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RESEARCH ARTICLE

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Made in Africa – How to make local agricultural machinery manufacturing thrive

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Abstract

Manufacturing has the potential to drive economic growth, job creation and poverty reduction, but African manufacturers face challenges in competing with global markets. Agricultural machinery manufacturing may be one niche where African manufacturers can succeed. This paper examines the challenges and opportunities facing local agricultural manufacturers in Africa based on a survey of 386 manufacturers in four countries and qualitative methods. Results show that small, dedicated entrepreneurs have created vibrant local machinery markets. These manufacturers have several comparative advantages, in particular, the ability to develop machinery adapted to local agroecological conditions but face challenges related to financing, human resources, utilities, raw materials, production equipment and the regulatory environment. The paper offers recommendations on how to support local manufacturers to make "Made in Africa" the first choice for African farmers and agro-food processors.

KEYWORDS
Africa, agricultural mechanization, industrial policy, industrialization, manufacturing, structural transformation

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1 | INTRODUCTION

Manufacturing has been a cornerstone of economic development for most wealthy countries (Haraguchi et al., 2017; Kaldor, 1967; Szirmai et al., 2013) and can play a key role in sustained economic growth, job creation and poverty reduction in Africa (Abreha et al., 2021; Chang et al., 2016; Haraguchi et al., 2017; Mijiyawa, 2017; Signé, 2018). However, manufacturing plays only a limited role in Sub-Saharan Africa so far (Nnyanzi et al., 2022; Page et al., 2016), contributing 12% of the GDP and 11% of the employment (World Bank, 2022). Signé (2018) describes this as a "missed opportunity for economic transformation" (p. 1). There are now high hopes and increasing efforts to harness this "missed opportunity" (e.g. Abreha et al., 2021; Kruse et al., 2021). For example, the African Union envisions a central role for manufacturing in its Agenda 2063 (Bouchene et al., 2021; Signé, 2018) and the African Development Bank has chosen "Industrialise Africa" as one of its five priority areas.[1] However, there are few niches where African manufacturing can compete with global markets (de Brauw & Bulte, 2021; Frankema & Van Waijenburg, 2018).

Agricultural mechanization offers a unique potential for African manufacturing and the question of how to harness this potential will be the focus of this paper. Agricultural mechanization involves the use of mechanical power across the agro-food system, including farm production, post-harvest handling, storage and processing (Daum & Kirui, 2021). African agro-food systems are the least mechanized in the world (Daum, 2023; Diao et al., 2020; FAO & AUC, 2018). For example, only 10% of crop farmers use tractors (FAO & AUC, 2018). But mechanization is high on the African development agenda (FAO & AUC, 2018) and there are signs of rapid mechanization in some areas, due to farming system evolution and structural change causing labour shortages (Baudron et al., 2019; Berhane et al., 2017; Daum, 2023; Daum & Birner, 2020; Diao et al., 2016, 2020).[2] Diao et al. (2020) argue that African mechanization is no longer held back by lacking demand but, now, rather by supply-side constraints. This is in line with recent empirical studies from countries such as Benin (Hinnou et al., 2021) and Zambia and Zimbabwe (Adu-Baffour et al., 2019; Ngoma et al., 2023), showing that there is indeed an effective demand for mechanization.

Mechanizing Africa's 85 million farms (Lowder et al., 2021) will create a large demand for the products of agricultural machinery manufacturers such as tractors, power tillers, plows, rippers, planters, shellers, threshers and mills, among others. Additional demand will come from the agro-food processing sector, which is one of Africa's fastest-growing economic sectors, driven by a growing and increasingly wealthy urban population (Bughin et al., 2016; Malabo Montpellier Panel, 2018). While agricultural mechanization creates large opportunities for manufacturing, harnessing these potentials in today's globalized world requires African manufacturers to compete with (low-cost) imports from today's manufacturing powerhouses such as India and China.

Historical research shows that local manufacturers have played a key role in today's mechanized countries (e.g., Biggs & Justice, 2021; Binswanger, 1986; Daum et al., 2018). While not all of today's mechanized countries have started to manufacture large machineries such as combined harvesters and tractors, and attempting so may not be needed in today's globalized world, many have developed industries for "light manufacturing" such as tractor implements and processing technologies, which require more local adaptation (Biggs & Justice, 2015; Biggs & Justice, 2021; Binswanger, 1986; FAO & AUC, 2018). Compared to global actors, local manufacturers in the vicinity of farmers can be much better positioned to develop engineering solutions that are adapted to local agro-ecological conditions (Biggs & Justice, 2015; Biggs & Justice, 2021; Binswanger, 1986; FAO & AU, 2018; Mrema et al., 2018; Samarakoon, 2011), providing them with some protection against imports (see also Frankema & Van Waijenburg, 2018). Studies show that Africa is characterized by large agro-ecological variations and that machinery demands and suitable designs, therefore, vary considerably (e.g., Daum et al., 2023; Samarakoon, 2011; Takeshima, 2017b; Takeshima et al., 2015). In a landmark paper on mechanization, Binswanger (1986) emphasized that "both agro-climatic factors (soil, terrain, rainfall) and economic factors (land, labor, capital, farm size, and materials available) require adaptive innovation on a scale that has been vastly underestimated" (p. 50). In Asia, where mechanization is more advanced than in Africa, vibrant local manufacturing markets have played a key role and were able to compete with foreign imports (Belton et al., 2021; Biggs & Justice, 2015; Diao et al., 2020). These markets have become an important source of rural employment and are associated with positive spillover effects for rural development (Biggs & Justice, 2015). However, in Africa, this sector has largely been neglected (Samarakoon, 2011). In an influential framework on agricultural mechanization in Africa, the Food and Agriculture Organization and the African Union Commission have therefore identified "building sustainable systems for manufacture" as a top ten priority (FAO & AUC, 2018).

Several studies provide valuable insights into African manufacturing. These studies have often taken a macroeconomic perspective, comparing African manufacturing vis-à-vis other world regions (Diao et al., 2021; Kruse et al., 2021), other sectors (Mensah et al., 2018) and over time (Kruse et al., 2021; Nguimkeu & Zeufack, 2019; Rodrik, 2016). Other studies have focused on the institutional framework conditions for African manufacturing (e.g., Singé, 2018), sometimes focusing on specific constraints such as access to finance, transportation infrastructure and electricity (e.g., Abdisa & Hawitibo, 2021; Azolibe & Okonkwo, 2020; Fowowe, 2017; Nnyanzi et al., 2022). These challenges are also frequently assessed by the World Banks Enterprise Surveys (World Bank, 2021). Such studies and assessments are also of high relevance to understanding the situation of agricultural machinery manufacturing, but agricultural manufacturers face a range of unique opportunities and challenges. To our knowledge, despite their vital role in manufacturing and agricultural transformation, there is no comprehensive study specifically analyzing the characteristics, opportunities and challenges of African agricultural machinery manufacturers.

The objectives of this research were to explore the characteristics, opportunities and challenges for local agricultural machinery manufacturers in Africa, taking four countries, Benin, Kenya, Mali and Nigeria, as case-study countries. The study aimed to not only attest to opportunities and challenges but to also understand which factors and actors are key to harnessing opportunities and addressing challenges. For this, the study combined a set of quantitative and qualitative methods. To understand the opportunities and constraints experienced by local manufacturers, a quantitative survey with randomly chosen local manufacturers ($N = 386$) was conducted. To further explore the factors and actors that are key to the success of manufacturers, the surveys were supplemented with two qualitative data collection methods: 1) net-maps, a participatory appraisal method that helps to map the factors, actors and bottlenecks affecting a certain outcome and 2) key informant interviews, a method that enables in-depth discussions with key stakeholders. The qualitative data collection methods were applied to a wide range of different stakeholders, such as knowledge- and skills-building organizations, policymakers and regulatory bodies, end-users (i.e., farmers and agri-food processors), financial institutions and development partners, among others. The qualitative data collection allowed us to holistically explore the entire "innovation system", that is, the "network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect their behavior and performance" (World Bank, 2006, p.vi). The innovation system framework captures all "actors and factors that co-determine innovation" (Klerkx et al., 2012, p. 457), making it highly suitable to understand potential bottlenecks and to develop policy recommendations, in this case, on how to create a conducive business environment for local agricultural machinery manufacturers and make them thrive vis-à-vis global competitors.

2 | AFRICAN (AGRICULTURAL) MANUFACTURING: EVOLUTION, OPPORTUNITIES AND CHALLENGES

Scholars focusing on African manufacturing typically distinguish four periods: 1) heavy state support and protectionist policies, 2) prolonged crisis, 3) state withdrawal and 4) rising global competition. After independence, government support and protectionist policies fueled manufacturing growth in the 1960s and 1970s (e.g., Mijiyawa, 2017; Signé, 2018). In agricultural manufacturing, the situation was more mixed, with many countries importing machinery to modernize farming, foreclosing the development of local manufacturers (FAO & AUC, 2018). The 1980s and 1990s witnessed manufacturing setbacks due to the oil and commodity price crisis, unfavourable exchange rates and reduced public support (Signé, 2018). In the 1990s, structural adjustment reforms led to trade liberalization, privatization, and a decline in industrial policymaking and public support. Unsupported and unprotected, many manufacturers could not survive, leading to an "erosion of the industrial base of the continent" (Mijiyawa, 2017, p. 150), a trend that also affected agricultural manufacturing (FAO & AUC, 2018). The 2000s brought intense competition from global manufacturing powerhouses (Mijiyawa, 2017; Page et al., 2016). In agricultural manufacturing, such competition comes in particular from Asia (i.e., India and China), but also from Latin America (i.e. Brazil), Eastern Europe and Turkey (FAO & AUC, 2018).

More recently, several scholars found signs of an African "manufacturing renaissance" (Kruse et al., 2021). Since the 2010s, the contribution of manufacturing to Sub-Saharan Africa's GDP rose by 3 percentage points to around 12%, and the share of employment rose by 1 percentage point to around 11% (World Bank, 2022). The "manufacturing renaissance" appears to be driven by small, often informal manufacturers who mostly produce for domestic markets (Diao et al., 2021; Kruse et al., 2021). Manufacturing's share of GDP varies widely across Sub-Saharan Africa: from 2% in Liberia and Sierra Leone to 33% in Gabon (World Bank, 2022); and 70% of African manufacturing value-added comes from South Africa, Egypt, Nigeria and Morocco (Signé, 2018). Agricultural machinery manufacturing sectors equally differ across Africa, as further discussed with regard to the four case study countries in section 2.2. As noted by Houmy et al. (2013), "in some countries, only the simplest of hand tools are made mostly in the artisan (blacksmith) sector; in other countries, sophisticated manufacturing facilities exist" (p. 27).

Historically, manufacturing growth has often followed a particular sequence. Ito (1986) described the experience in India as the following sequence: "1) mastering of operation, 2) mastering of maintenance, 3) mastering of repair, 4) accumulation of modification know-how, 5) creation of new design, 6) domestic manufacture based on the new design" (p. 334). Similarly, Adubifa (1993), using the case of manufacturing of car parts, suggested the following sequence of manufacturing growth: 1) the importation of fully built-up vehicles with sales and service outlets that import the bulk of spare parts and components, 2) the development of domestic repair and maintenance capabilities and the local production of simple spare parts and components, 3) the importation of components for local assembly and 4) the integration of locally made components and selected machine-cores for vehicle production. African countries are at different stages of these manufacturing growth sequences, with significant variation across different types of machinery. When it comes to larger machinery like tractors or combine harvesters, most countries are still in the stage of mastering operation, maintenance and repair, relying heavily on the import of fully built-up machinery. However, some countries, such as Benin, Ethiopia and Mali, have progressed to the point of local assembly for certain machinery, and the production of simple spare parts has also begun (FAO & AUC, 2018; Kergna et al., 2020; RdB & FAO, 2021). In the realm of "light manufacturing," which includes tractor implements and processing technologies (e.g., threshers, shellers), some African countries have achieved domestic manufacturing based on their own designs, as described by Ito (1986).

Several studies have analysed the opportunities and challenges of African manufacturing, revealing constraints related to human capital, financial capital, infrastructure and the policy environment, among others, which can raise production costs and undermine competitiveness. Regarding human capital, African manufacturing is believed to benefit from an "abundance of low-cost, underemployed labour" but much of this labour lacks "skills and efficiency" (Signé, 2018; p. 7). According to the Enterprise Surveys of the World Bank (2021), 16% of manufacturing firms in

Sub-Saharan Africa identify an "inadequately educated workforce as a major constraint". Access to financial resource capital is another major challenge (Abdisa & Hawitibo, 2021; Dinh et al., 2012; Fowowe, 2017), which 38% of manufacturing firms identify "as a major constraint" and 23% as their "biggest obstacle" (World Bank, 2021).

Poor infrastructure heavily affects the production costs, competitiveness and marketing opportunities of African manufacturers (Dinh et al., 2012; Signé, 2018). Calderon et al. (2018) found that Sub-Saharan Africa "ranks at the bottom of all developing regions in virtually all dimensions of infrastructure performance" (p. 2). Across Africa, manufacturing firms struggle with patchy, unreliable and costly energy access (Abdisa & Hawitibo, 2021; Ampah et al., 2021; Calderon et al., 2018; Geginat & Ramalho, 2018; Nyanzu & Adarkwah, 2016; Signé, 2018). 77% of all manufacturing firms regularly experience electrical outages – on average nine outages per month, each lasting on average 6 hours (World Bank, 2021). Fifty-three percent of the firms use expensive backup generators, which produce 30% of the electricity used (World Bank, 2021). Electricity costs are thrice as high compared to other developing regions (Signé, 2018). Transportation infrastructure also remains a challenge. Railroad networks are few and poor and Sub-Saharan Africa is the only region witnessing declining road densities over the last two decades (Calderon et al., 2018; Meijer et al., 2018; Signé, 2018). Africa also struggles with "substantial gaps" in ports (Signé, 2018). According to the Enterprise Surveys of the World Bank (2021), 24% of manufacturing firms in Sub-Saharan Africa identify transportation as a "major constraint".

Regarding the policy environment, there are many positive developments – as well as some persisting challenges. Trade barriers within Africa have been reduced thanks to the African Continental Free Trade Area (AfCFTA), among other initiatives. Trade barriers to global markets have been reduced, too, but trade policies continue to undermine the availability and quality of raw materials and production equipment as well as affect their costs in some countries (Ampah et al., 2021; Signé, 2018). The costs of doing business have declined thanks to reform efforts in many countries, but firms continue to be affected by "notoriously high levels of corruption and bureaucratic restrictions" (Signé, 2018, p. 9). According to the Enterprise Surveys of the World Bank (2021), 39% of manufacturing firms in Sub-Saharan Africa identify corruption as a "major constraint". Next to bureaucracy and corruption, manufacturers can also suffer from macroeconomic instability (Signé, 2018). Nnyanzi et al. (2022) highlight the importance of improving governance for the sector, which is rule of law, regulatory quality and government effectiveness, among others. After years of neglect, some countries have begun to support the building of industries and the transformation of informal craftmanship to (small-scale) manufacturing. However, in many countries, this is not the case or industrialization efforts focus only on a few large flagship projects.

There are no comprehensive studies on the specific challenges faced by agricultural manufacturing industries in Sub-Saharan Africa. However, the FAO has published several reports on agricultural mechanization in Africa where the plight of local manufacturers is also touched upon. Ampah et al. (2021) and Daum and Birner (2017) shed some light on manufacturing in Ghana, and Sims et al. (2012) explore manufacturing in the context of machines and tools for Conservation Agriculture in Southern Africa. Houmy et al. (2013) draw a distinction between state-owned manufacturers and private manufacturers, which can be formal and industrial or informal and artisanal. State-owned manufacturers are often heavily supported with subsidies, tax exemptions and prioritization in public tenders (Houmy et al., 2013). According to Houmy et al. (2013), state-owned manufacturers achieve high product qualities, but their products are expensive due to "high overheads, cumbersome purchasing procedures, and low production efficiencies" (p. 27). Ampah et al. (2021) argue that government assembly plants often lack "the technical capacity and managerial efficiency to compete with imports" (p.8). Private agricultural manufacturing is undermined by a business environment that is characterized by lacking access to electricity and finance, lacking standards and testing and lacking knowledge and skills development related to both technical and economic aspects, as well as by high taxation, and high import duties on raw materials (as compared to low import duties on finished goods) (Ampah et al., 2021; Daum & Birner, 2017; Houmy et al., 2013; Sims et al., 2012). In the past, numerous African countries made attempts to foster domestic manufacturing by supporting joint ventures with foreign manufacturers. These ventures involved inviting foreign manufacturers to establish local manufacturing plants with either private or public local businesses, subject to specific conditions, such as the requirement to source materials locally. However, such endeavours often failed due to setbacks such as the inadequate quality of locally produced raw materials (Diao et al., 2020; Takeshima & Lawal, 2020). Informal and artisanal manufacturers – who are often located in rural areas and close to farmers – are significant sources of simple, affordable and locally adapted machines and tools, but quality standards are poor and variable and working conditions can be bad (Daum & Birner, 2017; FAO & AUC, 2018). All types of manufacturers struggle to compete with low-cost imports from global manufacturing powerhouses such as China and India, as well as from development partners and government projects importing machinery in bulk from abroad (FAO & AUC, 2018).

3 | RESEARCH COUNTRIES, SAMPLING AND METHODS

3.1 | Research countries: an overview of agricultural mechanization and manufacturing

This research was conducted under the project "Program of Accompanying Research for Agricultural Innovation" (PARI).[3] Of the 14 countries covered by PARI, 4 were chosen for this study: Benin, Kenya, Mali and Nigeria. These countries are located in West and East Africa and are characterized by different degrees of agricultural mechanization and different economic characteristics and business environments (see Table 1).

In Benin, 23% of the farmers use draft animals and 1% use tractors for land preparation. In contrast, post-harvest processing and storage are mechanized to a much larger degree and a significant portion of the equipment is locally produced (RdB & FAO, 2021). In Kenya, 33% of farmers use draft animals, while 2% have adopted tractors, however, these statistics are more than 10 years old (De Groote et al., 2020). The Kenyan government estimates a higher mechanization rate of 30% but provides no empirical basis for this (GoK, 2021). Similar to Benin, there is a greater degree of mechanization in post-harvest processing such as shelling/threshing and milling (De Groote et al., 2020). In Mali, 40% of the land is cultivated with draft animals and less than 1% of farmers own tractors, although tratorization rates are much higher in Southern regions such as Sikasso and Segou (Kergna et al., 2020). In these high-production areas, motor pumps, shellers/threshers, mills and other mechanized equipment are also common (Kergna et al., 2020). In Nigeria, draft animals are employed by up to 25% of farmers and tractor use stands at around 7% (Takeshima & Lawal, 2020).

Nigeria has by far the largest manufacturing sector in terms of value added (55 billion US$), followed by Kenya (7 billion US$), Benin and Mali (both between 1 and 2 billion US$). Table 1 shows that manufacturing contributes between 7 and 13% of GDP and 6 and 18% of employment. Of the four countries, Kenya consistently ranks best in the quality of the business environment indicators; manufacturers in all the other countries struggle with a relatively poor enabling environment (see Table 1). Manufacturing is high on the policy agenda of all four countries. For example, in Kenya, manufacturing is on the government's "big four agenda" (GoK, 2021).

Local manufacturing is emphasized to a different degree in the agricultural mechanization strategies in the case study countries. In Benin, the "Stratégie Nationale de Mécanisation Agricole" (SNMA) (2022–2026) recognizes the presence of local manufacturing companies as a significant opportunity. While large machinery such as tractors are imported, local manufacturers produce machinery implements and post-harvest and processing equipment (RdB & FAO, 2021). The SNMA highlights that local manufacturers are said to suffer unfair competition with imports due to a lack of knowledge and skills development, difficult access to finance, availability and costs of electricity and raw materials and lack of standards, testing and certification (RdB & FAO, 2021). To address these issues, the SNMA envisions the "establishment of a framework for promoting local manufacturing". Within the next five years, the SNMA plans activities such as "organizing an awareness campaign to encourage artisans to enter the sector", "strengthening the capacities of manufacturers in the field of business management and manufacturing", "strengthening the structures responsible for standardization and quality control", "organizing (…) exhibition fairs for agricultural equipment" and "encouraging the creation of a national federation of professionals in the agricultural equipment manufacturing sector and establishing a system of grouped supply of raw materials" (RdB & FAO, 2021).

TABLE 1 Characteristics of the four case study countries.

	Benin	Kenya	Mali	Nigeria	Year	Source
Economic Characteristics						
Population (million)	12	54	20	206	2020	World Bank (2021)
GDP/capita (US$)	1,291	1,838	858	2,097		
Manufacturing Sector						
Share of GDP (%)	10	8	7	13	2020	World Bank (2021)
Value added (Billion US$)	1.516	7.203	1.185	54.759		
Share employment (%)	18	6	8	12		
Agricultural Sector						
Share of GDP (%)	27	35	36	24	2020	World Bank (2021)
Share employment (%)	38	54	62	35		
Use of tractors	1% of cropland	2% of farms	0.4% of farms (own)	4% of farms	2012–19	RdB & FAO (2021), De Groote et al. (2020), Takeshima and Lawal (2020), Kergna et al. (2020)
Business Environments						
Ease of Doing Business (Rank, of 190)	149	56	148	131	2020	World Bank (2021)
Enabling Business of Agriculture (0–100)	33	65	34	49	2019	
Global Competitiveness Index (Rank, of 137)	120	91	123	125	2017/18	Schwab (2018)
Higher Education and Training	114	97	119	116		
Availability of financial services	119	58	120	102		
Transport Infrastructure	120	62	116	128		
Quality of electricity supply	131	94	116	136		
Irregular payments and bribes	130	94	131	124		

In Kenya, local manufacturing also plays a crucial role in the National Agricultural Mechanization Policy (NAMP) (GoK, 2021). The NAMP recognizes that "inadequate local manufacturing of agricultural machinery and equipment" poses a significant obstacle to mechanization (GoK, 2021). The GoK (2021) identifies several factors contributing to this issue, including high costs and poor quality of raw materials, expensive energy costs, insufficient funding for research and development, and limited knowledge and skills development. It also highlights that local producers face disadvantages due to "unfavourable taxation regimes" and a "low capacity (trained personnel, infrastructure, equipment) for testing and evaluation of agricultural machinery and equipment for quality assurance" (GoK, 2021). Policy interventions to address some of these challenges are discussed. One such intervention is the implementation of better standards, testing and certification through the Kenya Agricultural Mechanization Testing Centre (GoK, 2021). Another proposed intervention involves strengthening public research institutes to enhance research and development in the agricultural manufacturing sector (GoK, 2021).

In Mali, the mechanization strategy – the "Stratégie de mécanisation agricole au Mali" is already from 2008 (GdM, 2008). This strategy describes various challenges that local manufacturers were encountering at that time, many of which persist today. Apart from facing infrastructural obstacles, the document indicates that local manufacturers are at a disadvantage compared to importers due to factors such as low productivity, inability to compete for public contracts, and the high cost of raw materials due to particularly high customs duties (GdM, 2008). The primary objective of the strategy was to enhance the enabling environment for local manufacturing, including by supporting the development of knowledge and skills, research and development, standards and testing, access to finance and more fair tax regimes by reducing taxes on raw materials (GdM, 2008). However, as the results will demonstrate, many of these objectives are yet to be accomplished in Mali.

Unlike the other three case study countries, Nigeria does not possess a dedicated agricultural mechanization policy but mechanization is addressed by other policies such as the "Agriculture Promotion Policy (2016 – 2020)". One of the stated objectives is to stimulate "domestic production of equipment linked with complementary targeted import and standardization of agro-technology" (FMARD, 2016). The document points toward some challenges such as a "poor resource base and poor technical skills" and suggests policy interventions such as to enhance skill building but otherwise provides only a few details on specific policy interventions to support local manufacturing.

3.2 | Study sites, sampling and methods

The goal of this study was to obtain a holistic understanding of the opportunities and challenges for local manufacturing of machinery and equipment for agro-food systems, and the factors and actors affecting the success of such domestic manufacturers. To obtain such a holistic understanding, multiple methods were used – a survey among manufacturers, net-maps sessions and key-informant interviews – and interacted with a wide range of stakeholders. Table 2 provides an overview of the data collection methods and sample sizes in the four countries. In each country, 3–4 local administrative regions (zones, districts, or counties, depending on the country) were chosen that are dominated by agricultural production and characterized by the presence of local agricultural manufacturers (see Table 2).

To obtain insights into the perspectives of local manufacturers, we have conducted a quantitative survey among 386 manufacturers in the four countries (see section 2.2.1.). To obtain insights from other stakeholders, 45 qualitative participatory net-map sessions were conducted (see section 2.2.2.). These sessions were conducted with stakeholder groups such as manufacturers as well as end-users (farmer and processing industry associations), raw materials providers, regulatory bodies, financial institutions and knowledge and skills-building institutions, among others. The net-maps sessions helped to identify the complex network of factors, actors and bottlenecks affecting the business environments of manufacturing, that is, the agricultural innovation system (World Bank, 2006). The net-maps session also served to identify respondents for the 97 key-informant interviews (see section 2.2.3). The interviews allowed us to further discuss some of the aspects that affect the success of manufacturers. All data were collected between

TABLE 2 Sampling framework.

	Regions	Manufacturers	Net Maps		Key Informants
			Sessions	Participants	
Benin	ADH4, ADH5, ADH7	50	16	62	30
Kenya	Kiambu, Kisumu, Nairobi, Nakuru	94	13	78	25
Mali	Koulikoro, Segou, Sikasso	151	6	50	12
Nigeria	Kaduna, Niger, Oyo	91	10	109	30
Total		**386**	**45**	**299**	**97**

June and December 2020. Informed consent was obtained from all study participants. Using different methods and talking to a wide range of stakeholders helped to triangulate the data collected (as recommended by Bitsch, 2005).

3.2.1 | Survey

For the study, 386 manufacturers were surveyed. For this, lists with all manufacturers in specific regions were generated with the help of local organizations.[4] From these lists, sub-sets of manufacturers were randomly sampled. In Benin, 50 manufacturers were sampled. In Kenya, 120 manufacturers were sampled, however, due to Covid-19-related restrictions, only 94 manufacturers could be interviewed. In Nigeria, 91 manufacturers were interviewed. In Mali, 151 manufacturers were interviewed.

3.2.2 | Net maps

To understand bottlenecks in the agricultural innovation system affecting the success of agricultural manufacturers, 45 focus group discussions were conducted using net maps, a participatory appraisal method (Schiffer, 2007). Net-maps help to understand the complex networks of factors and actors affecting a certain outcome, relying on visualization and group interaction (Schiffer, 2007). Visualization helps to engage the participants and to structure the discussion. Group interaction allows drawing on the combined “swarm intelligence” of the participants and enables constant cross-checking by other participants, sparking discussions. Net-Maps have been used in previous studies, for example, to understand challenges associated with the provision of veterinary services in Uganda (Ilukor et al., 2015), livestock vaccination campaigns in Zambia (Lubungu & Birner, 2018) and social safety net programs in India (Raabe et al., 2010). Daum and Birner (2017) have used net-maps to understand the governance challenges of agricultural mechanization in Ghana. In this study, net-maps were mostly conducted as part of focus group discussions. The net-map sessions were typically conducted with 6–12 respondents, but smaller groups in some cases due to COVID-19-related health restrictions or security concerns, e.g., in Mali. The net-maps sessions were conducted in a standardized sequence of five steps. In the first step, participants were asked the following question:

1. Who are the actors and factors that affect the success of manufacturers?

The mentioned actors and factors were written on post-its with different colours (representing different categories of actors and factors) and placed on a large sheet of paper. In the second step, participants were asked the following question:

2. How are these actors and factors linked among each other and with the manufacturers, and how do they affect the success of manufacturers?

The linkages were indicated on a large sheet of paper, connecting the different actors. Different types of linkages (e.g., flows of information, money and goods/services) were indicated with arrows using different colours. In the third step, participants were asked the following question:

3. What is the degree of influence of the different actors and factors on the success of manufacturers?

The perceived level of importance of the actors and factors was assessed on a scale from 1 to 10 and indicated on the paper sheet using either stars or checker pieces to visualize the level of influence once a consensus was reached. In the fourth step, participants were asked the following question:

4. Where are bottlenecks and challenges between the actors affecting the success of manufacturers?

The bottlenecks were indicated on the large sheets of paper using red arrows. In the fifth step, participants were asked to discuss the following question, based on the final net map:

5. How can the identified bottlenecks be addressed?

During all steps, the participants were asked to elaborate on their opinions (e.g., on why and how the mentioned actors and factors affect the manufacturing). The stakeholders discussed these questions collectively, revealing important insights.

3.2.3 | Key informant interviews

Across the four African countries, 97 key-informant interviews were conducted with actors who were identified as being key to the success of manufacturers (see Table 3). Respondents were selected based on the net-maps sessions and the literature review and identified using snowball or chain-referral sampling. For the interviews, interview guidelines were used using semi-structured and open-ended questions.

4 | RESULTS

4.1 | Business characteristics

4.1.1 | Owners and business background

Table 4 provides an overview of the characteristics of the business owners. Most manufacturers were motivated to pursue their profession because of aspiration (65%) or because of family tradition (24%). Almost all manufacturers are male, typically between 35 and 55 years old. Most manufacturers have received only limited formal training. In Benin and Mali, most manufacturers have no formal education or only primary education. In Kenya and Nigeria, there is a much higher share of manufacturers with secondary education (39% and 30%) and university degrees (30% and 41%). Only 38% have participated in any type of business training, which may explain why only 44% of businesses use accounting systems (see Table 7). The high share of manufacturers who own farmland (70%) is noteworthy, suggesting a strong familiarity with the needs of local agriculture.

TABLE 3 Overview of qualitative data collection.

Key informant interviews	Benin	Kenya	Mali[a]	Nigeria	Total
Policymakers	6	4	1	3	**14**
Knowledge/skills-building organizations	7	11	2	6	**26**
Financal institutions	3	1	1	4	**9**
Manufacturer organizations	9	4	3	10	**26**
Customer organizations (i.e. farmers, processors)	5	5	3	5	**18**
Development partners	0	0	2	2	**4**
Total	**30**	**25**	**12**	**30**	**97**

[a]Not all planned key informant interviews could be completed due to security considerations.

Figure 1 shows the decades during which the sampled enterprises were originally founded. The majority of Malian and Nigerian manufacturers were founded in the 1990s and 2000s, whereas most manufacturing businesses in Benin and Kenya were founded in the 2010s. Table 5 shows that manufacturing companies are mostly private (94%). Sixty-five percenr of the manufacturers surveyed are formally registered (but only 45% in Nigeria) and 59% are part of an association (but only 16% in Kenya).

4.1.2 | Production characteristics and trends

Agricultural manufacturers mostly produce machinery for crop production and post-harvest handling (44%) and crop processing (24%), but many manufacturers also produce machinery for other sectors such as livestock production, construction and transportation (see Table 6). In Kenya, which has significant meat and dairy industries, a particularly large share of the machinery produced is for the livestock sector (27%). Among the most common types of machinery produced are mills, threshers and shellers in Benin; choppers, mills, threshers and shellers in Kenya; plows, rippers, harrows, carts and trailers, planters and seeders in Mali; and mills, threshers and shellers in Nigeria. An average manufacturer in our sample produces around 17 threshers and shellers, 13 mills, 12 tractor attachments for land preparation (e.g. plows, harrows or rippers) and several other types of equipment, per year. A total of 14% of all manufacturers produce machinery that can be powered with renewable energy, in particular pumps and dryers.

A total of 58% of the manufacturers across the four countries stated to produce only on-demand and 29% stated to produce both on-demand and regularly (see Table 7). Respondents cited market risks (61%) and lack of capital (56%) as reasons for on-demand production. Another stated reason was the ability to customize machinery to customers' preferences (36%). The downside of on-demand production is that it reduces production efficiency and raises costs vis-à-vis importers, who typically produce on a large scale using an assembly line production system. Further, customers must wait for their machinery to be produced and delivered. Customers also typically need to make a down payment before the actual production begins, which helps manufacturers to minimize market risks and source the required capital for production. Upfront payments are particularly common in the cases of larger and motorized equipment. For customers, the necessity of making a substantial down payment constitutes a risk factor as they cannot see the final product yet, unlike when purchasing finished, imported machinery. The risk is exacerbated as only 27% of all manufacturers reported being subject to some kind of third-party testing. The production designs of machinery are typically based on the ideas of the manufacturers themselves (68%) or are copied from other manufacturers and importers (67%). A total of 39% of the manufacturers stated that the design of products is influenced by the ideas and preferences of customers. A total of 62% of the manufacturers stated that they do their own research and development. On average, 42% of all profits are re-invested into the manufacturing business.

TABLE 4 Owner and business background.

	Benin	Kenya	Mali	Nigeria	Average
Motivation					
Aspiration	89	71	36	65	65
Family tradition	6	11	62	17	24
No alternatives	4	12	2	11	7
Others	0	5	0	7	3
Gender					
Male	100	91	100	99	97
Female	0	9	0	1	3
Age					
Below 35	19	14	15	9	14
35–45	32	46	30	32	35
45–55	40	30	36	37	36
55–65	6	9	15	16	12
Above 65	2	0	3	7	3
Educational level (highest)					
None	4	0	31	4	10
Primary	52	25	51	11	35
Secondary	20	39	3	30	23
University	10	30	4	41	21
Vocational	6	5	5	7	6
Others	8	0	7	6	5
Educational background					
Agriculture	10	-	28	40	26[a]
Engineering	84	-	42	44	57[a]
Business	0	-	4	2	2[a]
Others	6	-	26	13	15[a]
Farmland ownership					
Yes	57	82	74	65	70
No	43	18	26	35	31
Business training					
Yes	49	30	28	44	38
No	51	70	72	56	62

[a]Except Kenya.

4.1.3 | Marketing, customers and competition

Table 8 gives some insights into the types of customers of local agricultural machinery manufacturers, and Table 9 provides insights related to their main competitors. Mirroring the insights on the type of types of equipment produced, agricultural machinery manufacturers mainly sell to farmers (64%), particularly small-scale (>2 ha) (33%) and medium-scale (2-15 ha) (30%) farmers, as well as processing companies (11%). Most manufacturers' customers are from their region (80%) and the share of customers from abroad is very small (2%). Manufacturers mostly acquire

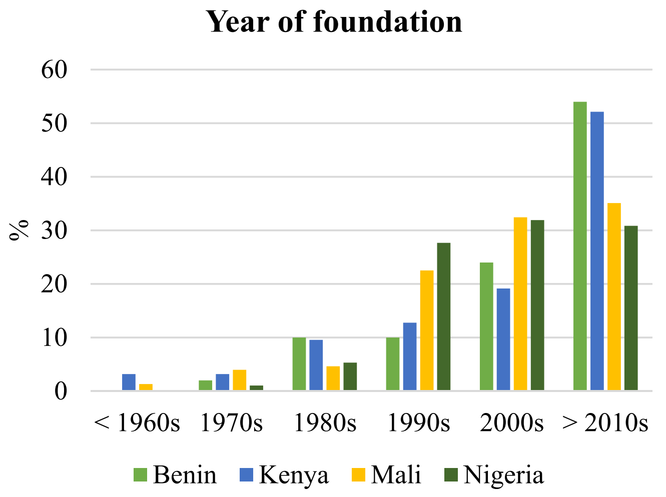

FIGURE 1 Years of foundation.

TABLE 5 Business characteristics.

	Benin	Kenya	Mali	Nigeria	Average
Type					
Private (domestic owner)	96	89	96	96	94
Private (foreign owner)	2	6	1	0	2
Shareholder company	0	1	1	4	2
Public	2	3	0	0	1
Public-private	0	0	3	0	1
Others	0	0	0	0	0
Formal registration					
Yes	58	79	76	45	65
No	42	21	24	55	36
Association					
Yes	78	16	85	57	59
No	22	84	15	43	41
Business location					
Settlement < 10,000 people	8	29	21	3	15
Settlement 10,000–50,000 people	36	14	21	14	21
Settlement 50,000–100,000 people	22	23	24	45	29
Settlement > 100,000 people	34	34	35	37	35

customers through word-of-mouth advertisement, a reputational mechanism that may help to ensure some quality standards and social media. In the case of social media, there are large differences between the four countries, with 61% of manufacturers in Kenya using this type of marketing, but only 5% in Mali. A total of 43% of all manufacturers grant credits to customers, allowing them to pay off the products over time, a practice that is particularly common in Mali, where 87% of the manufacturers do this. Manufacturers stated that customers can pay in cash (96%) or using

TABLE 6 Types of machinery produced.

	Benin	Kenya	Mali	Nigeria	Average
Shares of machines produced (%)					
Crop production, post-harvest handling	22	35	71	48	44
Crop processing	33	25	8	31	24
Livestock production, processing	7	27	6	8	12
Horticulture production, processing	2	3	4	0	2
Forestry	6	0	2	2	3
Construction, transportation, and others	30	10	9	11	15
Number of machines sold (last 12 months)					
Threshers, shellers	12,2	16,2	11,2	27,4	16,8
Mills	15,2	22,6	4,4	9,4	12,9
Plows, harrows, rippers	0,8	4,8	39,7	2,7	12,0
Choppers	0	21	0,6	1,0	5,7
Carts, trailers	0,3	1,8	19,5	0,1	5,4
Seeders, planters	2,6	1,3	13,1	2,5	4,9
Irrigation equipment	0	7,5	5,8	0	3,3
Tractors, incl. two-wheel-tractors	0,4	3,5	2,4	0,50	1,7
Generators	0	4,8	0,8	0	1,4
Others	22,1	22,7	5,8	1,1	12,9
Machines with renewable energy					
Yes	8	17	9	21	14
No	92	83	91	79	86

bank transfers (40%). In Kenya and Nigeria, mobile money transfer is also common, a mechanism that is absent in the two Francophone countries.

The perceived main competitors are domestic (72%), with manufacturers perceiving their advantages vis-à-vis importers as being related to quality (75%), price (44%), local adaptation (36%), after-sales services (35%) and reputation/trust (18%) (see Table 9). Eighty-five percent of the manufacturers stated that they provide some form of after-sales service and 80% provide a warranty (see Table 8).

4.1.4 | Human resource management and staff characteristics

Table 10 shows some descriptive statistics related to human resource management and employees. Manufacturers have 7,9 employees on average, with manufacturers in Kenya employing the most staff (12,2). Employees typically have primary (40%) or secondary education (43%). In Kenya and Nigeria, there is a high share of employees who have a university degree (43% and 32%, respectively) or have completed vocational training (22% and 27%, respectively). A total of of all manufacturers provide "on-the-job"-training, which typically lasts around three years. In 37% of the cases, this is part of a more formal collaboration with vocational training centres where trainees obtain additional knowledge and skills. In the other 63% of the cases, this training is more informal, and trainees are only trained by the manufacturers themselves. On average, manufacturers had 9,9 trainees in the last three years, 41% of whom received some salary.

TABLE 7 Production characteristics.

	Benin	Kenya	Mali	Nigeria	Average
Production mode					
On-Demand	56	62	53	59	58
Mixed	38	15	32	31	29
Regularly	6	23	15	10	13
Reasons on-demand (%, multiple)					
Market risks	70	65	-	49	61[a]
Lack of capital	48	51	-	51	56[a]
Customer specifications/preferences	44	33	-	34	37[a]
Others	12	6	-	3	7[a]
Down payment					
Yes	96	84	98	85	91
No	4	16	2	15	9
Production design (multiple)					
Own development	72	72	59	80	68
Copy from other manufactures	84	55	63	66	67
Customers	52	54	10	64	39
Employees	0	10	3	8	4
Government bodies	0	0	5	2	2
Others	0	11	0	8	4
Own research and development					
Yes	68	53	74	54	62
No	32	47	26	46	38
Distribution of profits (%)					
Private use	55	60	-	53	56[a]
Invest in business	39	40	-	47	42[a]
Others	6	0	-	0	2[a]
Third-body testing					
Always or mostly	32	28	29	19	27
Never or rarely	68	72	71	81	73
Accounting system					
Always or mostly	36	77	23	39	44
Never or rarely	64	23	77	61	56

[a]Except Mali.

4.2 | Business environment

An enabling business environment is key to the success of local agricultural manufacturers. Figure 2 gives a representation of the mixed impression of the business climate across the four sampled countries. Manufacturers' perception of the business environment is mostly positive in Kenya and Mali, and more negative in Benin and Nigeria. However, it is important to note that manufacturers' judgments are subjective and do not necessarily enable cross-country comparisons.

TABLE 8 Customers and marketing.

	Benin	Kenya	Mali	Nigeria	Average
Customers					
Smallholder farmers (<2 ha)	15	48	91[a]	36	33[b]
Medium-scale farmers (2-15 ha)	12	21		27	20[b]
Large-scale farmers (>15 ha)	18	8		7	11[b]
Processing companies	22	7	4	22	11
Cooperatives	15	1	4	1	5
Public organizations and programs	13	5	0	4	5
Transporters and retailers	4	5	0	3	3
Others	1	5	1	0	2
Location of customers					
Within region	73	70	94	85	81
Outside region, within country	24	27	4	14	17
Outside country, within Africa	3	4	2	1	2
Advertisement (multiple)					
Word-of-mouth	74	68	76	69	72
Social media	30	61	5	27	31
Showroom and display	46	37	3	19	26
Shows and exhibitions	14	27	10	30	20
Dealer network	12	21	10	12	14
Newspapers, radio, TV	8	16	15	7	12
Others (e.g. competitions, extension)	2	12	3	15	8
Point of sales (multiple)					
Workshop	100	93	-	81	91[b]
Dealer network	4	39	-	13	19[b]
Others	0	6	-	6	4[b]
Customer credits					
Yes	26	37	87	24	43
No	74	63	13	76	57
Payment mode (multiple)					
Cash	100	93	99	91	96
Bank	42	53	0	66	40
Mobile	0	64	1	33	25
Others (e.g., in-kind)	8	7	3	2	5
Warranty					
All or mostly	98	77	61	86	80
None or mostly not	2	23	39	14	20
After-sales services					
Yes	98	86	71	84	85
No	2	14	29	16	15

TABLE 8 (Continued)

	Benin	Kenya	Mali	Nigeria	Average
Unmet Demand					
Yes	91	74	97	73	84
No	9	26	3	27	16

[a]In Mali, the questionnaire did not distinguish between different categories of farmers.
[b]Except Mali.

TABLE 9 Competition.

	Benin	Kenya	Mali	Nigeria	Average
Main competitors					
National	77	71	66	76	72
International (inside Africa)	1	1	15	2	5
International (outside Africa)	15	27	16	21	20
Public imports	7	1	3	1	3
Perceived advantages over importers (multiple)					
Quality	78	77	78	66	75
Price	46	34	52	44	44
Local adaptation	50	18	47	32	37
Availability	12	37	57	38	36
After-sales services	46	46	23	25	35
Trust, reputation	14	22	13	23	18
Others	4	6	11	1	6

Figure 3 shows the top 10 business constraints that manufacturers perceive as undermining their business. Some of the major constraints are related to the access and costs of finance, access and costs of electricity (i.e., in Mali and Nigeria), and access and costs of inputs (i.e., raw materials for production). There are also constraints related to market risks, the access and costs of machinery for production and unfavourable import policies, among many others (see Figure 3).

Table 11 provides some more insights into the aspect of finance, which was identified as the main business constraint in Benin and Kenya and the second largest business constraint in Mali and Nigeria (where access and costs of electricity were ranked as slightly larger constraints). Overall, very few manufacturers across the four countries used external capital. Those who used external capital in the last three years, that is between 2017 and 2020, obtained it primarily from microfinance institutions (11%), commercial banks (10%) and friends and family (6%). 26% of all manufacturers sampled in the four countries applied for formal credit in the last three years. As reasons for not applying for formal credit, manufacturers cited tedious application processes, preferences for other sources, perceived lack of success chances and strict repayment schedules, among others (such as lacking interest and fears of becoming indebted). Of those who did apply for formal credits, the vast majority (87%) received the credits. The low application rates and high approval rates may be due to manufacturers underestimating their chances of receiving credits and/or a form of self-selecting bias, where only manufacturers with high chances of receiving credits make the effort to apply for it.

Table 12 provides more detailed insights into some aspects of the enabling environment. In Benin and Kenya, most manufacturers have access to the electricity grid, this aspect was thus not perceived as a large business constraint (see Figure 3). This contrasts with Mali and Nigeria, where the share of manufacturers connected to the grid is lower (81% in Nigeria; 76% in Mali), and where electricity from the grid is also costly and unreliable, undermining

TABLE 10 Human resource management and staff characteristics.

	Benin	Kenya	Mali	Nigeria	Average
Number of employees					
2020	4,6	12,2	7,0	7,8	7,9
2017	2,9	15,3	6,6	7,3	8,0
Education of employees					
None	36	7	16	10	17
Primary	48	23	60	30	40
Secondary	32	60	14	66	43
University	8	43	3	32	22
Vocational	4	22	3	27	14
Others	0	2	4	7	4
On-the-job training					
Does manufacturer train trainees? (%)	58	79	74	74	71
Number of trainees (last 3 years)	11,1	11,2	3,9	13,4	9,9
Lengths (in years)	3,7	3,2	3,3	3,3	3,4
Share receiving payment (%)	0	55	64	45	41
Monthly payment, if paid (US$)[b]	-	105,1	82,7	79,2	89,0[a]
Collaboration with a vocational training center (%)	45	28	40	36	37

[a]Kenya, Mali and Nigeria only.
[b]Conversion from local currency to US$ as per 31/12/2020.

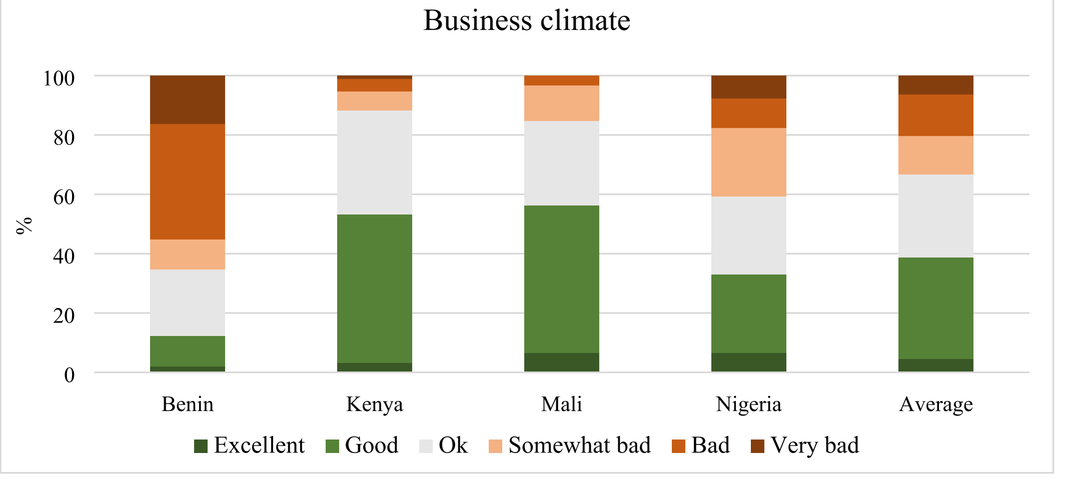

FIGURE 2 Business climate.

production processes (see also Figure 3). On average, manufacturers are relatively satisfied with the knowledge and skills of trained job market entrants. Across the four countries, only 26% stated that they were “not really” or “not at all” satisfied (Benin stands out with 64% dissatisfaction). Almost all manufacturers (89%) who stated that they were “somehow”, “not really” or “not at all” satisfied with job market entrants, suggested that the knowledge and skills-

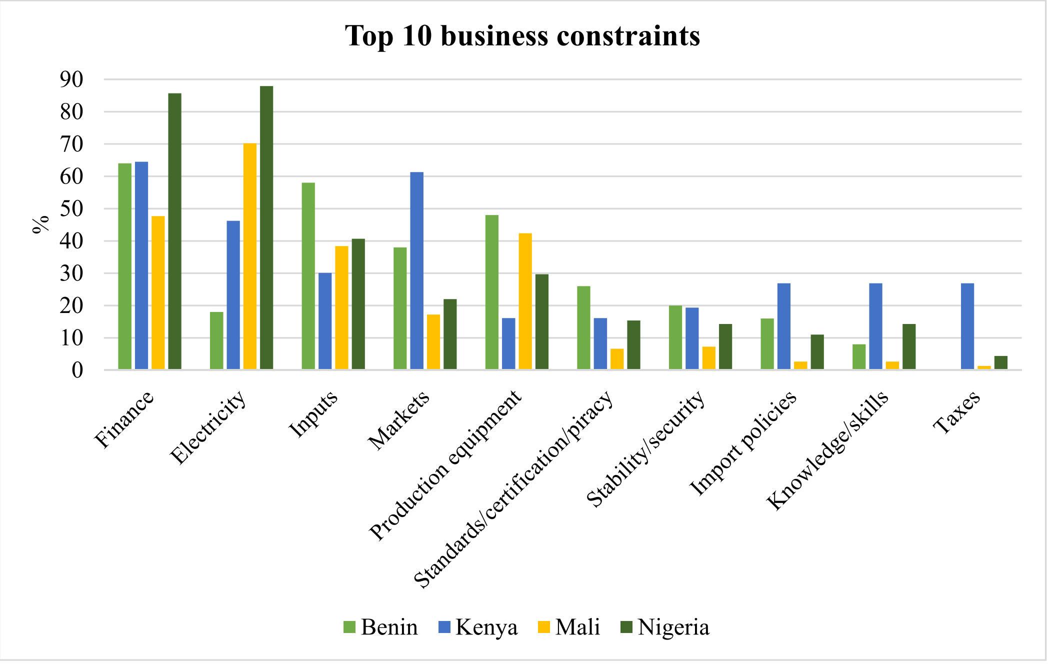

FIGURE 3 Top 10 business constraints.

building domain should incorporate more practical and applied elements (see Table 12). Table 12 also shows the entry barriers that manufacturers have experienced when starting their business; although their businesses are of various ages, as detailed in Figure 1. The main entry barriers are related to a lack of capital (74%), production equipment (37%) and raw materials (28%).

The results from the net-maps and interviews are illustrated in the stylized agricultural innovation system (see Figure 4), which reveals that a wide range of different factors and actors influence the success of manufacturers. In all countries, a large share of manufacturers is self-organized in associations and chambers of commerce to advocate for their interests and coordinate activities. These organizations have been described as central for local manufacturers, however, they are not always well-funded, as was noted in the case of Mali. Figure 4 also shows that there are various bottlenecks between key components of the agricultural innovation systems, which can undermine the success of local manufacturers. Some of these challenges were already clear from the above-shown quantitative insights from the manufacturer surveys, but others are new.

Six input factors are key to the production process of manufacturing: finance, labour, electricity, land, raw materials and machinery. Access to finance is needed for manufacturers to overcome their capital constraints, and it is also important for other actors such as suppliers and customers. However, mirroring the insights from the manufacturers themselves, the qualitative insights also show that access to finance is often a challenge for manufacturers: credit applications are demanding and tedious, interest rates are high and repayment schedules are ill-adopted to the characteristics of the agricultural sector. Labour is another key factor. While labour is generally available, the available knowledge and skills may be limited, highlighting the importance of the education system. All countries have some initiatives to improve knowledge and skills in manufacturing, such as the Programme Nationale de la Formation Professionnelle in Mali, however, such initiatives do not appear to reach the majority of manufacturers and their employees. In all countries, informal and formal “training-on-the-job”-models have emerged (see also Table 10). Formal models in partnership with vocational training centres are more common among larger manufacturers, but some smaller manufacturers also offer this type of training. Formal technical education was often seen as being too

TABLE 11 Capital and finance.

Finance	Benin	Kenya	Mali	Nigeria	Average
Finance sources (multiple, last 3 years)					
Microfinance	14	0	20	11	11
Commercial bank	2	26	7	5	10
Friends, family	2	4	11	8	6
Moneylenders	2	1	1	1	1
NGOs, faith-based organizations	2	0	1	0	1
Others	0	1	7	1	2
Credit application (last 3 years)					
Yes	24	30	31	20	26
No	76	70	69	80	74
Credit application accepted					
Yes	91	100	78	78	87
No	9	0	22	22	13
Credit conditions					
Annual interest rate	8,3	12,4	10,6	17,3	12,2
Reasons for non-application (multiple)					
Tedious process	57	24	14	32	32
Prefer other sources	21	52	20	15	27
No chance	32	8	18	37	24
Strict repayment schedule	19	39	12	8	20
Interest rate	3	0	2	8	3
Others (i.e. no interest, fear)	35	23	40	4	26

theoretical by both key informants and experts, and the manufacturers themselves (see Table 12). Importantly, it is not only the labourers who need sufficient knowledge and skills but also the manufacturers themselves. While key informants and experts often stated that some manufacturers have high levels of knowledge and skills, the knowledge and skills of the majority of manufacturers were said to be limited, as the following quotes from Benin and Nigeria suggest:

"If we build the capacity of local artisans, I think they can do a lot more. Currently, they are left to their own devices. They need support."

"Most manufacturers are blacksmiths trained on the job and do not have advanced technical training."

"There is a need for us to be trained to get the required skill to do the job effectively."

Next to engineering knowledge and skills, current and future manufacturers also need knowledge and skills related to business management (see Table 4).

In all countries, the research system was identified as a potentially key factor for the success of local manufacturers. Research is necessary to develop locally adopted engineering solutions. Developing locally adapted machinery has been identified as a potentially large comparative advantage of local manufacturers, as further discussed below, however, these opportunities are not fully harnessed in countries where the public research system was weak. In all countries, the research system was said to be poorly funded and to fail to follow the latest developments, as illustrated by the following quote from Benin and Mali:

"The state must necessarily finance research and development so that researchers can develop machines adapted to the processing of our local products."

TABLE 12 Business environment.

	Benin	Kenya	Mali	Nigeria	Average
Direct government support (last 3 years, multiple possible)					
Knowledge and skills	36	11	1	13	15
Loans and credits	2	5	2	9	5
Free or subsidized production equipment, industrial land, etc.	4	1	4	7	4
Others	2	1	3	0	2
None	58	83	90	73	76
Access to the electricity grid					
Yes	96	98	76	81	88
No	4	2	24	19	12
Satisfaction with job market candidates (with degrees)					
Very much	2	46	22	20	22
Mostly	6	23	47	44	30
Somehow	28	19	19	18	21
Not really	14	7	7	13	10
Not at all	50	4	4	5	16
Need for education system change[a] (multiple possible)					
More practice	91	100	82	-	89[b]
Better teachers	5	5	11	-	7[b]
More theory	0	5	11	-	5[b]
Updates curricula	0	5	5	-	3[b]
Others	0	10	0	-	3[b]
Entry barriers when starting a business (multiple possible)					
Lack of capital	76	89	47	82	74
Lack of production equipment	24	44	50	29	37
Lack of raw materials and parts	40	38	3	30	28
Lack of land	2	22	11	11	12
Lack of knowledge and skills	4	20	5	10	10
Lack of electricity	2	2	2	24	8
Others	14	58	18	27	29

[a]Only asked to respondents who answered the question on satisfaction with job market candidates (with degrees) as somehow, not really, or not at all.
[b]Except Nigeria.

"Most machines built by manufacturers are adaptations from outside; we don't have our design. Therefore research should be funded to create our makes."

Utilities were identified as key bottlenecks in the agricultural innovation system (see also Figure 3). In many countries, transportation infrastructure is poor, raising the costs of production and undermining the marketing of products overall longer distances and abroad. Moreover, particularly in Mali and Nigeria, electricity is not only costly but also unreliable, which can heavily undermine production processes. Some manufacturers use generators to become independent from the public electricity grid, but this raises the costs of production. Industrial land and machinery for production are other key constraints, as identified by the manufacturers themselves and in the key informant and expert interviews, as the following quote from Mali shows:

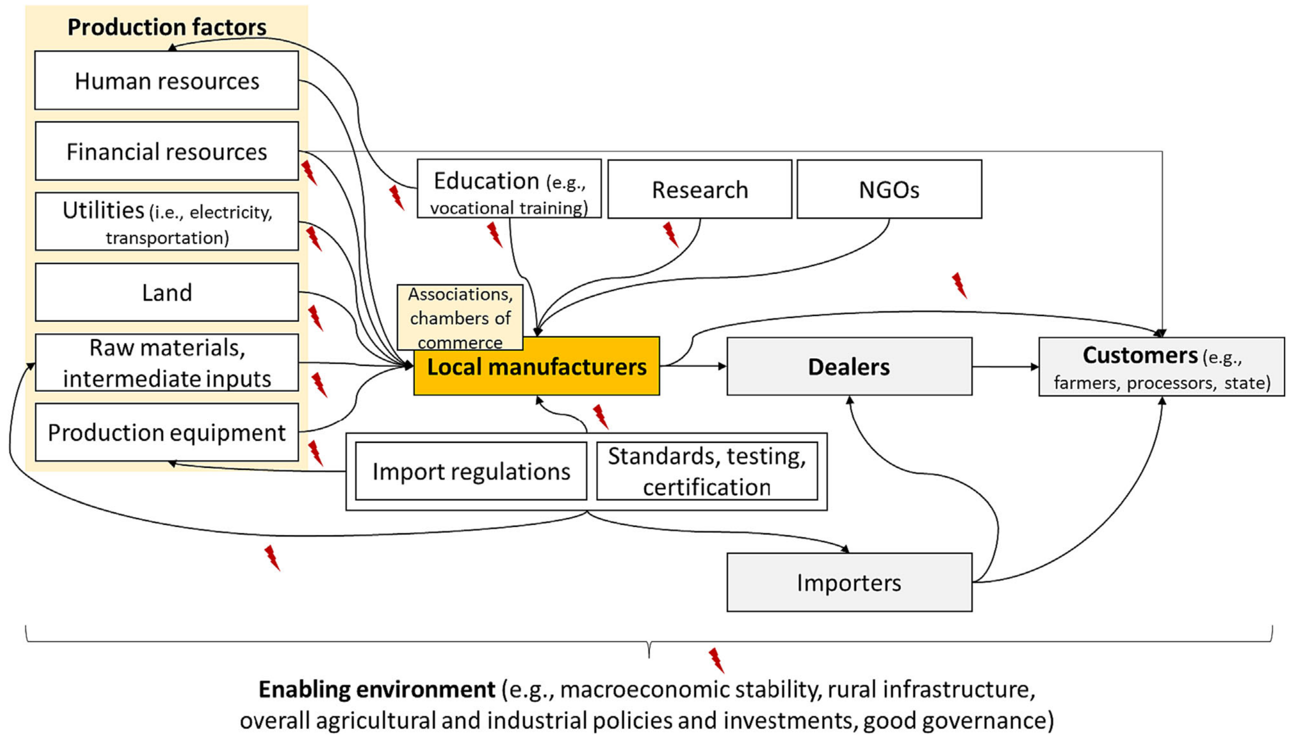

FIGURE 4 Stylized agricultural innovation system of manufacturers.

"Manufacturers need advanced equipment to make their manufactures as beautiful as imported ones."

Lastly, the access and costs of raw materials and parts can be problematic, as noted by key informants and experts in all countries. It was stated that there can be quality problems with raw materials and parts for production.

Despite these challenges, local manufacturers are typically very confident that they have a comparative advantage vis-à-vis importers due to superior product quality, among others (see also Table 9). The qualitative interviews with representatives of farmers and from the food and beverage processing sectors reveal a more mixed picture. Some respondents indeed found that local manufacturers have an advantage over importers related to quality as well as prices and after-sales services (i.e., repairs and spare parts availability). One aspect that was frequently highlighted as a comparative advantage was the ability to tailor machinery to the specific local agro-ecological conditions, as the following quote from Benin, Kenya and Nigeria highlights:

"Machines made outside do not meet our realities. (…) To guarantee the future of this sector, we [need to] manufacture machines adapted to our reality."

"Locally manufactured products are built for local purpose and hence superior."

"The machines imported to the country are not suitable for our environment, though they are of good material. Therefore, we always take them to the local fabricators for modification around here before using them."

But many key informants and experts also emphasized challenges, suggesting that outdated machinery design, lacking standards and testing, poor quality raw materials, lacking production equipment, lacking knowledge and skills, among others, can translate to products of limited quality, as the following quote from Benin and Mali suggests:

"Despite the efforts that manufacturers make, people still complain about the maintenance and quality of local equipment. (…) They don't have the engineering skill at hand."

"Our machines are robust, but they are not performing as imported ones. Used materials will never give good quality machines, they should be trained to select appropriate materials for making machines.".

In the absence of standards, testing and certification of locally produced goods, customers often opt for imported machinery to reduce their risks. The need for testing and certification was a strong theme in the interviews with the stakeholders from the agricultural innovation system and is reflected in the following quotes from Benin and Nigeria:

"There should be an organization that controls and certifies locally manufactured machines."

"The machines certification is not done at all. Nobody has come to our area to check the products we are producing. Though we were told in training that there are organizations in charge in the country but they have never come to our area."

Another disadvantage of local manufacturers is that they mainly produce only on-demand, which means they cannot benefit from the efficiency gains related to assembly-line types of production. In many cases, on-demand manufacturers require a substantial down payment before starting production, which constitutes a risk for customers. Local manufacturers can also be disadvantaged because finished products come with lower import duties and taxes as compared to raw materials needed for local manufacturers. Moreover, it was remarked that government and development projects often favour imports. For example, respondents in Mali stated that government and development partners' projects supporting mechanization often prefer imported equipment – even if this is more expensive – because importers can deliver larger quantities in a shorter time. Lastly, key informants and experts also discussed problems related to the enabling environment. In addition to problems related to education, research and electricity already discussed above, this includes rural infrastructure and problems related to the costs of doing business, in particular the enforcement of contracts. Most contracts (e.g., between manufacturers and raw material- and parts-providers, or manufacturers and their customers) are informal. The lack of legal options in case of non-compliance with the agreed terms of the transaction is associated with high transaction costs, as the following quotes from Benin and Mali suggest:

"During collaborations, some actors did not respect the terms of contract (…), which are, in most cases, verbal, thus creating a climate of lack of trust between these different actors".

"Because of illiteracy, many manufacturers don't respect the terms in the contract such as dimension and time to deliver. This creates disputes among manufacturers and customers.".

5 | DISCUSSION AND POLICY IMPLICATIONS

Local manufacturing can contribute to economic development in Sub-Saharan Africa, enabling job creation and poverty reduction. Agricultural machinery manufacturing can play a key role in driving overall manufacturing development, given the huge number of gradually mechanizing African farmers and the demand from the rapidly growing agro-food processing sector. Harnessing this potential requires African agricultural manufacturing to compete with imports from manufacturing powerhouses such as China and India. This paper suggests that local manufacturers have several comparative advantages, particularly the ability to develop locally adapted machinery, an aspect that is of much higher importance related to agricultural manufacturing than other manufacturing sectors (see also Biggs & Justice, 2015; Biggs & Justice, 2021; Binswanger, 1986; FAO & AUC, 2018; Mrema et al., 2018; Samarakoon, 2011). Another comparative advantage is the ability to facilitate access to spare parts and repair services (FAO & AUC, 2018). These aspects provide local manufacturers with a degree of protection against imports (see also Frankema & Van Waijenburg, 2018). Markets for local machinery have emerged in all four case studies countries, however, manufacturers face a range of challenges related to production factors such as finance, human resources, industrial land, utilities (i.e., electricity), raw materials and production equipment, as well as challenges related to the overall regulatory environment, resonating with the challenges faced by the overall manufacturing sector in Africa (see section 2). While some of these challenges are acknowledged by the agricultural mechanization policies of the case study countries, the results reveal additional bottlenecks and make clear that more efforts are needed to generate a supportive environment for local manufacturers.

Policies and investments to create a supportive environment for local agricultural manufacturing played a key role in many of today's mechanized countries (Daum et al., 2018; Donovan et al., 1987), including, more lately, many Asian countries (Bhattarai et al., 2020; Diao et al., 2020). So far, despite some increasing public support, the results of this paper show that not enough is being done to support local agricultural machinery production. While infant-industry and industrial protection arguments have re-emerged in African policy debates (Economist, 2020; Page et al., 2016), a lot can be done in terms of industrial policies and investments to generate a level playing field for local manufacturers without resorting to such more drastic measures – as shown by the "Enhancing the Quality of Industrial Policies (EQuIP)" project (GIZ & UNIDO, 2022). Not all potential policy instruments can be discussed here, and it should be clear that there are no blueprints, but some key areas for needed policy action can be distilled from the results of this paper. Importantly, while public actors have typically played a key role in creating the necessary support functions needed for agricultural manufacturers (Donovan et al., 1987), private and third-sector organizations can also play an important role (see also Daum et al., 2018; FAO & AUC, 2018), and strengthened collaboration among the three sectors can help to choose, design and implement the right policies and investments.

Improving the enabling environment for local agricultural manufacturing requires both general policies and investments, as well as policies and investments that are specifically tailored to the sector. General policies and investments relate to macroeconomic conditions concerning credit markets and exchange rate policies, electricity networks and transportation infrastructure, and primary, secondary and tertiary education, among others (see also Ampah et al., 2021; Belton et al., 2021; Bhattarai et al., 2020; Dinh et al., 2012; Donovan et al., 1987; Geginat & Ramalho, 2018). Of particular importance in this regard is also stability and security, a lack of which was highlighted by 15% of the manufacturers as a key constraint as it can have detrimental effects on infrastructure and production equipment, undermine market demand and investments, and lead to brain drain, among other consequences. Moreover, it has the potential to disrupt supply chains. This issue is supported by a recent study conducted in Myanmar, where supply logistics for machinery retailers were disrupted due to a military coup and Covid-19-related lockdowns (Takeshima et al., 2023). To reduce supply chain risks, governments could diversify supply chains, foster regional trade, invest in transportation networks and logistics systems and strengthen security measures to protect supply chains, among others.

There is also a need for policies and investments tailored directly to the sector, such as those related to knowledge and skill-building. Vocational training models that combine "on-the-job"-training at the workshops of manufacturers with "in-classroom"-teaching in training centres are a particularly proven and promising solution (Daum & Kirui, 2021; Signé, 2018). This approach is pursued in all four case study countries; however, so far, while informal on-the-job training is already widespread, it is mostly not combined with training at vocational centres. The results also suggest that knowledge and skills-building efforts at existing institutions for vocational training and higher education are at times outdated, and often too theoretical, suggesting a need for refresher courses for teachers and updated curricula, including paying more attention to some of the latest technological developments such those related to renewable energy and better integration of theory and practices (Ampah et al., 2021; FAO & AUC, 2018; Kirui & Kozicka, 2018). There is also a need for training for already existing manufacturers. This could take innovative formats where trainers meet at the workshop of manufacturers to discuss the scope for improvements or where manufacturers bring their latest products to the training compounds, among others (FAO & AUC, 2018; Houmy et al., 2013). Valuable lessons can also emanate from the exchange with other manufacturers within their countries, from other African countries, and from other regions such as Asia (Gulati & Das, 2020). Next to engineering knowledge and skills, manufacturers need to be better equipped with entrepreneurial knowledge and skills (Dinh et al., 2012; FAO & AUC, 2018; Signé, 2018).

The success of manufacturers does not only hinge on their knowledge and skills. Given the large capital constraints, a better investment climate and long-term financing options can help local manufacturers invest in production equipment to improve product quality and enhance productivity. In addition to implementing supportive policies for the finance sector as a whole, governments can play a vital role in strengthening the capacity of financial institutions by providing technical support to work effectively with local manufacturers. Furthermore, governments could establish loan guarantee programs that mitigate the risks for financial institutions when lending to local manufacturers. Tax incentives can also be introduced as a means to incentivize financial institutions to channel their resources towards local manufacturers. Governments could also collaborate with international development finance institutions, such as the African Development Bank and the International Finance Corporation, to set up dedicated funds to provide capital to local manufacturers. Given the limited access to land, policies related to industrial land (e.g. industrial parks) could help them to grow and use synergies.

While private research and development play a central role in manufacturing, there is still a need for long-term public research related to the design of new machinery and local modification and adaptation of machinery (Biggs & Justice, 2021; Bhattarai et al., 2020; Cramb & Thepent, 2020; Donovan et al., 1987; FAO & AUC, 2018). A whole new area for research and development relates to the use of renewable energy as a power source. Making sure that African manufacturing sectors are powered and that African agricultural value chains are mechanized using renewable energy solutions is key for climate change mitigation and can help farmers and other value chain actors to become independent from the patchy and costly electricity supply (Bouchene et al., 2021). The potential for using renewable energy to power mechanization is high, particularly related to stationary farm operation (e.g., solar pumping and irrigation) and post-harvest handling and food processing such as drying, refrigeration and cooling (IFC, 2019). IFC (2019) estimates the "addressable" market in sub-Saharan Africa for solar-based agri-food equipment to be 11 billion US$.[5] It is encouraging that a small but significant share of the local manufacturers has experimented, or already offers solutions, in this regard. The importance of renewable energy sources has also been explicitly highlighted in agricultural strategies, for example in Kenya (GoK, 2021). The integration of renewable energy could be supported with training programs for local manufacturers and start-ups. However, to stimulate demand, it is vital to raise awareness among end users of agricultural machinery, too.

Importantly, when investing in research and development efforts, the linkages between public research and development and local manufacturers should not be forgotten, to ensure that the developed engineering solutions do not end up on the shelf (see also FAO & AUC, 2018; Houmy et al., 2013). Such linkages should not only be oneway; public research and development organizations can learn as much from local manufacturers as vice-versa. Importantly, public research should encompass not only agricultural engineering but also socio-economic aspects that can support manufacturers in their business development. This includes examining the demand and willingness to pay for various types of machinery, such as locally produced versus imported, motorized versus non-motorized and fossil-fuel-based versus renewable options – as well as how these preferences are influenced by different attributes such as machinery quality, after-sales services and standards/certification (Daum & Kirui, 2021; Takeshima et al., 2013).

The results strongly suggest that the success of local manufacturers in Africa is also shaped by more "invisible" aspects related to the regulatory framework. These aspects are, for example, trade regulations, testing, certification, licensing, standards and the costs of doing business. The aspects were also found important in studies from other world regions (Belton et al., 2021; Bhattarai et al., 2020; Donovan et al., 1987). While trade barriers within Africa generally have been reduced over the last few years, trade policies affect the availability, quality and costs of raw materials and production equipment in the four case study countries (see also Ampah et al., 2021; Signé, 2018). In the four case study countries, as well as other African countries, most agricultural machinery is exempted from import duties, however, the raw materials needed by local manufacturers are charged with – sometimes high – duties (see Ampah et al., 2021; Diao et al., 2020; FAO & AUC, 2018).[6] To create a more level playing field for local manufacturers, governments could align import tariffs and duties on finished equipment and raw materials. The empirical data suggest that few manufacturers sell to customers from outside their regions (17%) or other countries (2%), even if they have similar agroecological conditions, which can be attributed to infrastructure problems, transaction costs and unfavourable trade policies and practices, among other reasons. Investments and policies to support regional trade and integration could help to change this (see also Frankema & Van Waijenburg, 2018). Regional associations that bring together manufacturers in neighbouring countries might be useful.

Testing and certification are other important topics. Across the four countries, only 27% of the manufacturers reported that their machinery is subject to some form of third-party testing and certification. Informal mechanisms related to reputation can only partly counterbalance this lack. In the absence of impartial testing and certification, it is difficult for customers to choose reliable machinery, and they may resort to suboptimal mental aids such as choosing foreign over domestic production (see also Ampah et al., 2021; Daum & Birner, 2017; FAO & AUC, 2018; Houmy et al., 2013). Testing and certification can create upward pressure on manufacturers to raise the quality of their products. In the absence of testing and certification, quality can vary widely, and the so-called "lemon-market problem" (Akerlof, 1970) can lead to a downward spiral of quality (or even fraud) since customers consider only prices for decision-making (Daum & Birner, 2017). To reduce the uncertainty and risks for customers, machinery testing has emerged across the world, either through public-, private- or third-sector mechanisms (Daum et al., 2018). Making tests easily available for customers, including in the form of certificates, allows them to make better decisions (see also FAO & AUC, 2018). In numerous African countries, the absence or limited capacity of testing and certification organizations poses significant challenges. For instance, the Kenya Agricultural Mechanization Testing Centre, although well-established on paper, grapples with critical issues like understaffing, inadequate equipment and insufficient funds (GoK, 2021). To address these issues and enable these organizations to fulfil their mandates effectively, it is crucial for governments to increase their support in terms of staff, equipment and funding. FAO and AUC (2018) suggest that given the significant costs of public testing centres, countries could set up regional testing centres, following the example of the "Asian and Pacific Network for Testing of Agricultural Machinery" (ANTAM), however, such centeres do not yet exist. Local and regional bodies can also play a role in much-needed standard setting.

Lastly, efforts are needed to reduce the costs of doing business, thereby reducing the transaction costs and risks between manufacturers, suppliers and customers, among others. As noted above, this, in particular, necessitates taking specific actions such as facilitating business establishment, improving knowledge and skills development, ensuring affordable and reliable electricity supply, enhancing infrastructure and security, improving access to credit, promoting cross-border trade, establishing standards and certification, reducing corruption and enforcing contracts, among others (see also World Bank, 2020).

While this paper has primarily focused on supporting local agricultural manufacturers, there is also potential to attract global manufacturers to establish local plants, thereby strengthening domestic manufacturing sectors. Examples of successful initiatives can be found in countries like Ethiopia and Mali, where global manufacturers such as Mahindra have been encouraged to set up local assembly plants where machinery such as tractors are assembled from semi-knocked-down forms (FAO & AUC, 2018; Kergna et al., 2020). This approach can facilitate countries' progression on the manufacturing ladder (Adubifa 1993; Ito, 1986). Governments can incentivize foreign producers by providing financial assistance, tax breaks, grants, land subsidies, infrastructure development, streamlined regulatory processes and other benefits. Additionally, there is scope to promote joint ventures between global manufacturers and domestic companies, whether they are private or public entities. China's success in driving manufacturing growth through such joint ventures serves as a notable example (Nippa & Reuer, 2019). In the context of agricultural manufacturing, joint ventures may also be promising (Abeyratne & Takeshima, 2020), however, there are also examples of failures (e.g., Takeshima & Lawal, 2020). Trying to attract global manufacturers can also impose financial burdens on governments and strain their budgets. In the context of light manufacturing for tractor implements and post-harvest and processing equipment, where there are already many highly motivated local manufacturers, as shown in this paper, it may be more beneficial to support existing local manufacturers instead.

In summary, this paper suggests great potential for local agricultural manufacturing to contribute to overall economic development in Sub-Saharan Africa. Markets for local machinery have emerged in all of the African case studies countries, despite a wide range of challenges. These markets are dominated by small but dedicated local machinery manufacturers, many of whom are guided by the vision of bringing innovative engineering solutions to help transform agriculture. Ensuring a more supportive, enabling environment can help these local manufacturers to fulfil this vision and harness their comparative advantages, vis-à-vis global manufacturers. The return of local manufacturing to the development agenda of African policymakers is a promising sign. But it must be ensured that policies and investments do not focus on a few, politically attractive flagship projects, but are rather designed to maximize the long-term success of the sector. With the right policies and investments creating an enabling environment, local manufacturers can produce the machinery to make “Made in Africa” the first choice of African farmers and agro-processors.

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CONFLICT OF INTEREST STATEMENT

The authors report there are no competing interests to declare.

DATA AVAILABILITY STATEMENT

Data is available under https://figshare.com/articles/dataset/Data_Manufacturing/21822111.

ETHICAL STATEMENT

The study was conducted according to the guidelines laid down in the Declaration of Helsinki and the ethics committee of the University of Hohenheim. All study participants gave informed consent to participate in the study.

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ENDNOTES

[1] https://www.afdb.org/en/high5s (Accessed 27/10/2022)

[2] Agricultural mechanization plays a crucial role during structural transformation, which involves a shift towards more capital-intensive farming, and both agricultural mechanization and structural transformation have the potential to contribute to the expansion of farm sizes (Al-Amin et al., 2023). A study conducted by Takeshima (2017a) in Nepal showed that the use of tractors altered the returns-to-scale in farming, favouring larger farms. Consequently, this transformation can change the demand for machinery, potentially leading to the adoption of larger machinery. In many of today's mechanized countries, agricultural transformation has coincided with increased consolidation in the manufacturing sector, resulting in fewer, but larger companies (Binswanger, 1986).

[3] See https://research4agrinnovation.org/

[4] In Benin, this list was generated with the Territorial Agency for Agricultural Development, the Ministry of Industry, and the Ministry of Agriculture, among others. In Kenya, we generated this list with the County Agricultural Office and the Kenya National Bureau of Statistics (KNBS). In Nigeria, we worked with the Agricultural Machineries and Equipment Fabricators Association of Nigeria (AMEFAN) and the Federal Institute of Industrial Research (FIIRO). In Mali, the list was generated by the respective regional associations of the "Fédération Nationale des Artisans du Mali".

[5] IFC (2019) and IRENA, FAO (2021) see the highest feasibility of off-grid renewable energy for powering irrigation pumps and cooling/refrigeration systems. While there are existing solutions for agro-processing activities like threshing and milling, they are mostly in the pilot stage and less feasible (IFC, 2019; IRENA, FAO, 2021). There are also several pilot projects on the use of renewable energy to power farm operations. Experiments show that the use of e-tractors is possible in principle but still requires frequent recharging/swapping of batteries (after around 0.5 to 1 ha for power-intensive operations such as tillage), limiting their real-world applicability (Bagire et al., 2022).

[6] However, it is also important to point out that importers also face constraint due to tedious and slow import procedures and "unofficial" duties can also affect machinery imports (Daum & Birner, 2017; Diao et al., 2020).

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