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Human Capital as a Critical Capability and Asset for Supply Chains in Africa: An Econometric Analysis of the Automotive Sector

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Abstract

The African continent is one of the major suppliers of raw materials, which are necessary for the supply chain, yet the continent remains far behind in integrating into the global supply chain. Therefore, building supply chain resilience is one of the continent's major objectives, including Agenda 2063, Sustainable Development Goals, and the regional supply chain under the African Continental Free Trade Agreement (AfCFTA). A solution for the redress of the supply chain in Africa and to exploit the full potential of its natural capital in the service of good integration of its supply chain remains the strengthening of its human capital. This paper uses econometric methods to analyse how human capital could be a critical capability of African supply chains. In this paper, we focus on the automotive supply chain, which remains one of the most important areas of global supply chains. The African continent is, at the same time, the continent with the lowest human capital and the least integrated in the global supply chains. In Africa, we find a dependence between the various measures of human capital and exports of all the components of automotive supply chains, characterised by strong correlations, except the automotive tier 3 supply chain products, which indicates that human capital is an important driver for Africa to upgrade in automotive supply chain. Econometric models to capture just-in-case and just-in-time supply chains confirm human capital as a key asset to the African automotive supply chain.

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1. Introduction

Research on African supply chains has grown significantly since COVID-19, as the continent has experienced various instances of supply chain disruptions (Banga et al., 2020; Grynspan, 2022; ITC, 2022; UNCTAD, 2022e). Supply chains refer to all activities and networks associated with the flow and transformation of goods from the raw material stage involving suppliers through to the final consumers, consisting of product development, sourcing and procurement, manufacturing, logistics and transport, distribution, and customer service (Handfield et al., 2002; Reddy, 2013; Techtarget Network, 2021). While all these activities are critical to the productive transformation of global economies, Africa's performance continues to lag behind other regions, its participation in global value chains remaining low at only 1.7 per cent in 2019 compared to 1.5 per cent in 2000 (OECD, 2022:23). Building supply chain resilience has become a priority in the agenda of many policymakers, including the regional supply chain under the African Continental Free Trade Agreement (AfCFTA) which is expected to promote intra-African trade (Agarwal et al., 2022; De Melo & Twum, 2021; ITC, 2022; OECD, 2022; UNCTAD, 2021a).

This raises the question of what the potential and policy requirements for Africa's supply chain development are. One perspective to analyse this is the importance of human capital, which has long been considered a key factor in economic growth theories. Human capital is beneficial for technological progress, job creation, poverty reduction, capital accumulation, and sustainable development (Becker, 1962; Mincer, 1995). Human capital includes formal education, skills, and health that people accumulate over their lives, which helps to improve workers' and national productivity as well as total output value (Becker, 1962; Weiss, 2015; World Bank, 2019b, 2021). World Bank's Changing Wealth of Nations 2021 Report shows that human capital constitutes 64 percent of total wealth in 2018 and is the largest asset across all income groups globally (World Bank, 2021). This finding emphasises the importance of education and training as investments that could enhance individual and national productivity (Becker, 1964, 1994), end extreme poverty (World Bank, 2019b), and allow countries to have a skilled workforce prepared to compete in the global economy and achieve sustainable, inclusive economic growth (World Bank, 2019a). Skilled labour helps attract more sophisticated foreign direct investment (Lorentzen, 2007), and is a particularly strong determinant of backward and forward global value chain participation (Yameogo & Jammeh, 2019).

Differences in human capital also explain the gender disparity in employment and entrepreneurship (ITC, 2022). For instance, empirical evidence in Ghana shows that elements of the human capital theory, including the level of education, business training, and knowledge gained during work experience, are crucial factors for female entrepreneurship that could enhance businesses and thus supply chain relationships and flexibility across the continent (Adom & Asare-Yeboa, 2016; Barrientos, 2001; Chinomona & Maziriri, 2015). Similar findings are shown by empirical research in South Africa (Bobek et al., 2023). Indeed, human capital is likely to have a critical role in enhancing supply chain development, integration, resilience, flexibility, competitiveness, and sustainability, and preventing supply chain disruptions.

The paper at hand therefore asks: What is the empirical relationship between human capital and supply chain performance in Africa? To what extent does human capital explain disparities in supply chain performance across African countries? To answer these questions, we consider the automotive supply chain, which includes manufacturing of tier 1 products (automotive parts and systems), tier 2 products (non-automotive grade parts), tier 3 products (raw and semi-raw materials), other supporting activities and equipment, and final vehicles. It provides an interesting case study due to: (i) its high potential for intra-African trade and structural transformation; (ii) its high vulnerabilities due to dependence on specific original equipment manufacturers (OEM), (iii) its requirements for high-skilled labour as the industry trends towards Connected, Autonomous, Shared and Electric (CASE) innovations; (iv) its importance to Africa's energy transition; and (v) the importance of addressing the low female participation rate in the sector in order to achieve greater gender equality overall. To capture the dynamic relationships in Africa's automotive supply chains, we conduct a quantitative analysis using a Panel Vector Autoregression (VAR) Model for just-in-case (JIC) supply chain and a Simultaneous Equations Model (SEM) for just-in-time (JIT) supply chain, using human capital data from the World Bank's Changing Wealth of Nations (World Bank, 2021) and automotive export data from UNComtrade. Our findings for the JIC supply chain model show that human capital has a positive effect on all components of the automotive supply chain at 1 per cent significance level, while the JIT supply chain model results show that human capital has a positive effect on tier 1 exports but a negative effect on tier 2 exports at 10 per cent significance level, with a statistically insignificant effect on tier 3 exports.

This paper contributes to the existing literature in three ways. First, we present the situation of human capital development and automotive exports as a measure of supply chain performance in Africa, highlight the heterogeneity across African countries, and analyse the relationship between the two through a correlation matrix. Second, we use an econometric model to quantify the nuances between human capital and different parts of the automotive supply chain in Africa. Third, we provide brief policy recommendations that should be considered and adapted according to different supply chains, national development goals, and local contexts.

The rest of the paper is structured as follows. Section 2 reviews the literature relevant to this study and provides a brief description of the research approach. Section 3 presents stylised facts related to measurements of human capital and automotive supply chain performance across African countries, supported by a correlation matrix between the two variables. Section 4 describes and provides the rationales for the chosen econometric model, and discusses the econometric modelling results. Section 5 concludes.

2. Literature review

Research has suggested that a national economy's successful supply chain transformation in terms of building production capability and localisation of supply chains involves technical skills, purposeful technology transfer, and a robust research and development (R&D) sector for innovation (ITC, 2022; OECD, 2022). These inherently demand an advanced knowledge-intensive learning process that requires a high level of human capital. Human capital is commonly defined as the levels of formal education, training, and health that people invest in and accumulate throughout their lives, which improves the quality and performance of labour, their own and national productivity (Amadeo, 2022; Becker, 1962; OECD, n.d.; Weiss, 2015; World Bank, 2019b). It is considered an asset necessary for public and private sector organisations to achieve their goals (Nkwanyana, 2021).

The World Bank (2021) identifies two broad approaches to measuring human capital: indicators-based approach and monetary measure-based approach. The indicators-based approach estimates human capital based on variables or indicators of population characteristics, such as literacy rate, levels of education, years of schooling, enrollment ratio, test scores, number of researchers, life expectancy, stunting rate, and mortality rate. Examples of human capital measures using this approach include the UNDP's Human Development Index (HDI) and the World Bank's Human Capital Index (HCI). In contrast, the monetary measure-based approach calculates the total stock of human capital from a financial wealth accounting perspective, either indirectly (as the residual of a country's total discounted value of future consumption flows after natural and produced capital have been considered), or directly (as the stream of past investments in human capital from the cost side, or from the income side as the stream of future earnings that human capital investment generates) (World Bank, 2021, p.145). One prominent example of an income-based, future output-oriented direct monetary approach to measuring human capital is used in the World Bank's Changing Wealth of Nations (CWON) Report (World Bank, 2021), which follows the lifetime income approach by Jorgenson & Fraumeni (1989, 1992a, 1992b) and estimates human capital as the total present value of the expected future labour income that could be generated over the lifetime of the current working population, including both the employed and self-employed labour force (Hamilton et al., 2018).

These various measures complement each other and have their own strengths and weaknesses. For example, it is often challenging for the indicators-based approach to gather and standardize metrics for all the data of all relevant indicators, a common issue in economic index-building. In addition, measuring human capital residually is useful but often prone to measurement errors. While the CWON monetary measure provides the current stock of human capital in countries, it omits human capital that produces household services (World Bank, 2021).

The CWON approach shows that human capital constitutes 64 percent of total wealth as of 2018 and is across all income groups globally the largest asset compared to natural and produced capital. However, significant disparity between male and female human capital, and between regions, has persisted (World Bank, 2021). Women continue to account for only 37 percent of human capital in 2018 globally, indicating a very small increase from 35 percent in 1995. Regionally, female human capital is the lowest in South Asia at 13 percent, followed by Middle East and North Africa (26 percent), and East Asia and Pacific and Sub-Saharan Africa (both at 33 percent). All regions have witnessed a growth of female human capital by at least 1 percentage point between 1995-2018, except for Sub-Saharan Africa. The region's female human capital saw a decline of 11 percentage points while its male human capital gained 11 percentage points, which was later exacerbated by the COVID-19 pandemic, during which Sub-Saharan Africa lost 13 percent of its human capital. In a crisis like COVID-19, women are often disproportionately affected due to factors such as social norms, prevalence of informal employment, and their roles as unpaid domestic care worker (ILO, 2021; UNCTAD, 2021b).

Existing literature argues that the lack of progress in human capital development has been a key factor for Africa's dependence on primary commodity exports and an important barrier for Africa's economic transformation (Awiti, 2017; Baah-Boateng, 2013; Nguegan, 2017). Consistent with this perspective, the high level of human capital requirement needed to generate African countries' supply chain transformation has been a major barrier to the development of Africa's supply chains, which have often been unable to productively engage in higher-value-added supply chain activities that can generate more sustainable industries and services, wealth, and economic development. This threatens Africa's supply chain resilience during challenging periods and global shocks, such as COVID-19 and the war in Ukraine (Bowman, 2022; UNCTAD, 2022a).

For example, at the macroeconomic level, the growing importance of digital supply chain capabilities means that a lack of digital supply chain talent will hinder Africa from participating in digital supply chains in the age of 'Industry 4.0' (Abdul Rahman et al., 2022; Alicke et al., 2022; Debrah et al., 2018). Moreover, as ITC (2022) and OECD (2022) show, technology is one of the key determinants of whether African automotive firms can take advantage of the mega-trends of automation and electrification in the automotive production and supply chain processes, or whether African pharmaceutical firms can be more involved in the production of active pharmaceutical ingredients or the raw materials. To successfully gain such technology a well-educated workforce and R&D community are essential for firms to engage more in higher-value-added automotive manufacturing and upstream pharmaceutical supply chain activities (ITC, 2022). A good case in point is the success of Morocco's automotive industry, which has increased vehicle production rapidly from 42,066 units in 2010 to 464,864 in 2022 (data from OICA.net). Morocco's systematic investments in education, skill development, engineering, and R&D capacities were a critical factor for bolstering local capabilities, building technical know-how in vehicle manufacturing, and attracting multinational companies such as Renault and Peugeot (Japan International Cooperation Agency & Boston Consulting Group, 2022; Vidican-Auktor & Hahn, 2017).

At the firm level, underdeveloped human capital, including human resources shortage and inadequate supply chain management knowledge, skills and competence, or suitable training, has shown to negatively impact the performance of supply chain management, indicated by case studies in South Africa's public sector and state-owned entities (Ambe et al., 2023; Nkwanyana, 2021). Further research suggests that human capital is one of the key determinants, besides infrastructures and connectivity, for the effective deployment of operational agility, quality, cost management and outsourcing strategies that are key to enhance firm performance and global competitiveness in supply chains (Griffith, 2006; Santa

et al., 2022). More nuanced research by Anyanwu (2018) argues that while tertiary education has a significant positive association with manufacturing value added (MVA) in Africa – a key goal of supply chain development – primary education has an inverted U-shaped relationship and secondary education has a negative significant relationship This could be due to the fact that the skills provided at the higher levels of primary education, which helps develop numeracy and literacy skills and tends to produce unskilled labour, and all levels of secondary education, which helps develop abstract reasoning, creativity and problem solving abilities common among skilled labour, are insufficient for higher MVA as manufacturing becomes more sophisticated and requires technological and R&D capacities that usually tertiary education could better provide (Anyanwu, 2018).
However, this body of literature has either not quantified the relationship between human capital and supply chain performance in Africa or not focused specifically on supply chain performance as a dependent variable. Nor has it taken a broader economic perspective of human capital, i.e. the wages and earnings generated by a well-educated and healthy workforce rather than the specific supply chain management skillset (Fung & Chen, 2010; Supply Chain Strategy Blogs, 2022). As such, the paper at hand closes the research gap by empirically examining the potential effects of human capital on supply chain performance in Africa.

We focus on Africa's automotive supply chain due to the following reasons: First, the automotive sector is important to many African economies, with high export potential for intra-African trade under the AfCFTA (close to $2 billion rise expected under partial tariff liberalisation by 2025, according to UNCTAD (2021)) and the Pan-African Auto Pact[1], which could serve as a launchpad for longer-term structural transformation. Vehicle demand in Africa is rising and could reach 10 million units per year by 2030 (Black & McLennan, 2016), but automotive manufacturing remains limited to South Africa, Morocco, Algeria, and Egypt, accounting for only around 1 percent of world production. The mainly small-scale assembly operations of the other African countries (such as Angola, Ethiopia, Ghana, Kenya, Lesotho, Mozambique, and Namibia), which involve minimal value added and human capital required, have prevented their greater participation in the supply chain (ITC, 2022; data from

[1] The Pan-African Auto Pact (PAAP) aims to connect potential automotive powerhouses to trade quickly and easily. Potentially able to create a market of 5 million new vehicles a year, PAAP include the following regional policies: the AfCFTA, the Ghana Automotive Development Policy, the National Automotive Industry Development Plan (NAIDP) of Nigeria, etc. (Deloitte & African Association of Automotive Manufactures, 2020).

OICA.net). Second, the increasingly complex supply networks in the automotive industry, with greater use of sophisticated technologies, parts, and softwares, have aggravated not only the vulnerabilities of the automotive supply chain as shown by the challenges it has experienced since COVID-19 and the war in Ukraine, but also the levels of technical know-how and specialised labour required to produce high-quality inputs for vehicle assembly (Ambe & Badenhorst-Weiss, 2010; ITC, 2022; Prystav, 2023). In the context of the global rise of Connected, Autonomous, Shared and Electric (CASE) innovations, Africa's scarcity of high-skilled labour in engineering, engine manufacturing, artificial intelligence, machine learning, and additive manufacturing has resulted in low R&D investment needed to upgrade the production processes of inputs and final vehicles (ITC, 2022; UNCTAD, 2023).
Third, Africa's automotive sector is critical to its energy transition, especially given the growing carbon neutrality regulations and the global trend towards manufacturing of low-emission vehicles which require many critical minerals abundant in Africa (JICA & BCG, 2022; ITC, 2022). Fourth, the low female participation in the automotive sector is a risk to inclusive growth on the continent, which is why it is so important to understand more about the industry for the potential implications of female human capital development on achieving greater gender balance. Indeed, the auto sector has the lowest share of female production and non-production workers, at only 11 per cent and 25 per cent respectively, compared to other high-technology industries such as communications equipment (26 per cent and 44 per cent) and healthcare (15 per cent and 29 per cent) sectors according to data from the World Bank Enterprise Surveys. Developing the auto sector while mainstream gender in trade and development policies has the potential to grow a more gender-diverse workforce in the sector (UNCTAD, 2022d). In fact, the rise of electric vehicles (EVs) and the new relevant skillset might be beneficial to female workers: for example, it was reported that 6 out of 10 new hires in India's EV sector tend to be women skilled in business modelling, design redevelopment, e-mobility, and renewable energy management (Mukherjee & Verma, 2022). Fifth, the automotive industry is one of the few sectors with available data in terms of a breakdown of the supply chain stages and export data, the latter a useful measure of trade and supply chain relationships among African countries and between African countries and the global economy.

Thus, we ask specifically: How does human capital affect automotive supply chain performance in African countries? To understand this empirical relationship, we use the World Bank (2021) CWON definition of human capital to conduct econometric modelling of the relationship between Africa's human capital and automotive supply chain performance measured as automotive exports across different stages of the supply chain. We take into account the differences of the two types of supply chain: (i) just-in-case (JIC) supply chain where the company orders more goods or services from suppliers than expected to sell; and (ii) just-in-time (JIT) supply chain where the company orders the exact units or services expected to sell to customers (United We Care, 2022). The next section presents an overview of the data and statistics related to Africa's human capital and automotive supply chain, part of which will then be used in the econometric analysis in the following sections.

3. Data and Statistics

This section analyses the level and trend of human capital, supply chains in Africa and the relationship of dependence between human capital and supply chains in Africa.

3.1 Data sources

Before analysing the human capital and supply chain statistics in Africa, it is worth clarifying the data sources used in this paper. Data on trade and supply chains are from the United Nations Comtrade database (UNComtrade) and the UNCTAD statistics database (UNCTADStat). According to United Nations (2022), "the United Nations Comtrade database aggregates detailed global annual and monthly trade statistics by product and trading partner for use by governments, academia, research institutes, and enterprises."
Education data used in the study is from the UNESCO Institute for Statistics (UIS). The UNESCO Institute for Statistics (UIS) is the official source of internationally-comparable data on education, science, culture and communication.

This paper uses the World Bank Human Capital Index, estimated by the World Bank under the Human Capital Project (HCP). According to World Bank (2020), the Human Capital is "a global effort to accelerate more and better investments in people for greater equity and economic growth. The Human Capital Project (HCP) aims to protect and invest in people. As of April 2023, the HCP has grown to a network of 87 committed governments participating and taking action in three distinct areas."
Data on human and natural capital values are from the World Bank's The Changing Wealth of Nations Reports on global wealth accounting. The latest edition, "The Changing Wealth of Nations 2021", provides an updated database and rich analysis of the world's wealth accounts spanning 146 countries, annually from 1995 to 2018. It contains the widest set of assets covered

so far, including human capital broken down by gender and many different forms of natural capital, spanning minerals, fossil fuels, forests, mangroves, marine fisheries and more (World Bank, 2020). The estimation of human capital under the Changing Wealth of Nations 2021 is inspired by Hamilton et al. (2018).
Other variables are from the World Bank World Development Indicators.

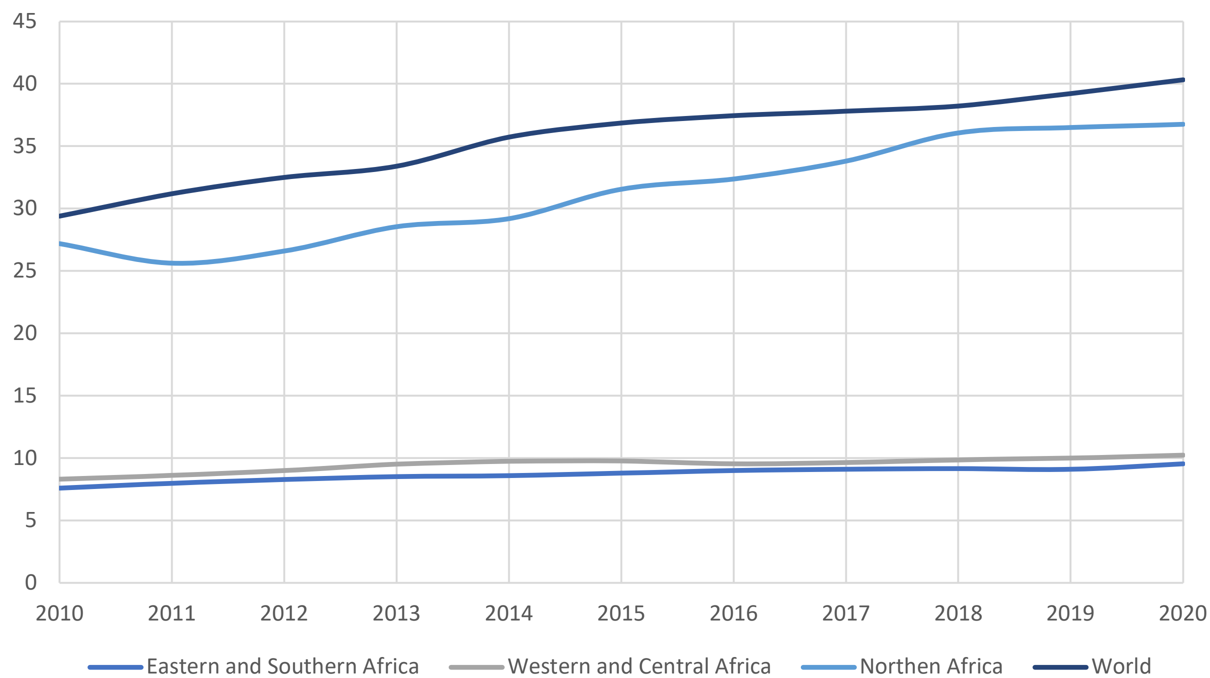
3.2 Measurements of Human Capital

To analyse human capital in Africa, we use various variables and indicators, including 3 measures from the indicator-based approach to human capital (gross enrolment ratio for tertiary education, researchers in research and development per million people, and the World Bank's Human Capital Index (HCI)), and a measure from the monetary measure-based approach to human capital (the World Bank's CWON value of human capital). In macroeconomic and econometric analyses, education level is most often used as a proxy for human capital (see Romer (1993), Quah (1996, 1997), Sala-i-Martin (1997a, 1997b), Barro and Lee (1994), Sachs and Warner (1995), Barro (1997), Murphy, Shleifer & Vishny (1991) and Durlauf et al. (2005)). While secondary education is commonly used (Murphy, Shleifer & Vishny, 1991; Sala-i-Martin, 1997a, 1997b), this study focuses on the enrolment ratio for tertiary education because higher value-added participation in supply chains often requires a higher level of education. In particular, Anyanwu (2018) found that primary and secondary education have no significant positive relationship with manufacturing value-added development in Africa, while tertiary education has a significant positive association.

We find that Africa's level of education, particularly the enrolment ratio for tertiary education (data from the UNESCO Institute for Statistics), is the lowest among the world continents. The gross enrolment ratios for tertiary education in Eastern, Southern, Western and Central Africa are four times lower than the world average in 2020. In fact, the gross enrolment ratios for tertiary education in Eastern and Southern Africa, and Western and Central Africa were 9.55 and 10.23 per cent in 2020, respectively, while the global average was 40.32 in 2020. The gross enrolment ratio for tertiary education in Northern Africa, with 36.75 per cent in 2020, is also lower than the global average. While since 2010, enrolment in tertiary education has increased considerably in the world and Northern Africa, the gross enrolment ratios for tertiary education have remained almost stable in other African subregions (Figure 1).

On a country level, Algeria is the only African country where the gross enrolment ratio for tertiary education is over 50 per cent. Only three African countries, namely Algeria (52.50), Mauritius (44.26), and Morocco (40.62), had tertiary school enrolment rates greater than the world average in 2020. In addition to these countries, Egypt, Tunisia, Namibia, Botswana, South Africa, Cabo Verde, and Gabon have a gross enrolment ratio for tertiary education of more than 20 per cent. In almost half of African countries, more than 90 per cent of youths of university age do not attend university.

Figure 1: Gross enrolment ratio for tertiary education (percentage)

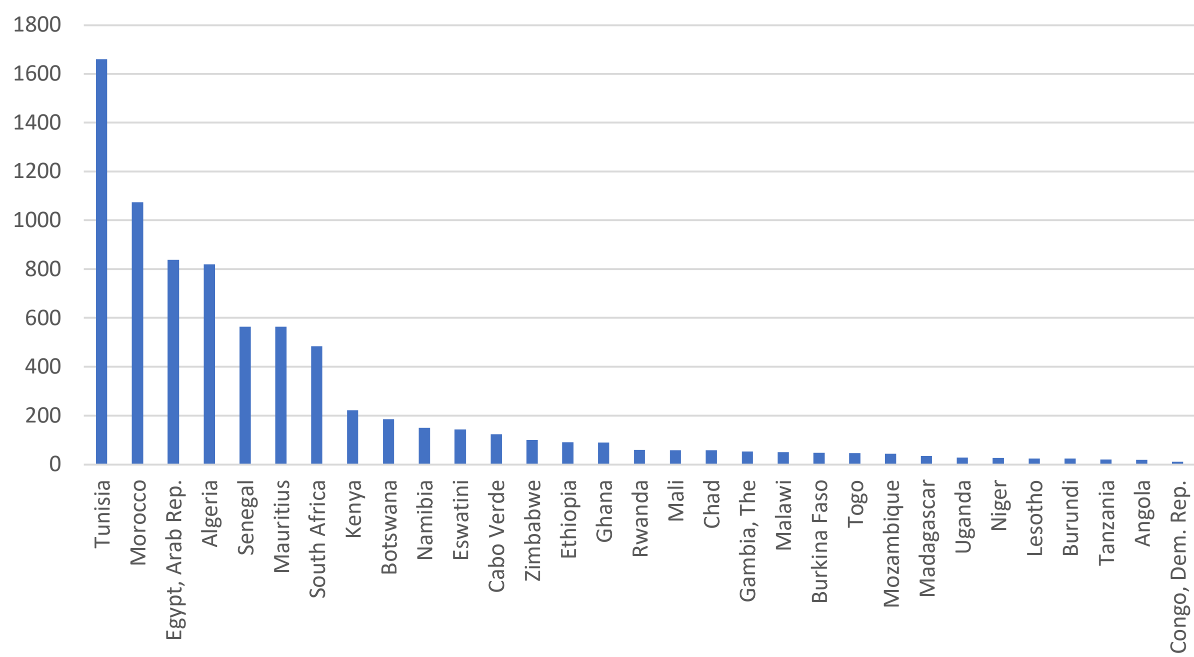


Source: UNCTAD calculations, based on UNESCO Institute for Statistics (UIS), and World Development Indicators

Moreover, there is an interdependence between the level of tertiary education and research in a country, even if the research concerns only graduate students. The more researchers and research centres a country has, the more its universities can attract students. On the other hand, many graduate students from a country encourage more research. Research capability also positively affects the supply chain since research is a part of supply chains and allows the development of policy actions for successful integration in the global supply chain.

Yet, unlike other continents, there are very few researchers in Africa, as a result of historical, institutional, financial, and macroeconomic reasons as well as the problems of gender imbalance and 'brain drain', that hinder effective investment in education and/or flourishing of the academic and research sectors (Aina, 2010; Mkandawire, 1995; Psacharopoulos, 1986; Teferra & Altbachl, 2004; Uwaifo Oyelere, 2007). Regarding researchers in research and development per million people (data from the World Bank World Development Indicators), only Tunisia, with 1660 researchers in research and development per million people, has a researcher rate per inhabitant more than the world average, which is 1597. Most African countries have less than 100 researchers in research and development per million people. Worldwide, developed countries, more particularly those in North America (with 4821 researchers in research and development per million people) and European Union countries (with 4171 researchers in research and development per million people), have the highest rate of researchers. In Africa, the rate is highest in North African countries (Tunisia, Morocco, Egypt, and Algeria), followed by Senegal, Mauritius, and South Africa (Figure 2).

Figure 2: Researchers in R&D (per million people) last data available between 2010 and 2020



Source: UNCTAD calculations, based on World Development Indicators

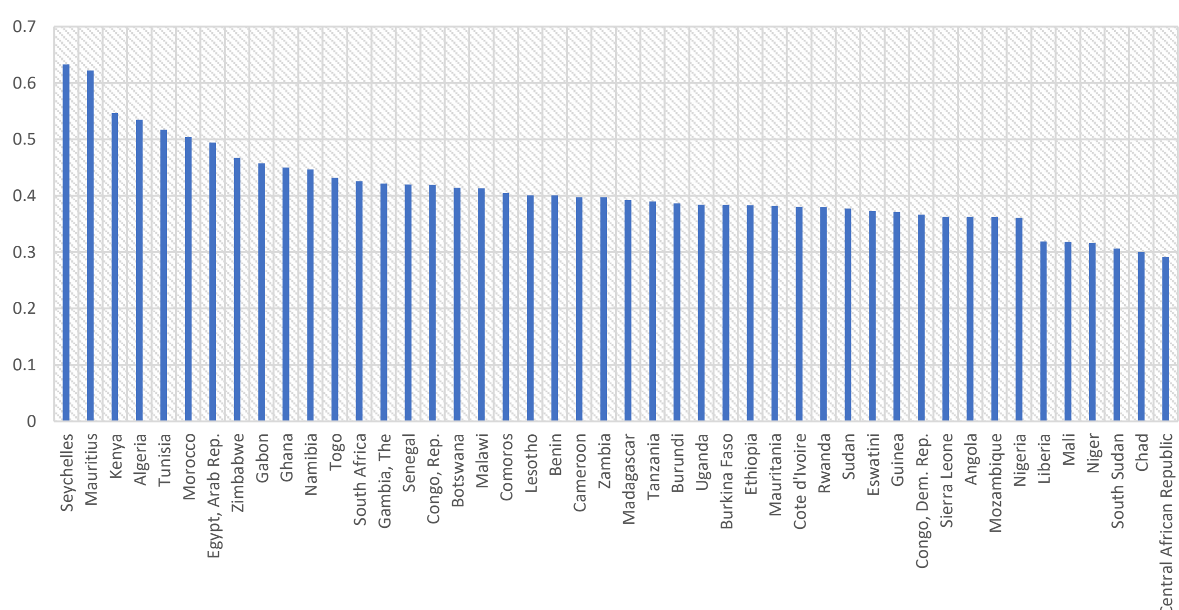
Although education and research are integral parts of human capital, human capital is not limited to these two measures; it also includes health. There are several ways to measure a country's human capital, such as the World Bank Human capital index, the component

'Human capital' of the UNCTAD Productive Capacity Index, the component 'Human capital' of the World Bank Wealth of Nations, and the Human Development Index of UNDP.

The World Bank's Human Capital Index (HCI) ranges from 0 (worse) to 1 (best). It is an international metric that benchmarks the key components of human capital across economies. This Human capital index highlights how current health and education outcomes shape the productivity of the next generation of workers and underscores the importance of government and societal investments in human capital (World Bank, 2020). According to the World Bank (2020), more human capital is associated with higher earnings for people, higher income for countries, and stronger cohesion in societies.

The Human Capital Index ranged from 0.29 (Central African Republic) to 0.63 (Seychelles) in Africa. It is in two SIDS (Seychelles and Mauritius, with 0.63 and 0.62, respectively) that the Human Capital Index is highest in Africa, followed by Kenya, with 0.55, and four North African countries (Algeria, Tunisia, Morocco, and Egypt, in order). It is in LLDCs, particularly in Mali (with 0.32), Niger (with 0.32), South Sudan (with 0.31), Chad (with 0.30) and Central African Republic (with 0.29), where the human capital index is the lowest in Africa.

Figure 3: Human capital index (scale 0-1) for African countries in 2020



Source: UNCTAD calculations, based on World Development Indicators

The values of human capital, as a component of the Wealth of Nations, were modelled by the World Bank (2021), measuring the discounted value of future earnings for a country's labour force, the likelihood that various types of individuals will be working and how much they will earn when working need to be known (Hamilton et al., 2018). Its latest estimate is from 2018. This human capital measure, adopting a direct monetary approach to estimating human capital, considers the present value of future earnings for the labour force.

According to this estimate, Africa, except Northern Africa, is the region with the least human capital in 2018. While in 1995, on average, Sub-Saharan Africa had a human capital per capita higher than those of South Asia ($ 7,870 vs 6,089), the value of Human capital per capita of Sub-Saharan Africa became lower than those of South Asia ($ 12,278 vs 14,769) in 2018 (Table 1). The human capital per capita was estimated at $ 30,989 in the Middle East & North Africa in 2018. North America had the highest human capita, with $ 612,452 per capita in 2018. Furthermore, East Asia and the Pacific invested well in human capital; its human capital per capita increased by 140 per cent between 1995 and 2018, from $ 49,107 per capita in 1995 to $ 118,093 per capita in 2018.

Table 1: Value of Human Capital (per capita, constant 2018 USD)

Human Capital (per capita, constant 2018 USD)	1995	2000	2005	2010	2015	2018
East Asia & Pacific	49,107	55,790	65,061	82,052	105,384	118,041
Europe & Central Asia	128,957	142,468	152,194	163,012	171,434	180,093
Latin America & Caribbean	44,848	47,913	49,579	56,208	64,698	66,709
Middle East & North Africa	26,801	26,396	26,261	30,332	31,764	30,989
North America	461,403	536,869	546,905	537,602	585,338	612,452
South Asia	6,089	7,142	8,490	10,130	12,513	14,769
Sub-Saharan Africa	7,870	7,228	7,747	10,613	12,062	12,278

Source: UNCTAD calculations, based on World Bank (2021).

3.3 Measuring Automotive supply chain performance in Africa

In this part, we analyse the supply chain in the automotive sector in Africa. The automotive supply chain comprises final vehicles, supporting equipment for automotive, supporting activities and services for automotive, automotive tier 1, tier 2 and tier 3 products. This decomposition of the automotive supply chain and classification of HS codes into each stage of the supply chain are based on Bam et al. (2021) and Sanon & Slany (2023). In general, the fundamental steps of a supply chain, as for Techtarget Network (2021), include:

- Sourcing raw materials, provided by tier 3 suppliers;
- Refining those materials into basic parts, provided by tier 2 suppliers;
- Combining those basic parts to create a product, provided by tier 1 suppliers;
- Order fulfilment/sales;
- Product delivery; and
- Customer support and return services.

The automotive supply chain generally includes the following:

- Final vehicles – such as tractors, diesel powered buses, motor cars and other motor vehicles, dump trucks, and mobile cranes, that are ready for wholesale and distribution;
- Automotive tier 1 products - automotive parts and components including: pneumatic tyres, locks, engines and parts, cooling pumps, compressors for refrigerating equipment, electric fans, parts for air conditioners, air filters, transmission shafts and cranks, electric accumulators, starter motors, ignition magnetos, generators and alternators, radio receivers, safety seat belts, brake system parts, wheels, shock absorbers, radiators, mufflers and exhaust pipes, steering wheels, speed indicators, seats and parts of seats;
- Automotive tier 2 products - non-automotive parts and components used for production of automotive parts and components including: acrylic and vinyl polymer based paint, lead-acid electric accumulators, rubber tube, inner tubes of rubber, safety glass, rear-view mirrors, aluminium structures and parts for construction, bearings and parts, filament lamps, semiconductor devices, bumpers and parts.;
- Automotive tier 3 products - raw and semi-raw materials, used automotive supply chain including: natural graphite, silica sands and quartz sands, iron ore, manganese ores, copper ores, nickel ores, aluminium ores, natural rubber latex, bovine skins, cotton, iron or non-alloy steel in ingots, copper in various forms, cobalt ores, alkali metals, polypropylene, polyvinyl chloride, polyurethanes;

- Supporting equipment or services – such as screws, skip hoists, tube mills, metal rolling, machine tools to forge metals, screwdriver bits, industrial robots, metal treating machines, and electric wire coil-winders.

We analyse the total and intra-African exports of the African automotive supply chain components. We use the export data from UNComtrade database (HS 2012 at 4- and 6-digit levels) and we only consider African countries which do participate in automotive exports along the supply chain and have available data.[2] Figures 4 and 5 provide total African and intra-Africa exports of automotive supply chain products. The African continent intervenes in the automotive supply chain mainly in the supply of raw materials, which does not require specialised human capital in supplier countries since it is mainly foreign companies that exploit these raw materials. However, the recipient country could benefit from the transfer of skills and capital.

Between 2018 and 2022, total exports of automotive tier 3 products – raw materials – were around $35 billion in Africa, while total exports of final vehicles did not exceed $15 billion. Exports of other components were below $5 billion. Figure 4 shows that exports of automotive raw materials jumped between 2016 and 2018 from $24.93 billion in 2016 to $26.46 billion in 2018, between two stable periods: 2012-2016 and 2018-2022. Exports of automotive tier 1 products have remained steady at around $5 billion since 2012.

Focussing on the African regional supply chain in the automotive sector, Figure 5 shows that during the last years, the continent became less involved in the regional supply chain in the automotive sector. Since 2018, we are witnessing a drop in intra-African trade of automotive tier 3 products from $6.83 billion in 2018 to $2.03 billion in 2022[3]. The intra-African exports of final vehicles decreased from $2.86 billion in 2014 to $1.52 billion in 2022, while the intra-African exports of automotive tier 1 products decreased from $1.06 billion in 2012 to $0.81 billion in 2022.

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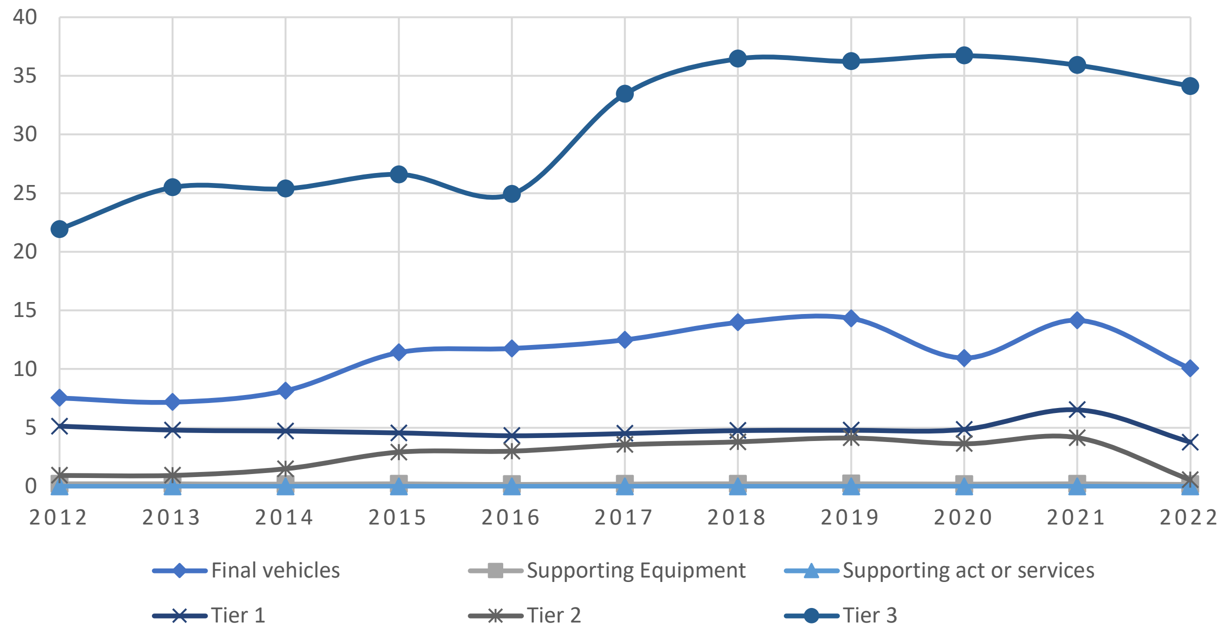
[2] The list of African countries in our export data from UNComtrade does not include Algeria, Chad, Djibouti, Equatorial Guinea, Eritrea, Gabon, Guinea, Guinea-Bissau, Liberia, South Sudan, Sao Tome and Principe, and Somalia.

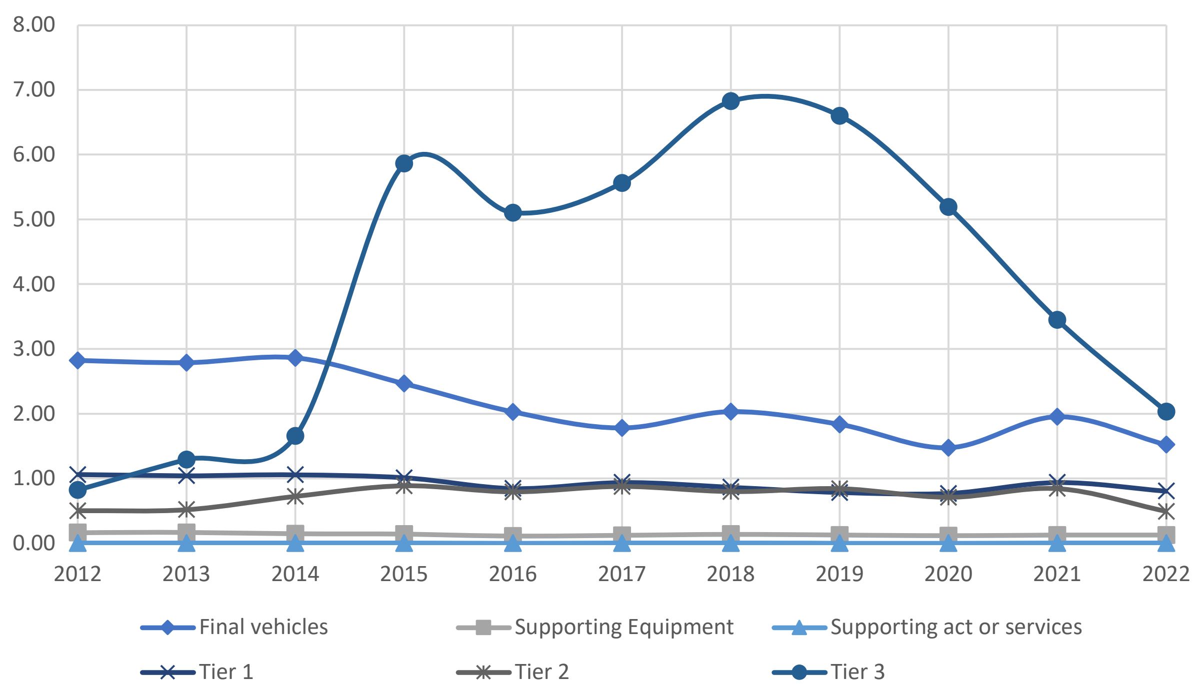
[3] The data could be incomplete for 2022, as few countries have not yet reported all data for 2022, potentially explaining the drop from 2021 to 2022.

Figure 4: African exports of automotive supply chain products (in billion USD)



Source: UNCTAD calculations, based on UNComtrade database

Figure 5: Intra-African exports of automotive supply chain products (in billion USD)



Source: UNCTAD calculations, based on the UNComtrade database

Table 2: Share of total African exports of automotive supply chain products (in percentage)

Countries	Final vehicles	Supporting Equipment	Supporting activities or services	Tier 1	Tier 2	Tier 3
South Africa	70.79	66.95	84.25	61.62	11.00	39.65
Morocco	25.76	12.81	1.25	16.96	55.19	0.44
Egypt, Arab Rep.	0.60	4.11	0.00	2.92	13.03	2.59
Tunisia	0.30	4.90	7.94	15.55	12.78	0.13
Tanzania	0.30	1.24	3.12	0.16	0.19	0.14
Kenya	0.28	1.15	0.27	0.49	1.04	0.06
Botswana	0.19	0.36	0.10	0.34	2.92	0.03
Cote d'Ivoire	0.18	1.58	0.11	0.06	1.15	3.75
Zambia	0.11	0.66	0.04	0.50	0.09	16.29
Congo, Dem. Rep.	0.11	0.27	0.09	0.07	0.01	24.97
Angola	0.04	1.17	0.11	0.11	0.06	0.01
Mozambique	0.03	0.31	0.02	0.09	0.02	2.02
Zimbabwe	0.02	0.11	0.66	0.11	0.13	2.29
Cameroon	0.02	0.05	0.00	0.02	0.15	1.08
Ghana	0.02	0.28	1.44	0.09	1.51	1.41
Mauritania	0.01	0.02	0.01	0.01	0.00	2.76
Benin	0.01	0.05	0.00	0.01	0.04	1.23

Source: UNCTAD calculations, based on UNComtrade database

The country-based analysis reveals that South Africa is, by far, the most developed African country in the automotive supply chain. This country alone exports more than 70 per cent of African final vehicles. It is followed by Morocco, which exports a quarter of African final vehicles. Thus, these two countries export more than 96.5 per cent of African final vehicles. No other country exports more than 1 per cent of African final vehicles. Moreover, South Africa exports two-thirds of African automotive supporting equipment, followed by Morocco with 12.8 per cent. Tunisia stands out in exports of automotive supporting activities or services, tier 1 and 2 products. Tunisia exports about 8 per cent of African automotive supporting activities or services, far behind South Africa with 84.25 per cent. Tunisia exports 15.55 per cent of African automotive tier 1 products far behind South Africa with 61.6 per cent and just behind Morocco with 16.96 per cent. Morocco has specialised in producing automotive tier 2 products in the African automotive supply chain, as it exports more than half of African automotive tier 2 products. Egypt stood out for this automotive supply chain component as the second African exporting country of automotive tier 2 products, with 13 per cent, far behind Morocco and just ahead of Tunisia with 12.8 per cent and South Africa with 11 per cent. The Democratic Republic of Congo and Zambia are involved in the automotive supply chain, as a supplier of raw materials. Respectively second and third exporter of automotive raw materials behind South Africa, the Democratic Republic of Congo and Zambia export a quarter and 16.3 per cent of African exports of automotive raw materials.

At the intra-African exports of automotive supply chain level, South Africa still dominates along the chain, except in tier 3 products – raw materials – where the Democratic Republic of Congo exports two-thirds of automotive raw materials intended for African countries (see Annex – Table A1). Other African countries, in addition to those mentioned above, intervene significantly in intra-African exports of automotive tier 2 products, such as Botswana, Ghana, Côte d'Ivoire and Kenya in with respectively 14.36 per cent, 7.41 per cent, 5.40 per cent and 5.06 per cent. Zimbabwe intervenes in selling to African countries of automotive tier 3 raw materials with 12.35 per cent.

In order to verify the interdependence between the different components of automotive supply chains in Africa, we make bilateral correlations between exports of final vehicles, automotive supporting equipment, activities or services, tier 1, tier 2 and 3 products. The correlations table (Annex – Table A2) between total exports suggests significant dependencies between all components, except between automotive tier 2 and tier 3 products. The dependence is very strong between exports of automotive supporting equipment with final vehicles, automotive supporting activities or services, and automotive tier 1 products, with correlations above 0.80. The strongest dependency is between automotive supporting activities or services and automotive tier 1 products, with a correlation of 0.90. The correlations between automotive tier 2 products and other automotive supply chain products are relatively lower, with a correlation of less than 0.50, but remain significant at the 1% threshold, except with tier 3 products where the correlation is not significant even at the 10% threshold.

The interdependence between the different components of automotive supply chains in Africa is less strong when considering intra-African exports. The table of correlations (Annex – Table A3) between intra-African exports suggests no dependence between the intra-African trade of automotive raw materials and the other automotive supply chain components because the corresponding correlations are not significant even at the 10 per cent threshold. However, there is an interdependence between all intra-African exports of other components of the automotive supply chain: final vehicles, automotive supporting equipment, activities or services, tier 1, and tier 2 products, except between automotive supporting activities or services and automotive tier 2 products where the correlation is not significant.

3.4 Relation between human capital and supply chain performance

A correlation between the exports of the different components of the automotive supply chain with variables and indicators of human capital shows a dependence between the automotive supply chain and human capital in Africa. Table 3 shows that countries with a high enrolment rate for tertiary education are also the countries that export the most different components of the automotive supply chain except automotive raw materials. There is a dependency between development research with automotive supporting activities or services, tier 1 and 2 products, while there is no dependence between development research with exports of final vehicles, automotive supporting equipment, and automotive tier 3 products.

Moreover, a positive and significant correlation exists between the human capital index and the automotive supporting equipment, automotive tier 1 and 2 products. Its correlation with automotive supporting activities or services is only significant at the 10 per cent threshold. Its correlation is not significant with final vehicles and automotive tier 3 products. The table shows a significant dependence on the value of Human Capital per capita with all components of the automotive supply chain in Africa. Furthermore, automotive tier 1 and 2 product exports are significantly linked with all four supply chain variables and indicators. Exports of automotive supporting activities or services are also linked with all four supply chain variables and indicators; its dependence on the human capital index is only significant at the 10 per cent threshold. However, exports of automotive raw materials are only correlated to the value of human capital per capita.

Table 3: Correlation between automotive supply chain and human capital for all African countries with available data from 1995 to 2020.

	Enrolment for tertiary education	Researchers in R&D	Human capital index	Human Capital Value
Final vehicles	0.22 ***	-0.01	0.12	0.43 ***
Supporting Equipment	0.28 ***	0.20	0.27 **	0.53 ***
Supporting activities or services	0.33 ***	0.37 **	0.24 *	0.38 ***
Tier 1	0.36 ***	0.64 ***	0.24 **	0.35 ***
Tier 2	0.50 ***	0.92 ***	0.32 ***	0.33 ***
Tier 3	-0,01	-0.07	-0.09	0.30 ***

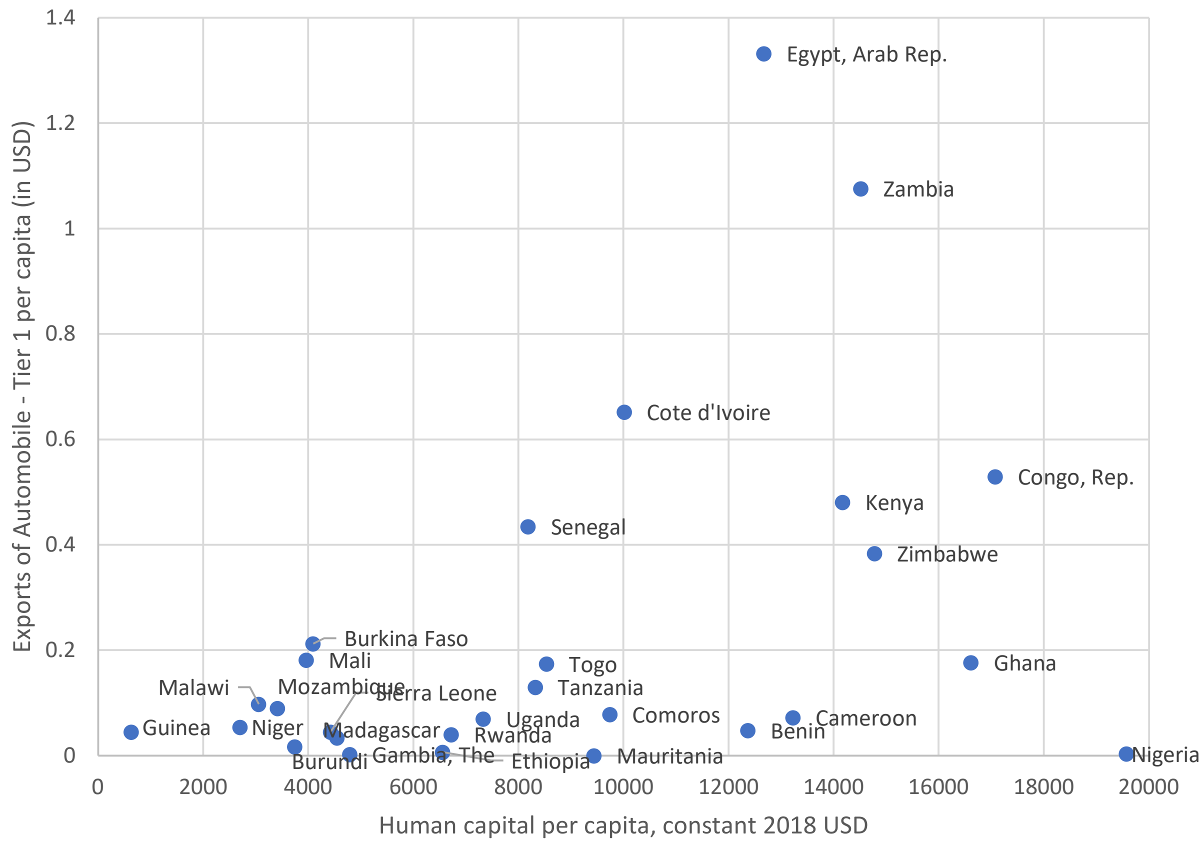
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Source: UNCTAD calculations, based on various sources

The figure below illustrates the correlation between the value of human capital per capita and exports of automotive tier 1 products. The figure reveals a concentration of African countries with low human capital and low integration in the automotive supply chain, considering exports of automotive tier 1 products. This is the case of countries like Guinea, Niger, Malawi, Burundi, and Mali, all having a human capital of less than $ 4000 and having automotive tier 1 products exports per capita of less than $ 0.2 per capita, on average over the years 2016-2018. Overall, countries with high human capital tend to have higher exports of automotive tier 1, as the case of Egypt, Zambia, the Republic of Congo, and Kenya, all having both a per capita human capital of over $12,000 and a per capita export of automotive tier 1 over $0.4 over the 2016-2018 average. However, some countries have very high human capital without being well integrated into the automotive supply chain, such as Benin, Cameroon, Ghana and Nigeria, all having human capital of more than $ 12,000 per capita and exports per capita of less than $ 0.2.

We also note that the figure does not represent all African countries, as it excluded countries with outlier values of supply chain, such as South Africa, with an average export per capita of automotive tier 1 products of $ 58.23 over the years 2016-2018, Tunisia with $ 64.18, and to a small extent, countries like Botswana with $ 8.43, Lesotho with $ 7.13, Morocco with $ 10.83, and Namibia with $5.78. All these countries have also very high human capital per capita. This analysis shows that human capital can be considered a determining capability in developing supply chains, particularly automotive supply chains in Africa. In the following sections, we perform econometric modelling to consider to what extent human capital is a critical asset to the automotive supply chain in Africa.

Figure 6: Relation between exports of automotive Tier 1 and Human capital value per capita (average 2016-2018)



Source: UNCTAD calculations, based on UNComtrade database and World Bank (2021)

4. Econometric model and results

4.1 Description of Econometric model

To further confirm human capital as a key asset to the automotive supply chain performance in Africa, we estimate econometric models to analyse the effect of human capital wealth stock on exports along the automotive supply chain. The dependent variables are the various exports of automotive supply chain which are our measures of Africa's automotive supply chain performance, as export performance is often considered a key indicator of local manufacturing capacity and success (Black & McLennan, 2016). We focus on automotive tier 1, tier 2, and tier 3 products. Therefore, we have a vector of dependent variables. We use exports per capita of automotive tier 1, 2 and 3 products to eliminate the population effect on the values.

The main independent variable is the human capital component of the Wealth of Nations, estimated by the World Bank (2021). Like exports, we use per capita values of human capital. We use the CWON measure of human capital that estimates the current stock of human capital in monetary terms, as the present value of total expected future earnings of the entire labour force, from a financial wealth accounting perspective. The estimation process does not only derive human capital outcomes indirectly from variables related to educational attainment and health, but also account for labour market outcomes such as probability of employment and labour market premiums across countries (World Bank, 2021). We recognise that the CWON measure remains an imperfect estimate of human capital, like all measures of human capital: it underestimates human capital as it leaves out positive externalities; it omits human capital that produces household services; it assumes a relatively stable GDP that grows moderate over the working life of 50 years which is a condition not easily satisfied by countries experiencing natural disasters or wars (Hamilton et al., 2018; World Bank, 2021). However, compared to other measures of human capital, the CWON measure emphasises the intrinsic value of a good education and good wealth, as well as the role of human capital as a productive asset that generates income through wages and earnings which are important indicators of successful value chain upgrading, economic growth, and poverty reduction (World Bank, 2021).

In the econometric modelling, the covariates also include natural capital: renewable natural capital and non-renewable natural capital. These data are from the World Bank Wealth of Nations. A country's natural capital can directly act on its supply chain, especially at the tier 3 supply chain level (Lok et al., 2018; University of Cambridge Programme for Sustainability Leadership, 2011; Capitals Coalition, 2014; McKinsey & Company, 2022). Lok et al. (2018) found that understanding businesses and industries' dependency on natural capital helps them build resilience in their supply chain. According to Capitals Coalition (2014), natural capital is the one element on which the entire value chain depends and impacts, as it provides essential services to businesses, economies and society. The effect of natural capital on the supply chain may differ from whether natural capital is renewable or not.

In addition, the fact that a country is a least developed country (LDC), a landlocked developing country (LLDC), or a small island developing state (SIDS) can have potential linkages with its supply chains, including the automotive supply chain. The geographical position of LLDCs and SIDSs could affect their trade. For instance, the LLDCs are obliged to go through other countries to make maritime trade, so they depend heavily on the conditions and characteristics of these coastal partner countries, such as road and port characteristics and corridors, which strongly limit their supply chain. For example, Ethiopia, a landlocked developing country with 123 million inhabitants, needs Kenya, Eritrea, Sudan, Somalia, or Djibouti to access a littoral. While the country's supply chain is based on its freight transport, Ethiopia's freight transport sector servicing the global supply chain relies on a handful of corridors and infrastructure offerings, given its economic and landlocked geography (UNCTAD, 2022b). The Addis Ababa-Djibouti corridor has, by far, the greatest share of international freight movements of Ethiopia, with the port of Djibouti handling over 95 per cent of Ethiopian foreign trade by volume. Unfortunately, the port of Djibouti faces a lot of infrastructure challenges.

The LLDC situation is the opposite in the case of SIDSs on the supply chain issues because, unlike LLDCs, SIDSs have direct access to the sea and do not depend on any country for their maritime trades. However, these countries are stuffed with road or ferrous intra-border trade; their global and regional supply chains are limited only to air and maritime transport, which would negatively affect their supply chain. They are also quite remote and transport costs are high. LDCs, other than LLDCs and SIDSs, which in principle do not have geographical problems for the progress of their supply chain, are not immune to malfunctions in the supply chain because of their economic structure, which limits their exports. For example, according to Akiwumi and Adhikari (2022), the Least Developed Countries have a limited capacity to react to exogenous shocks, which makes their socio-economic progress fragile. The authors found that LDCs have the weakest productive capacities in the world, using UNCTAD's productive capacity index (PCI). In addition, LDCs lag behind other developing countries across all PCI sub-categories, including natural capital, human capital, energy, ICTs, transport, private sector, institutions and structural change (Akiwumi & Adhikari, 2022; UNCTAD, 2020).

The model is in the following form:

$$ASC = f(HC, NCR, NCNR, LDC, LLDC, SIDS)$$

Where

ASC represents the vector of automotive supply chains,

HC, human capital per capita,

NCR, renewable natural capital,

$NCNR$, non-renewable natural capital,

LDC is the dummy variable taking 1 if the country is LDC,

$LLDC$ is the dummy variable taking 1 if the country is LLDC,

$SIDS$ is the dummy variable taking 1 if the country is SIDS.

It should be noted that a country can be simultaneously LLDC and LDC. For example, in Africa, 13 out of the 16 African LLDCs are LDCs. Botswana, Eswatini, and Zimbabwe are the only LLDCs that are not not LDCs. Similarly, a country can be simultaneously SIDS and LDC, such as Comoros.

We use panel data from all African countries with data available on exports of automotive tier 1, 2 and 3 products and human capital. Due to the lack of regular data in African countries over the years, we are dealing with an unbalanced panel data set. The econometric model can be rewritten as follows:

$$ASC_{it} = A_0 + A_1\, HC_{it} + A_2\, NCR_{it} + A_3\, NCNR_{it} + A_4\, LDC_i + A_5\, LLDC_i + A_6\, SIDS_i + \varepsilon_{it}$$

with i representing the country and t the year. $A_0, A_1, \dots, A_6$ are parameter vectors.

This model keeps the LDC, LLDC, and SIDS statuses invariable over time. Throughout the period, no African country left or joined LLDC or SIDS status, and very few African countries joined or left LDC status.

4.2 Choice of the econometrics model

While a supply chain is defined as a "network of all the individuals, organisations, resources, activities and technology involved in the creation and sale of a product", according to Techtarget Network (2021), the dependent variables of the model are components of automotive supply chains. Since we have a vector of dependent variables that interact with each other in the form of a network, we are dealing with an econometric model of dynamic relationships. Thus, the model can be estimated by a Vector autoregression (VAR) model, Simultaneous equation model, Structural equation model, or simultaneous Vector autoregression (VAR) model. The choice of model depends on the characteristics of the supply chain, either just-in-time, just-in-case, or combined just-in-time and just-in-case supply chain.

In fact, a "Just-in-time" supply chain, also called pull system of supply chain, according to United We Care (2022), is a strategy in which a company orders from suppliers, goods or services when required and produces exact units of goods or services expected to sell to customers and clients. Thus, the variables in the "just-in-time" supply chain model are related to the other network variables at the current time. Therefore, the simultaneous equation model is the econometric model relative to this network system. The simultaneous equation model is a reduced form of a structural model in which some equations contain endogenous variables among the explanatory variables, and these endogenous variables are the dependent variables of other equations in the system (Zellner and Theil, 1962; Theil 1971; Martin et al., 2013; Davidson and MacKinnon, 1993; and Greene, 2012).

A "Just-in-case" supply chain, also called a push system in a supply chain, is a strategy in which a company orders excess goods or services from suppliers than required and produces more goods or services than expected to sell (United We Care, 2022). In the "Just-in-case" supply chain, the supply chain managers forecast the supply chain activities in ordering goods and services from the last period. Thus, the variables in the "just-in-case" supply chain model depend on the previous variables of the network, so the relevant econometric model to estimate the effects on supply chain activities is vector autoregression (VAR). The VAR is a system of many unilateral autoregression in a network. According to Prabhakaran (2019), a Vector Autoregression (VAR) is a multivariate forecasting algorithm that is used when two or more time series influence each other.

Furthermore, supply chain flexibility employs a hybrid push-pull inventory system to have some stages of the supply chain operate as "just-in-time" while others operate in "just-in-case", i.e., having a more accurate demand forecast than a "just-in-case" system but doesn't aim to keep standing inventory at zero, as in "just-in-case" systems (Oracle NetSuite, 2021). The equivalent econometric model combines the simultaneous equation model and the vector autoregression (VAR), which is the simultaneous vector autoregression. The data availability issue means that we cannot perform a Simultaneous VAR model, as this model is very restrictive in terms of data availability. In the following, we estimate the econometric model by Vector autoregression (VAR) and Simultaneous Equation Model.

In the case of the VAR model modelling automotive a just-in-case supply chain, we have:

$$ASC_{it} = A_0 + B\,ASC_{it-1} + A_1\,HC_{it} + A_2\,NCR_{it} + A_3\,NCNR_{it} + \varepsilon_{it}$$

Where $A0, A1, A2, A3$ and B are parameter vectors.

In VAR models, time-invariable variables disappear, so the coefficients of the LDC, LLDC and SIDS dummy variables are not estimated.

Explicitly, we can write our model as follows:

$$\begin{cases} Tier1_{it} = b_{11}\,Tier1_{it-1} + b_{12}\,Tier2_{it-1} + b_{13}\,Tier3_{it-1} \\ \qquad + \alpha_0 + \alpha_1 HC_{it} + \alpha_2 NCR_{it} + \alpha_3 NCNR_{it} + \varepsilon_{it} \\ Tier2_{it} = b_{21}\,Tier1_{it-1} + b_{22}\,Tier2_{it-1} + b_{23}\,Tier3_{it-1} \\ \qquad + \beta_0 + \beta_1 HC_{it} + \beta_2 NCR_{it} + \beta_3 NCNR_{it} + \varepsilon_{it} \\ Tier3_{it} = b_{31}\,Tier1_{it-1} + b_{32}\,Tier2_{it-1} + b_{33}\,Tier3_{it-1} \\ \qquad + \gamma_0 + \gamma_1 HC_{it} + \gamma_2 NCR_{it} + \gamma_3 NCNR_{it} + \varepsilon_{it} \end{cases}$$

Where
$b_{11}, b_{12}, b_{13}, b_{21}, b_{22}, b_{23}, b_{31}, b_{32}, b_{33}, \alpha_0, \ldots, \alpha_3, \beta_0, \ldots, \beta_3, \gamma_0, \ldots, \gamma_3$ are parameters to be estimated. In practice, the model is estimated by Panel VAR because of the time dimension.

In the case of the simultaneous equation models modelling just-in-time supply chains, we have

$$\begin{aligned} ASC_{it} = A_0 + C\,ASC_{it} + A_1\,HC_{it} + A_2\,NCR_{it} + A_3\,NCNR_{it} + A_4\,LDC_i + A_5\,LLDC_i \\ + A_6\,SIDS_i + \varepsilon_{it} \end{aligned}$$

Where $A0, A1, A2, A3$ and C are parameter vectors.

Explicitly the model is written:

$$\begin{cases} Tier1_{it} = c_{11}\, Tier2_{it} + \alpha_0 + \alpha_1 HC_{it} + \alpha_2 Equip_{it} + \alpha_3 Activ_{it} \\ \quad +\alpha_4 LDC_i + \alpha_5 LLDC_i + \alpha_6 SIDS_i + \varepsilon_{it} \\ Tier2_{it} = c_{21}\, Tier1_{it} + c_{22}\, Tier3_{it} + \beta_0 + \beta_1 HC_{it} \\ \quad +\beta_4 LDC_i + \beta_5 LLDC_i + \beta_6 SIDS_i + \varepsilon_{it} \\ Tier3_{it} = c_{31}\, Tier2_{it} + \gamma_0 + \gamma_1 HC_{it} + \gamma_2 NCR_{it} + \gamma_3 NCNR_{it} \\ \quad +\gamma_4 LDC_i + \gamma_5 LLDC_i + \gamma_6 SIDS_i + \varepsilon_{it} \end{cases}$$

Where
$Equip_{it}$ is the exports of automotive supporting equipment, and $Activ_{it}$ is the exports of automotive supporting activities or services of the country i in time t.

The simultaneous model requires that each individual model must have at least one covariate in its equation that is not in the other equations to have a good identification of the estimates of the simultaneous model. Identification in a system of simultaneous equations involves the notion that there is enough information to estimate the parameters of the model given the specified functional form. Identification requires rigorous conditions for each structural equation in the system, including the presence of noncollinear exogenous variables in the remaining system (Stata 18 documentation, 2023; Theil, 1971; Greene, 2012).

Thus, while natural capital is linked to the supply chain, it is explicitly linked to the tier 3 supply chain. Thus, natural capital will only appear in the tier 3 supply chain model. Automotive supporting equipment and supporting activities or services are components of automotive supply chains intervening mainly on automotive tier 1 products. These two variables will be added to the model of tier 1. Moreover, in the network of supply chain, there are no direct links between tier 1 and 3 supply chain; their interaction goes through automotive tier 2. Therefore, the model of tier 1 excludes the tier 3 variable and tier 3 model excludes the tier 1 variable.

In the case of the model combining just in time and just in case modelling by simultaneous VAR, the model is written:

$$ASC_{it} = A_0 + B\, ASC_{it-1} + C\, ASC_{it} + A_1\, HC_{it} + A_2\, NCR_{it} + A_3\, NCNR_{it} + \varepsilon_{it}$$

Where $A0, A1, A2, A3, B$ and C are parameter vectors.

This more complex model must simultaneously comply with the validity conditions of VAR and the simultaneous equation model. In that case, the time-invariable variables disappear, so the coefficients of the LDC, LLDC and SIDS indicator variables are excluded. Also, this model requires the identification conditions, as defined in the simultaneous model.

Explicitly, the model is written as follows:

$$\begin{cases} Tier1_{it} = b_{11}\,Tier1_{it-1} + b_{12}\,Tier2_{it-1} + b_{13}\,Tier3_{it-1} + c_{11}\,Tier2_{it} \\ \qquad + \alpha_0 + \alpha_1 HC_{it} + \alpha_2 Equip_{it} + \alpha_3 Activ_{it} + \varepsilon_{it} \\ Tier2_{it} = b_{21}\,Tier1_{it-1} + b_{22}\,Tier2_{it-1} + b_{23}\,Tier3_{it-1} + c_{21}\,Tier1_{it} \\ \qquad + c_{22}\,Tier3_{it} + \beta_0 + \beta_1 HC_{it} + \varepsilon_{it} \\ Tier3_{it} = b_{31}\,Tier1_{it-1} + b_{32}\,Tier2_{it-1} + b_{33}\,Tier3_{it-1} + c_{31}\,Tier2_{it} \\ \qquad + \gamma_0 + \gamma_1 HC_{it} + \gamma_2 NCR_{it} + \gamma_3 NCNR_{it} + \varepsilon_{it} \end{cases}$$

4.3 Econometrics results

This section presents the results of the two econometric models modelling the Just-in-case and just-in-time supply chain: Panel VAR and Simultaneous Equation Models. We have excluded outliers in the regression. Outliers lead to estimation biases in econometric models (Wilcox, 2022; Siegel and Wagner, 2022). In our model, outliers are obtained by analysing the distribution of dependent variables: exports of automotive tier 1, 2, and 3 products. The outliers in this analysis include the values of exports of tier 1 products per capita greater than \$10 of tier 2 products per capita greater than \$10, and of tier 3 products per capita greater than \$100. For instance, the outliers include Tunisia, South Africa and Tunisia for all years, Botswana (from 2014-2018), the Democratic republic of Congo in 2018, Lesotho (2016 and 2017), and Morocco (from 2015 to 2018).

The following table provides an inter-temporal summary, including average values, standard deviation, minimum and maximum of the main variables used in the model. The table shows that the average value of exports of automotive Tier 1 and 2 products are very low compared to the average values of Tier 3. The table presents the regression results of exports of the automotive supply chain on human capital per capita using the Panel VAR model. The model results are the additional effects on exports when considering exports from previous years, i.e., whether supply chain managers have considered their exports in automotive supply chains from previous years. Our model is robust, but convergence has remained incomplete for estimating several standard deviations. For instance, convergence is not complete for the estimation of standard deviations of lagged values of automotive tier 1, 2, and 3 products as well as standard deviations of population coefficients, which prevents analysis of the significance of the coefficients of these variables.

Table 4: Inter-temporal summary of the main variables in the models

Variable	Mean	Std. dev.	Min	Max
Auto Tier 1 (exports per capita)	0.36	0.74	0.00	5.48
Auto Tier 2 (exports per capita)	0.65	1.27	0.00	7.76
Auto Tier 3 (exports per capita)	10.93	18.80	0.00	92.25
Human capital per capita	11'887.60	11'069.56	572.07	48'658.54
Renewable Natural capital per capita	3'536.99	1'850.70	678.67	9'022.06
Non-renewable Natural capital per capita	1'556.05	3'621.66	0.00	17'236.42
Population (in millions)	29.90	35.81	0.10	195.87
LDC	0.60	0.49	0.00	1.00
LLDC	0.36	0.48	0.00	1.00
SIDS	0.08	0.26	0.00	1.00

The table 5 presents the regression results of exports of the automotive supply chain on human capital per capita using the Panel VAR model. The model results can be interpreted as the additional effects on exports when considering exports from the previous year, i.e., supply chain managers have considered their exports in automotive supply chains from previous years. Our model is robust, but convergence has remained incomplete for estimating several estimators. For instance, convergence is not complete for the estimation of standard deviations of lagged values of automotive tier 1, 2, and 3, as well as standard deviations of population coefficients, which prevents analysis of the significance of the coefficients of these variables.

The model confirms the capability of human capital for automotive supply chain development in Africa, as the effect of human capital is positive and significant at the 1 per cent threshold on exports of components of the automotive supply chain in Africa. Thus, ceteris paribus, an increase in human capital per capita leads to a significant increase in exports of the various components of the African automotive supply chain. In this model, the presence of natural resources, whether renewable or non-renewable, is not an asset for the supply chain in a country because the effects are negative. We note that the values of the coefficients appear to be very low. Indeed, all else being equal, an additional increase of one unit of human capital per capita would increase 2.16e-06 of exports per capita of automotive tier 1 products, 2.37e-

05 of exports per capita of automotive tier 2 products, and 0.00114 of exports per capita of automotive tier 3 products. The lowness of the coefficients is not only due to the low magnitude of the effects but also due to the order of magnitude between the dependent variables and the explanatory variables, as can be observed in the summary table of the main variables. If we try to convert to percentages, we find that an increase of 119 units of human capital per capita, which corresponds to 1 per cent of human capital per capita, would lead to a rise of 0.07 per cent, 0.4 per cent and 1.24 per cent of exports of automotive tier 1, 2, and 3 products, respectively, all else being equal.

Table 5: VAR regression of automotive supply chain

Dependent variables	Equation 1 Auto Tier 1	Equation 2 Auto Tier 2	Equation 3 Auto Tier 3
VARIABLES			
lag of Auto Tier 1	-0.0177	-0.209	-10.21
	(CNA)	(CNA)	(CNA)
Lag of Auto Tier 2	0.00770	0.0802	3.785
	(CNA)	(CNA)	(CNA)
Lag of Auto Tier 3	0.000332	0.0101	0.576
	(CNA)	(CNA)	(CNA)
Human Capital	2.16e-06***	2.37e-05***	0.00114***
	(1.70e-08)	(1.70e-08)	(1.70e-08)
Renewable Natural capital	-3.26e-06***	-4.33e-05***	-0.00220***
	(8.97e-07)	(8.97e-07)	(8.97e-07)
Non-renewable Natural capital	-3.33e-06***	-3.59e-05***	-0.00172***
	(1.12e-07)	(1.12e-07)	(1.12e-07)
Population	2.37e-10***	2.84e-09***	1.40e-07***
	(CNA)	(CNA)	(CNA)
Observations	81	81	81

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
CNA: The convergence is not achieved

Concerning simultaneous equation models that elicit just-in-time supply chain equations, we consider that participation at one supply chain level depends on simultaneously involving the other chain levels. Thus, supply chain managers ensure they receive in time when deciding on the quantity produced or exported. We recall that the outliers have been excluded from the model. First, the model shows a simultaneous dependence between exports of automotive tier 1 and 2 products. The respective coefficients of automotive tier 2 and tier 1 are significant and positive in the automotive tier 1 and tier 2 equations. This means that ceteris paribus, an increase in exports of automotive tier 1 products leads to a rise in exports of automotive tier 2 products in a country and vice versa. However, the simultaneous effect between automotive tier 2 and automotive tier 3 is not significant.

We find that with this simultaneous equation model, the effect of human capital is positive on automotive tier 1 (automotive parts and components) and negative on automotive tier 2 (non-automotive parts and components), however these effects are only significant at the 10 per cent threshold. The impact of human capital on automotive tier 3 (raw and semi-raw materials) is not significant. The results are intuitive as tier 1 products tend to be more knowledge- and technology-intensive products and more dependent on particular original equipment manufacturers (OEM) in the supply chain, so a greater human capital wealth stock would be beneficial to the manufacturing of this kind of product. In contrast, tier 2 and 3 products require less advanced technologies and tend to be also inputs to other industries so they are less dependent on certain OEMs. Furthermore, this model shows that renewable natural capital positively affects exports in automotive tier 3 while non-renewable natural capital negatively affects exports in automotive tier 3.

This model has also considered African countries' LDC, LLDC, and SIDS status. The effects on the automotive supply chain for a country to be LDC, LLDC, or SIDS are more or less contrasted. Ceteris paribus, the categorisation of these countries does not significantly affect participation in the automotive tier 3 supply chain. Also, being LLDC does not significantly impact the automotive supply chain in Africa, according to the model. However, a country's LDC status is positively associated with the automotive tier 1 supply chain and negatively with the automotive tier 2 supply chain. In contrast, a country's SIDS status is positively related to the automotive tier 2 supply chain and negatively to the automotive tier 1 supply chain, all else being equal.

Table 6: Simultaneous equation model regression of automotive supply chain

Dependent variables VARIABLES	Equation 1 Auto Tier 1	Equation 2 Auto Tier 2	Equation 3 Auto Tier 3
Auto Tier 1		1.760*** (0.309)	
Auto Tier 2	0.547*** (0.127)		3.916 (3.259)
Auto Tier 3		0.00175 (0.0170)	
Human capital	2.06e-05* (1.13e-05)	-3.81e-05* (2.01e-05)	-0.000137 (0.000325)
Renewable Natural capital			0.00619*** (0.00218)
Non-renewable Natural capital			-0.00153* (0.000790)
Auto Support Equipment	-0.329 (0.486)		
Auto Support Activities Services	22.73 (29.05)		
Population	-5.50e-09** (2.34e-09)	9.68e-09** (4.15e-09)	6.55e-08 (7.74e-08)
LDC	0.555** (0.250)	-1.066** (0.418)	1.621 (8.506)
LLDC	0.179 (0.136)	-0.318 (0.265)	-0.994 (4.316)
SIDS	-1.876*** (0.543)	3.341*** (0.816)	0.450 (17.52)
Constant	-0.404 (0.283)	0.805 (0.580)	-13.21 (14.33)
Observations	101	101	101
R-squared	0.112	0.386	0.130

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5. Conclusion

Africa's automotive supply chain is an exemplary case of the continent's significant potential in engaging in domestic, continental, and international production processes for greater industrialisation and green economic development beyond being only the largest supplier of raw materials required for vehicle production, if supported well by appropriate human capital development. Although Africa's global supply chains are the least developed compared to other continents, and Africa's automotive industry is small by global standards with the world's lowest motorisation rates (JICA & BCG, 2022), opportunities for growth are plenty, with growing demand for vehicles, carbon-neutral manufacturing, and local and intra-African supply chains.

This paper has argued that to effectively capture these automotive supply chain opportunities and increase competitive advantage for higher supply chain performance, human capital serves as both a critical capability and a key productive asset for African countries. Our correlation analysis between various human capital indicators and automotive exports along the supply chain across African countries shows that human capital, including tertiary education, research sector, skills, training, and productivity development have critical roles for Africa's automotive supply chain. Moreover, through analysing the relationship between human capital wealth stock measured as the expected future earnings of the labour force per capita and automotive supply chain performance measured as the exports per capita of African countries, with statistical models of dynamic relationships for both just-in-case and just-in-time supply chains, we show that human capital can be considered as a positive determining factor in the development of automotive supply chains in Africa, particularly for tier 1 products in the supply chain which usually involve higher value-added, knowledge-intensive production activities, often performed by the lead or anchor firms, which combine the tier 3 (raw and semi-raw materials) and tier 2 (non-automotive grade parts) into tier 1 (automotive parts and systems) products for final vehicle assembly. This is consistent with existing observations that tier 2, and 3 activities are also inputs to many other industries and so are less dependent on the sophisticated knowledge, technology and skillset required specifically for the automotive industry.

The main policy implications are twofold. First, since human capital as capabilities is a determining factor for Africa's automotive supply chain success, greater human capital investment should improve its automotive supply chain performance, in the context of complementary national development, physical infrastructure, and industrial policies. Second, given that human capital as a productive asset has a positive, negative, and statistically insignificant effect on Africa's automotive tier 1, 2, and 3 exports respectively, using simultaneous equation model, human capital investment might have very different impacts on different parts of the supply chain network. For example, skill training should increase its relevance to automotive tier 1 production, to upgrade the skillset so countries can become less dependent on tier 3 exports that comprise mostly critical minerals. This could bring greater supply chain resilience, flexibility, and performance.

We recognise the existing complexities behind human capital investment for supply chain development in Africa. The continent's education spending is already on average 5 per cent of national GDP, the governments committing 16 per cent of their budget allocations to education, and yet Africa's labour productivity has remained low, partly due to low spending efficiency, high drop-out rate in primary schools, and weak quality of education as shown by the lower test scores (African Development Bank, 2020). Healthcare investment faces persistent challenges due to food insecurity, malnutrition, inadequate access to safe water, and systematic factors such as the current debt crisis where developing countries have to spend more on interest payments than education and health (Kouame & Fraeters, 2021; UN Global Crisis Response Group, 2023). It is important that policymakers keep these in mind in formulating human development programmes. A holistic approach should be taken. This means promoting policies specific to supply chain development, i.e. education, skills and vacationing training that are designed to match current and future labour market needs and technology requirements along key parts of the target supply chains (e.g. automotive tier 1 production, skills related to the manufacturing of electric vehicles, active pharmaceutical ingredients, and medical devices), which are supplemented by the broader policies to improve the general access to healthcare and quantity and quality of education that emphasise literacy and numeracy skills, education innovations, R&D sector, intra-African mobility, and gender equity (African Development Bank, 2020; Aina, 2010; Yameogo & Jammeh, 2019).

Our analysis has examined Africa's automotive production and economic transformation potential from a human capital and supply chain perspective. As we have focused mainly on the sourcing, procurement and manufacturing stages of the automotive supply chain due to their significance for industrialisation and data availability, future research on this topic can consider also the downstream supply chain including distribution, logistics, and customer service stages for a fuller picture of the automotive supply chain and human capital needs. It is also important to note that the analysis in this paper is specific to the automotive supply chain in Africa, and the research approach will likely vary across different supply chains and regions.

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Annex

Table A1: Share of intra-African total exports of automotive supply chain products (in percentage)

Countries	Final vehicles	Supporting Equipment	Supporting activities or services	Tier 1	Tier 2	Tier 3
South Africa	77.76	82.80	81.36	76.38	43.76	17.52
Morocco	5.01	2.24	1.38	2.18	3.01	0.21
Tanzania	2.18	1.50	4.04	0.62	0.87	0.13
Kenya	1.94	1.65	0.32	2.86	5.06	0.09
Uganda	1.90	0.36	0.03	1.12	1.10	0.10
Botswana	1.39	0.60	0.13	1.80	14.36	0.19
Sierra Leone	1.04	0.05	0.00	0.02	0.01	0.00
Egypt, Arab Rep.	0.98	1.08	0.00	3.54	11.53	1.33
Tunisia	0.91	2.51	10.02	3.90	4.04	0.12
Cote d'Ivoire	0.82	1.18	0.05	0.17	5.40	0.19
Zambia	0.80	1.02	0.06	2.89	0.42	1.80
Congo, Dem. Rep.	0.67	0.46	0.18	0.36	0.03	64.37
Togo	0.45	0.05	0.00	0.06	1.72	0.00
Zimbabwe	0.13	0.12	0.86	0.62	0.64	12.35
Ghana	0.09	0.17	1.85	0.40	7.41	0.02

Source: UNComtrade database

Table A2: Correlation matrix between the total exports of automotive supply chains

	Final vehicles	Supporting Equipment	Supp. Act. or services	Tier 1	Tier 2	Tier 3
Final vehicles	1					
Supporting Equipment	0.86 ***	1				
Supporting activities or services	0.71 ***	0.89 ***	1			
Tier 1	0.67 ***	0.86 ***	0.90 ***	1		
Tier 2	0.31 ***	0.35 ***	0.27 ***	0.47 ***	1	
Tier 3	0.49 ***	0.50 ***	0.40 ***	0.35 ***	-0.03	1

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Source: UNComtrade database

Table A3: Correlation matrix between the Intra-African exports of automotive supply chains

	Final vehicles	Supporting Equipment	Supp. act or services	Tier 1	Tier 2	Tier 3
Final vehicles	1					
Supporting Equipment	0.74 ***	1				
Supporting activities or services	0.47 ***	0.75 ***	1			
Tier 1	0.89 ***	0.85 ***	0.68 ***	1		
Tier 2	0.26 ***	0.31 ***	0.10	0.38 ***	1	
Tier 3	0.06	0.11	0.00	0.01	0.07	1

*** p<0.01, ** p<0.05, * p<0.1

Source: UNComtrade database