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Investigating the trends of Price and production of manganese ore in Sub-Saharan Africa, 1927-2015

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Abstract

This article analyzes the price and the production in Sub-Saharan Africa. The chemical properties of manganese make it a strategic ingredient in the production of steel and batteries. The estimates show that major African firms produced an average value of the total world output of 41.7% in South Africa, 18.7% in Gabon, 8.9% in Ghana, 1.2% in the DRC, and 0.1% in Zambia, respectively. The global price positively affects the manganese mining. The global manganese market showed a strong long-term correlation estimated at 0.85 between the trends in manganese and steel prices. Producing firms negotiate the price in the metric tonne unit to accommodate the variation in manganese content.

Keywords: Ferroalloy manganese, manganese deposits, global metal price, mineral resources

1. Introduction

Manganese mining has been a topic of controversies compared with other

minerals. Manganese is an essential element in the process of converting iron ore into high-quality steel. The steel industry uses manganese to decrease brittleness and increase strength and remove oxygen and sulfur during iron smelting. The literature related to manganese mining argues that governance issues deal with small-scale mining and tax revenues (Hirons, 2014), mining development strategies and decentralisation of producing firms (Hilson et al., 2022). Furthermore, manganese mining has polluted rivers and lakes in Russia (Matveeva et al., 2022); and groundwater in India (Goswami et al., 2009). In fact, steel producers specify the manganese ore standard that manganese suppliers must meet. The industrial properties of manganese make this metal a strategic element in the production of steel for construction materials, and batteries for electric vehicles and electronic devices. The renewable industries use manganese in the nickel-manganese-cobalt design to produce lithium-ion batteries.

This article argues that the reserve and quality of the manganese ores are important for generating higher revenue if African producing firms balance their bargaining power of prices with the interest of all stakeholders. It examines the impact of price on manganese ore production in 5 parts. The first part describes the manganese deposits in the world and Africa. The second part introduces the extraction and processing of the manganese ore. The third part compares the trends in the manganese ore output. The fourth part assesses the variation in the price and production of manganese ore. The fifth part concludes the article.

1.1 Global manganese deposits

In the earth crust, manganese is the 12th most abundant element, but its average concentration represents 0.1% (Maynard, 2010). Nevertheless,

manganese is the 4th in terms of mined tonnes, ranking after iron, aluminium, and copper (Lindstad et al., 2007). Manganese ores occur in metamorphic rocks and sedimentary deposits. Pyrolusite is the main ore mineral of manganese. Manganese deposition occurs naturally on both the land crust and the surface of the seabed of the ocean.

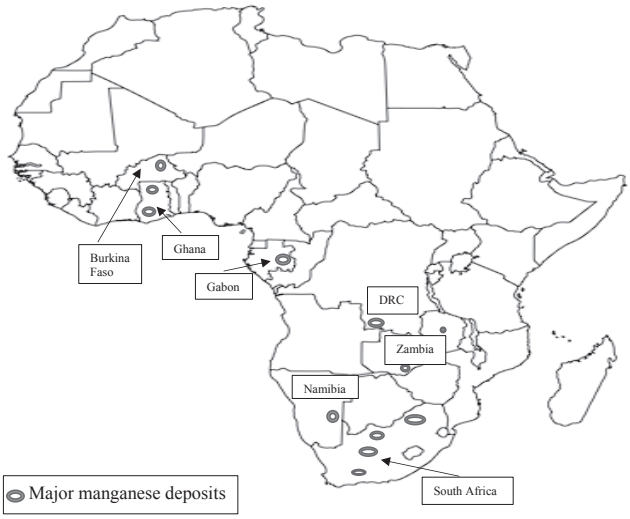
Manganese is widely distributed in nature, but large deposits of high-grade ore occur only in a few countries. The economically minable manganese deposits have natural concentrations of 150 to 500 times the average crustal abundance. In the earth crust, high-grade manganese deposits representing about 44% of the world totals occur in South Africa, Australia, and Gabon according to the degree of their concentration. Indeed, South Africa, Brazil, and Australia have the largest known reserves of manganese. The medium grade deposits occur in China, India, Brazil, and Ukraine. The lower grades occur in countries such as Namibia, Mexico, and Ivory Coast. In terms of geological age, the total terrestrial manganese deposit accounts about 82% are Precambrian, and the remaining 18% are both the Mesozoic and Cenozoic. Onshore, the world reserves of manganese ore occur in seven countries, which together make up 98% of the world deposits (Moreira et al., 2014).

Ancient civilizations used manganese oxide minerals as pigments and clarify glass, while the modern society uses manganese ore in steelmaking and batteries. Also, manganese is essential to both plant and animal life. The manganese trade has gone the full circle, and the rising market has provided a wide profit margin for suppliers in the world industry. In 1971, attracted by the quality of manganese deposits, Japan showed interest in African manganese ores.

1.2 Manganese deposits in Sub-Saharan Africa

The manganese reserves in Sub-Saharan Africa have a high concentration, especially the deposits in South Africa, Gabon, Ghana, the Democratic Republic of the Congo (DRC), and Zambia (Beukes et al., 2016). Three main types characterise the occurrence of manganese deposits, including residual deposits found in tropical regions, sedimentary deposits in Russia and South Africa, and the seabed nodules in which manganese combines with other metals (Moyo et al., 2019). Map 1. The geological location of the major manganese deposits in Sub-Saharan Africa.

Map 1 Geological location of major manganese deposits in Sub-Saharan Africa



Source: Author's drawing using the data of Beukes, 2016.

Manganese deposits in the DRC occur in the Lualaba province of the old Katanga province at 2 locations, the Kasekelesa and Kisenge (Putter et al., 2018). First, the Kasekelesa deposits are located near the railroad linking the Kolwezi city to Dilolo town, about 86 km west of Kolwezi. The company Minsudkat mined these deposits in 1939. The regional topography is that of the undulating plateau of grasslands. The manganese deposits are within a large, mineralised belt trending north-south about 3 km long and 800 metres wide. The ores occur in a vein-like body and in alluvial detritus cemented by laterite. These ore deposits have a mean of 20 metres in-depth. Second, a Belgian geologist discovered the Kisenge deposits in 1950. The Beceka-Manganese firm began the extraction of the ore the same year. These deposits are located about 350 km northwest of Kolwezi.

The deposits caused bare hillocks on a flat plain. Rock exposure is to that of the Kibaran system (Pohl & Günther, 1991). The manganese ores of Kisenge are known for their high-quality because they do not contain any copper, zinc, lead, arsenic, or phosphorus. These ores occur at three sites, including Kapolo, Kamata, and Kisenge. The Kisenge manganese mines are located within a landlocked area estimated at 1400 km from the Lobito port in Angola in the Atlantic Ocean. This long distance may constitute a prohibitive cost to export the manganese ore of Kisenge. At Kisenge mines, the ore lenses succeed each other in bed-like form. The extraction removed them from the contact with mica schists and the amphibolite.

African firms that extract and process the manganese ores export their products to the steel producers in the global market. The concept of steel describes an alloy of iron that is malleable in a range of temperature. It contains manganese, carbon, and other alloying elements (Nair & Kotha, 2001). Therefore, steel is not a single metal. Adding the manganese alloy

with steel increases the strength, ductility, hardness, toughness, magnetic permeability, and corrosion resistance. Furthermore, the properties of manganese make its end uses in the steel industry, batteries, cast irons, and chemicals. Steel -producing firms rely on imported manganese metals in their processing activities.

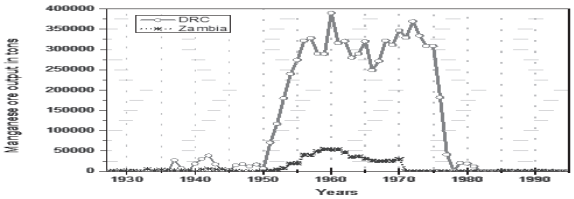
African economies export primary commodities, and most export little else (Deaton, 1999). Therefore, Africa has been an important supplier of the raw materials. It possesses economically interesting mineral reserves. African economies, especially the Sub-Saharan countries, depend on the extraction and processing of minerals to generate revenues. Before the 1990s, manganese produced in Africa represented more than 50% of free world production, excluding the former Union of Soviet Socialist Republics (USSR), and additionally included the best qualities. In the 1960s, Japan imported half of the minerals, including cobalt, manganese, uranium, and iron ore from Africa during the high economic growth era.

2. Extraction and processing of a manganese ore in Africa

Almost 90% of all ferromanganese goes in the production of steel because it can replace nickel. The steel has ductility, toughness, corrosion resistance, and is non-magnetic because of nickel and its substitute manganese. Manganese plays a key role in the modern industrial economy (Cunat, 2004). Figure 1 depicts the trend of manganese ore production in the DRC and Zambia from 1927 to 1993 in tonnes.

Figure 1 shows that the central African region, including the DRC and Zambia, firms in these 2 nations produced the lowest quantity of manganese, although other mining firms in these 2 countries have been leading producers of copper and cobalt (Kalenga & Balyahamwabo, 2020).

Figure 1 Manganese ore production in the DRC and Zambia from 1927–1993 in tonnes



Source: Author's collation from computation of data.

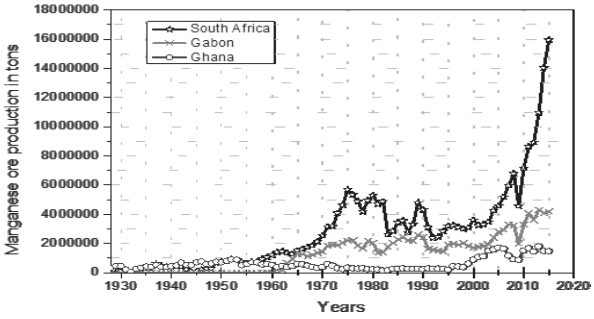
Firms extracted manganese from the surface deposit. The manganese deposit must have a market price that covers the costs of extraction, processing, and transportation to generate profit for the company. During the 1930s, manganese prices in the global market did not allow the Kisenge manganese deposits to be exploited. As steelmaking demands for manganese content have increased, manganese producers have seen their prices rise. Beceka manganese negotiated a 10-year selling contract with steel companies in 1950. It produced manganese ore until the 1980s.

The collapse of manganese ore production did not occur because of the depletion of reserves in these 2 countries. A manganese firm in the DRC ceased its production because of the civil war that erupted in Angola in 1975. The war resulted in the destruction of the railroad, making it impossible to reach the Lobito port. The transition to national roads required heavy investment and prohibitive costs in the DRC. Despite the end of the Angolan civil war, the Kisenge manganese firm could not fully resume production due to prohibitive processing and transportation costs. At Kisenge, along the Angolan border in western Katanga, during the late 1980s, the production decreased to 35,000 tonnes of manganese ore per year. Approximately 0.6 million tonnes of manganese ores grading 47%–50% were stockpiled after production ceased in 1993 (Oberhansli et al., 2015).

In Zambia, producing firms for distinct reasons were found unprofitable in the processing of manganese ores. Indeed, manganese ore values declined, indicating that the deposits were not commercially significant. It is due to the low-grade of manganese ore that producing firms divest from the project before it is fully developed. Manganese deposits have recently been discovered in eastern Zambia, especially in Nansanga and Lundazi districts, where firms mine the ore in open pits. Zambian firms have resumed production of manganese ore since 2018 (Chilombo & Van der Horst, 2021).

Zambian firms have produced less manganese ore than their counterparts in the remaining four countries in this study. Although Ghana is well-known for its gold for centuries, during the colonial period, manganese firms in this country played a second role as the suppliers of manganese ores just behind those of South Africa. Figure 2 shows the trend of manganese ore production in Gabon, Ghana, and South Africa from 1927 to 2015.

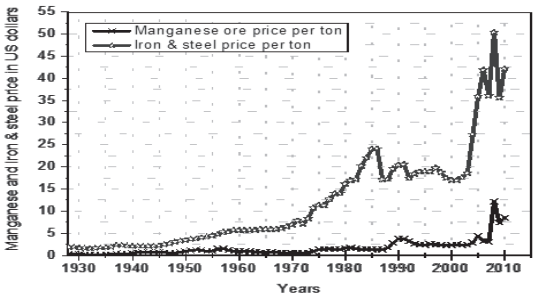
Figure 2 Manganese ores production in Gabon, Ghana, and South from 1927–2015 in tons



Source: Author's collation from computation of data.

Figure 2 depicts that firms in Ghana have been the leading producers of manganese ores on the African continent during the first half of the twentieth century. Also, it showed the leading position of Ghana until 1955, when South African firms became the largest producers of manganese in Africa. These South African firms took the leading position from 1955 onward, and they have maintained their leading position since the second half of the twentieth century. Besides, from 1962, manganese firms in Gabon developed their processing plants. These firms possess access to manganese reserves at the Moanda deposit. Figure 3 shows the average value of the price trends of manganese ore in U.S. dollars in the world market.

Figure 3 Trend of average value of the global price of manganese ore and iron and steel in US dollars per tonne



Source: Author's collation from calculation using data.

Figure 3 shows the stable trend of manganese ore and iron and steel prices on the global market of about 2.68 US dollars and 19.16 US dollars, respectively. In 2008, the outbreak of the global economic recession led to a fall in prices in the market. In 2010, the international economic recovery,

as well as the production of the world production of steel, increased the prices threefold. The producing firm uses the unit-pricing system with manganese ore to accommodate the variation in manganese content. Depending on the processing of the ore, the producer offers different ferromanganese grades, such as 38%, 48%, 50%, and 75% of the content. Every seller negotiates the price in metric tonne units to reflect the metal content.

The metric ton unit price of 48 to 50% of the manganese metal content in the ore depicted an average price of 1.62 US dollars. Iron and steel recorded an average value of 11.81 US dollars and a median value of 6.56 US dollars, respectively. The fiscal year 1933 recorded a price valley of 1.12 US dollars per ton, while the price peak of manganese ore reached 12.15 US dollars per metric tonne unit in 2008. Iron and steel recorded the price valley in 1932, while the price peak reached 50.41 US dollars per metric tonne unit in 2008. Each major producing firm in each nation contributed to a median value of 33.23% in South Africa, 18.87% in Gabon, and 6.19% in Ghana.

In the days before the first World War, when ferromanganese contained between 78% and 82% metallic manganese, ore of ferro-grade had to contained not less than 40% metallic manganese. The price was based on not more than 0.2% phosphorus, whereas the buyer rejected ores containing more than 12% silica (Weld, 1920). A few years later, the industry relaxed the standard grade to broaden the market for the leaner ores. The standard reduced the content of ferro-grade ores to 35% metallic manganese. The buyer had the option to reject ores containing more than 0.25% phosphorus.

During the entire period of study, the total production of manganese ore in Sub-Saharan Africa has reached an average value of 70.75%. Firms that exploit manganese in South Africa, Gabon, and Ghana take the leading

position in terms of productive capacities. Manganese ores merit interest in the fabrication of rechargeable batteries (Sun et al., 2020). Also, the essentiality and non-substitutability make the vulnerability to supply restrictions of manganese nonnegligible.

3. Comparison of manganese ore production

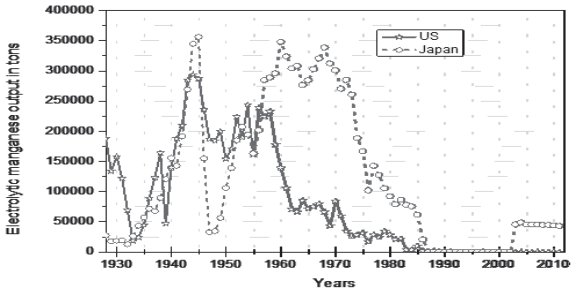
African countries depend on their export revenues for a single commodity or on a narrow range of commodities. In fact, commodity prices are highly volatile, showing short peaks followed by long troughs (Collier & Goderis, 2012). Also, commodity booms have unconditional positive short-term effects on output, but adverse long-term effects in countries with poor governance. African countries will not achieve economic independence until their firms can truly negotiate the price of products, not beg in the world marketplace. The African share of the world refinery production of metals such as aluminum, copper, lead, tin, zinc, and manganese are much smaller than the share of the corresponding minerals at the mining stage (Ericsson, 1991). This low level of refining constitutes a loss of added value and the transfer of jobs in the African manganese industry. Manganese remains at the extraction of ore without any further processing after the ferromanganese alloys to produce the steel and batteries for African markets.

The industrialization process has remained at low levels in regions of Sub-Saharan Africa, resulting in the import of manufactured goods from advanced nations. The local industry integrates better if semi-finished and finished products meet the needs of domestic markets instead of exporting raw materials. This practice has continued for decades because leaders chose to avoid implementing a balanced policy to maximize both their human and natural resources. Additionally, impoverished institutions, the

embezzlement of mineral revenues, and lack of transparency of state-owned firms are the chief reasons why resource-rich sub-Saharan Africa are underperforming economically (Hilson & Maconachie, 2008). The transformation of African states into newly industrializing countries would affect the price of the continent's resources as it had been the case in Asia.

During the First World War, not only were manganese supplies to the US from Russia stopped, but also, the lack of shipping reduced the supplies from India. The ferroalloys took a strategic position they had never held before the Second World War because of their crucial importance in the creation of new materials capable of withstanding high speeds, hot temperatures, and great stress. Figure 4 depicts the production of the electrolytic manganese in the US and Japan from 1927 to 2010 in metric tons.

Figure 4 US and Japan's electrolytic manganese output from 1927–1985 in tonnes

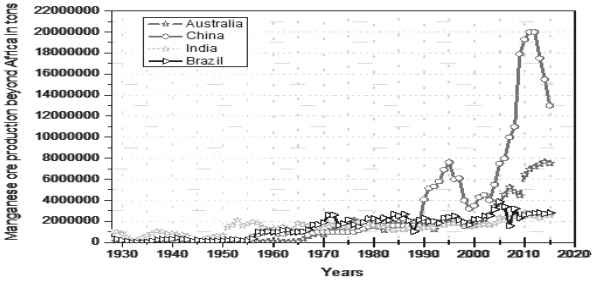


Source: Author's collation from computation of data.

Figure 4 shows that the US and Japan have been producing small quantities of electrolytic manganese, although they consume more of them for their industries. The output did not cease in 1985, but it decreased significantly from 1985 to 2003 and accounting for 40,000 tonnes per year in

Japan (Iwabu, 1978). In 1954, a South African firm produced the first electrolytic manganese metal from manganese ore by obtaining the techniques from the US (Harris et al., 1977). After this first successful trial, South African firms conducted significant R&D to construct electrolytic manganese plants. They made important investments in purifying the manganese ore within the country to exploit the existing reserves of this industry. By 1995, South African firms produced about 51% of the world's electrolytic manganese metal (Eric, 1995). Different methods for producing the electrolytic manganese metal have been developed through research experiments, such as, in South Africa from ore milling through to electronic winning and packing of the metal; in Kazakhstan from sulfate solutions; and in India from synthetic solutions and secondary sources (Biswal et al., 2015). Figure 5 shows the major producers of manganese ore beyond Africa from 1927–2015 in tons.

Figure 5 Total output of manganese ore in the world and major countries from 1927–2015 in tonnes



Source: Author's collation from computation of data.

Figure 5 shows the leading position of China in the world production of manganese ores in 2004. The trends in demand and supply also affect the price of manganese ores.

4. Price trends of manganese ores

This section divides the global price trends into four main periods. During the first period, before 1910, although manganese metal was known for its end use as a colorant for glass, the industry produced and traded a limited quantity. After 1910, this metal began to find new end uses in the manufacture of high-strength steel alloys (Yellishetty et al., 2011). Until the late 1920s, the industry established a global market for manganese and a reliable price series. During the period between 1927 and 1973, the manganese ore price trends were stable. The overall trend of price increased at a slow pace until it reached the first peak in 1957 for a metric tonne unit at 1.56 US dollars and the second peak in 1969.

The price level of commodities plays an essential role in the extractive industries. Firms extract the manganese deposits if the market price can cover the mining cost and generate a profit. In the early 1960s, the Gabonese firms started the extraction of manganese ores because the market price could cover the processing cost. Furthermore, the fall in the manganese price in 1982 left no choice for the Kisenge Manganese firm to exit the industry in the DRC. The firms of the country that consumes the largest share of the electrolytic manganese had held the right to set the benchmark of manganese price in the global market. During the first period, the American firms played this role from 1927 to 1970, when the shift occurred from the US in favor of Japanese firms. This shift marked the second period from 1970 to 1990, when the Japanese benchmark of manganese price was known as the international price of manganese ores. In the third period, concentrating on the years from 1990 to 2004, a mixed influence of Australian and Japanese firms witnessed a rise in price. The fourth period from 2004 to 2015, the shift in favor of Chinese firms that

became the largest producers and consumers of manganese ores in the world. They developed their benchmark for the sport prices used in the world market.

The world market of commodity experiences both booms and bursts that characterize the movement of commodity prices (Gajigo et al., 2011). In the late nineteenth century and the entire twentieth century, the London Metal Exchange has been the leading organization to determine the global prices of metals. In most cases, price booms in commodities are temporary, which increase revenues in the short run for the exporting firms. During the boom of the commodity in the 1970s, firms in developing countries, except Botswana, failed to manage their gains of earnings that led to increased spending and imports. As far as the price of manganese ore is concerned, it applies a different pricing system because there is no global standard of the metal content. It provides the possibility to negotiate its price based on global price benchmarks set by major global consuming firms such as those of the US, Japan, and China and the change in the capacities of global suppliers. African producers can refer to the established metric ton unit price to negotiate the sale contracts. The price negotiation between consumers and producers considers factors such as manganese content, the content of other elements, physical characteristics, quantity, and transportation rates.

The second period, from 1970 to 1989, witnessed the rise in metal prices, especially manganese, with a steady rise in the price that peaked at 2.85 per metric tonne unit in 1989. In the early 1970s, South African firms have developed new mines to extract rich manganese deposits in the Kalahari Field in Northern Cape Province. These mines increased the supply capacity and contributed to the stability of the global prices of manganese ore. The rise in ore prices from 1974 to 1981 was attributable to

comparatively high rates of international steel production, and the shock effect of oil price increases between 1974 and 1981. The global economic recession that started in 1982 led to a fall in manganese ore prices. During the 1980s, the steelmaking firms developed more efficient techniques of manganese use that maintained the metric ton unit prices flat. Steelmakers reduced their unit consumption of manganese in steelmaking by about one-fifth within two years in the US. They changed the combination of the ways to convert iron pigs into steel.

Manganese ore and alloy prices are determined on the spot market not on the commodity exchange markets (Carter et al., 2011). In fact, links to iron ore and steel have implications for the price trends of manganese ore and its products. The benchmark price for manganese ore grade is for high-grade ore with manganese content in the range of 48% and 80%. First, the industry used the American benchmark until the early 1970s. In fact, the U.S. market was the largest for manganese ore. After the leading era of the US manganese ferro-alloy smelters, the Japanese firms have become the most influential in setting annual prices since the early 1990s. In fact, the industry adopted the Japanese benchmark until 2008. Prices were set in the latter part of the calendar year in US dollars for the next year's shipments. Since 2009, it has relied on the Chinese benchmark to set the manganese ore spot prices. The largest consumer of manganese has the ability in setting manganese ore prices.

During the third period, from 1990 to 2004, the manganese ore price remained stable with a mean value of 2.86 US dollars per metric ton unit. After 1990, the global manganese ore market changed with the dissolution of the Soviet Union in 1991. The major consumers of manganese were firms in the US, Japan, and Western European countries. The entry of new firms from the old communist bloc, especially the Soviet Union and China,

influenced the trend of prices in the international market. The shortage of high-grade ore was attributable to sudden large ore purchases to a price peak per metric ton unit of 3.78 US dollars. After this peak in 1990, the prices remained stable from 1993 to 2004. The main factor for the flat trend of prices was the contraction of industrial production and the reactivation of mining plants in new areas where the known deposits in Western Australia were increasing supply on one hand and facilitating the price negotiations on the other hand.

In the fourth period, from 2005 to 2018, the manganese prices had trended upwards, especially due to the increased global consumption, particularly in Brazil, Russia, India, and China (BRICS), and lower production levels in the major firms in producing countries for local technical and economic reasons. During this period, the price continued to increase significantly as Chinese firms became the world's largest consumers of manganese ore. The global economic crisis that began in 2008 caused a global decline in the production of manganese ore and its ferro-alloy demand. Global prices declined significantly until they reverted in 2010 as the world economy began to recover. The high demand for manganese ore and alloys to meet the domestic appetite for metals in China has influenced the global price of manganese ore. The fiscal year 2008, has been the highest peak recorded for the first time in the long history of manganese ore at 12.15 US dollars per metric ton unit.

The decision related to the quantity of manganese ore to import depends on the global price on the market. The price of a commodity determines market adjustment in terms of the demand for and the supply of metals. Indeed, booms and bursts in extraction-oriented firms in the Northwest of China have adopted policies to join the efforts of building local communities (Woodworth, 2016). The recent use of manganese ore changed the

direction of the global supply chain. The manganese ore market has expanded due to new applications in the production of batteries for electric cars. The 2015 share of manganese ore production from Africa represented 38% of the world market (Olawuyi, 2018). The new generation of automobile production and artificial intelligence equipment have increased the demand for manganese ores in their industrial activities. Modern society requires the production of batteries for autonomous robots and electronic equipment.

5. Conclusion

The trend in global metal prices and the production of manganese ore show a positive correlation. The reserve and quality of the manganese ores on the African continent are economically profitable. The manganese ores show potential growth if African producers balance their price-bargaining power with the interest of all stakeholders. This article argues that major African firms produced a mean value of 41.7% in South Africa, 18.7% in Gabon, 8.9% in Ghana, 1.2% in the DRC, and 0.1% in Zambia, respectively. The global manganese market shows a strong long-term correlation, estimated at 0.85, between the trends in manganese and steel prices. The exporting firms of manganese ores pay all the insurance and transport costs until the products reach the destination port, also known as the cost insurance and freight term.

Manganese is a key element in the manufacturing of Lithium-ion batteries, allowing them to be durable, safe, and affordable. It increases the energy-storing battery's capacity by increasing the energy density by using high-grade manganese as its cathode material. It is imperative to ensure adequate supplies of manganese to manufacture steel. Manganese ores and

alloy prices are determined on spot China's market and Australia. The manganese market applies a different pricing system because there is no global standard of the manganese metal content. This practice opens the possibility for every producing firm to negotiate its price based on the global price benchmark. Global prices affect both the manganese ores and steel production.

The global price boom increases the temporary income of exporting firms in the short run, while its burst has an adverse effect on their revenues eventually. From 1927 to 1994, the metric ton unit price of manganese ore remained stable. From 1995 to 2004, the price has increased threefold because of the high demand for both manganese ores and steel. From 2005 to 2010, the demand for these metals has fallen, especially during the global economic recession that occurred in 2008. From 2010 to 2018, the BRICS has increased their demand for metals in the global market, leading to a shift from the American and Japanese firms as the main consumers of electrolytic manganese in favor of Chinese firms.

The high demand for manganese ore and alloys to meet both the domestic and international appetite for metals in BRICS, especially in China, has influenced the rising trend in the global price of manganese ores. Chinese firms have become the world's leading producers and consumers of electrolytic manganese. These firms set the metric ton unit price based on the spot market as the international benchmark. During the next decades, the industrial properties of manganese will make this metal a strategic element in the production of electric batteries for vehicles and electronic devices.

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