mineral sector governance.
- Capacity to manage mineral wealth.
- Infrastructure constraints.
- Artisanal and small-scale mining.

However, implementation has been slow, and there is a low level of awareness of the framework among key stakeholders in the mineral sector. As recommended in an UNCTAD study, countries should use existing guidelines to enact policies and regulations aimed at its implementation. The expectations of mineral-rich countries in Africa with regard to development benefits from the extractive sector are justified by its status as a key generator of export revenues and foreign exchange in mineral-exporting economies. Mindful of the magnitude of the extractive sector as a source of illicit financial flows, African countries should build on lessons learned from past engagement in international commodity governance to meet these expectations.

Sources: UNCTAD, based on Africa Centre for Energy Policy, 2020; United Nations, Economic Commission for Africa, 2014; Oxfam, 2017; UNCTAD, 2020c.

3.5.2 Enforcing sustainable development standards in materials supply chains

The increasing demand and supply of minerals and metals gives rise to environmental and social concerns, owing to the possible negative externalities of extractive industries on local communities (Marin and Goya, 2021; UNCTAD, 2020c). For instance, copper and lithium are particularly vulnerable to water stress, given high water-consumption requirements (International Energy Agency, 2022a). Although African countries, intergovernmental organizations and companies have intensified efforts to clean up mineral supply chains, raw materials often come from mines that provide poor environmental and labour protection; further, their profits are sometimes linked to armed conflicts. Referred to as conflict minerals, the supply chains of gold, tantalum, tin and tungsten are now subject to regulations issued by China, the United States and the European Union that aim to prevent the profits being used to fund armed groups in unstable or fragile resource-rich countries. The mining of other critical minerals used in the manufacture of batteries for electrical vehicles (cobalt, for example) but not currently listed as conflict minerals under the Dodd–Frank Act,[29] is, however, subject to risks. These include poor working conditions, child labour, the sexual exploitation of women and other human rights concerns (Honke and Skender, 2022; International Labour Organization, 2019). Women workers are particularly affected by issues of social and environmental practices in the mining sector, despite their potential to contribute to the development of large-scale mining and related capital- and technology-intensive industries (see box 14). The spillover of economic and social benefits of gender equality and decent work are increasingly recognized, calling for the need to reinforce efforts aimed at securing equal rights and opportunities for women workers and entrepreneurs in the mining sector (International Labour Organization, 2021). In Africa, the Africa Mining Vision proposes actions favouring gender equity and the empowerment of women (International Labour Organization, 2021).

[29] The Dodd–Frank Wall Street Reform and Consumer Protection Act was passed in 2010 by the United States Congress to curb risky financial industry activities that had led to the global financial and economic crisis of 2008-2009. It established a wide range of reforms throughout the entire financial system, aimed at providing greater financial market regulation, which includes improving transparency in the over-the-counter derivatives markets. In 2018, the United States Congress passed a new law that rolled back some of the restrictions of the Act, relaxing some of the regulations for smaller and medium-sized banks. The main purpose of the Dodd–Frank Act remains to protect consumers and taxpayers from egregious practices, such as predatory lending.

Box 14

Women in high-technology industries

To realize a more equal distribution of the benefits of high-technology supply chains, the integration of women is important.This section of the report is a first attempt to assess women's participation in high-technology industries. World Bank Enterprise Surveys are used to provide information on top women managers and the share of women production and non-production workers. On average across all industries, the survey reveals that only 13 per cent of the surveyed businesses in Africa are managed by women, compared with 27 per cent in East Asia and the Pacific, 16 per cent in Latin America and 8 per cent in South-East Asia. In addition, 17 per cent of all productive workers and 21 per cent of non-productive workers in the surveyed African countries are women, compared with 33 per cent and 34 per cent, respectively, in East Asia; 27 per cent and 40 per cent, respectively, in Latin America; and 5 per cent and 0.5 per cent, respectively, in South Asia. That comparison indicates that opportunities for women are currently greater in the areas of sales, advertising, servicing of products, routine office tasks and financing and legal functions, rather than in production. Across high-technology industries, the largest share of female workers is in communications equipment: they account for 26 per cent of employers in production and 44 per cent of non-production workers (see table).

Share of female workers in high-technology industries, various years

Industry and International Standard Industrial Classification of All Economic Activities code	Share of production workers	Share of non-production workers	Share of enterprises with women as top managers
	percentage		
Motor vehicles (ISIC 34)	11	25	6
Communications equipment (ISIC 32)	26	44	0
Electrical machinery (ISIC 31)	18	30	10
Pharmaceuticals (ISIC 2423)	12	30	7
Medical instruments (ISIC 33)	18	28	8
Machinery and equipment (ISIC 29)	13	27	7
All industries (average)	17	21	13

Source: UNCTAD calculations, based on World Bank Enterprise Surveys.
Note: Classifications used in this table are based on ISIC Revision 3.1.
Abbreviation: ISIC, International Standard Industrial Classification of All Economic Activities.

Source: UNCTAD, based on World Bank Enterprise Surveys.

There is a need for a new global governance architecture that addresses the needs for structural transformation in resource-dependent countries and improves the social benefits of mining (United Nations Environment Programme, 2020). An example is the Sustainable Development Licence to Operate, which is a holistic multilevel and multi-stakeholder governance framework aimed at enhancing the contribution of the mining sector to sustainable development (Pedro, 2021). For many years, the extractive industry focused on securing a social licence to operate as a measure to relieve social tensions and mitigate environmental damage at the operational level, mostly from local communities and other stakeholders. The approach is based on joint responsibility and recognizes how these conditionalities must be more stringent and go far beyond minimum standards of corporate social responsibility and compensations. Corporate social responsibility perspectives still range from being focused on economic benefits and compliance with ethical expectations, to being merely philanthropic (Singh et al., 2015) but they are nevertheless useful to improve social and environmental outcomes of economic activity.

Technological advancements, such as blockchain technology, can enhance corporate responsibility and environment sustainability by providing information to buyers on the origin of products and guarantees as to the authenticity of the information (Lema and Rabellotti, 2023). By leveraging blockchain technologies to collect and track reliable and trusted environmental, social and governance-related data and supply chain information more accurately and in a consistent manner (Capgemini, 2021), companies and suppliers will be able to monitor their carbon footprint and ensure accountability and sustainability throughout their supply chains.

A number of companies are also involved in marketing second-life batteries, highlighting the potential role of the circular economy, not only in increasing sustainability but also adding local value to the supply chain. To date, there is no facility that can fully recycle lithium-ion batteries – a potential investment opportunity. The International Energy Agency (2022a) estimates that by 2040, recycled quantities of copper, lithium, nickel and cobalt from spent batteries could reduce combined primary supply requirements for these minerals by about 10 per cent. The global capacity for battery recycling is currently only about 180 kilotons per year, of which China accounts for 50 per cent. To state a recent example, a joint venture between a United States company, Ace Green Recycling, and a leading investment company based in South Africa, Tabono, is investing in two battery-recycling facilities (*Mining Review Africa*, 2023). Progress towards the circular economy has also been made in Morocco. Given the country's large potential in high-technology supply chains, the development of a circular economy

model in Morocco – end-to-end electric vehicle production – would potentially attract a string of complementary investments into the upstream, midstream and downstream sectors of the electric vehicle supply chain. Such investments would open the way to the development of domestic vertical integration for electric vehicles, involving the production of electric vehicle battery metals, batteries, electric vehicles and battery recycling. It could further position the country as an attractive destination for the European electric vehicle market. By closing the loop in the supply chains, firms will be able to reuse the critical raw materials in electric vehicle batteries at low cost and render their electric vehicle supply chain more resilient, especially during periods of global commodity price volatility (Tanchum, 2022b).

3.6 Conclusion

The high-technology supply chains discussed in this chapter –the automotive industry, mobile telephones, solar panels, pharmaceutical products and medical devices – all involve a variety of economic activities and require many different inputs and raw materials. Although countries in Africa are marginally integrated in the supply chains of high-technology intensive industries, except for the export of raw materials, there is potential for deeper substantive integration in local and regional supply chains. Final assembly and export activity is largely concentrated in South Africa and some countries in North Africa, such as Egypt, Morocco and Tunisia; yet, even in these middle-income countries, most inputs are still imported from outside Africa. This is a hindrance for these supply chains to engage in employment creation and diversification. Acknowledging the potential of these high-technology supply chains for sustainable development, middle-income countries in Africa have already attracted investments in upstream activities and encourage local sourcing, for instance, through partnerships and local content requirements.

Although the limited productive capacities of low-income countries in Africa currently restrain their participation in high value added activities in these supply chains, this chapter demonstrated that the employment benefits stemming from the provision of services, such as those relating to consulting, project development and aftermarket-sales of goods and services, should not be neglected. Stronger partnerships with multinational companies can provide skills and knowledge spillovers.

Effective implementation of the African Continental Free Trade Area will be essential to leverage these opportunities, not only with regard to tariff liberalization but most

importantly, in harnessing joint investments in infrastructure and facilitating the building of clusters, which benefit from quicker, more flexible delivery to customers.

Given the abundance of critical minerals in Africa to meet demand in high-technology supply chains, the chapter argued that countries in Africa must significantly scale up investment in infrastructure, especially electricity and transport infrastructure, to increase the competitiveness of local suppliers and revise mining legislation to ensure greater benefits for the local economy. Local content regulations and conditionalities can set requirements for technology transfer and investments in community infrastructure. Moreover, a significant amount of production has already been committed to overseas buyers through offtake agreements; therefore, it is urgent for Governments to seek options for securing supply for value chains in Africa. These options could include public procurement engagement and measures to strengthen procurement options by local companies through digital transformation, technology-enabled services and improved supplier and customer management (see chapter 4).