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Mechanization and automation in Africa's agroprocessing sector

Implications for jobs and skill needs

Heike Baumüller, Zaneta Kubik and Tigabu D. Getahun

Abstract

A growing demand for higher-value agrifood products in Africa, driven in particular by the rapidly emerging urban middle class, will offer opportunities for the local food and beverage processing industry to generate revenue, create jobs and improve access to food on the continent. To be competitive, the industry will require efficient production methods that can generate a reliable supply of high-quality products. While the food industry in higher income countries has widely adopted power-driven machinery and automation technologies in their production, little is known about the level of mechanization and automation in African agroprocessing and even less about related impacts on employment levels. This study seeks to address this knowledge gap. To this end, a survey of 498 formal firms in the food and beverage manufacturing sector in four African countries (South Africa, Kenya, Nigeria and Ethiopia) was conducted. The findings show that all of the surveyed companies use power-driven machinery and around half also employ automation technologies. A number of factors could influence the adoption of automation, including firm size, labour costs, skills, infrastructure and access to machines and their spare parts. The results also suggest that automation is likely to change the nature of rather than replace jobs. To advance automation in the agroprocessing sector, governments should invest in tertiary education and training courses to strengthen in particular technical and soft skills, bring women into the technical professions, and develop social safety nets for lower-skilled workers who are more likely to be affected by job losses.

Acknowledgements

We would like to thank Anthea Dallimore, Myriam Velia, Michael Odebode and Sabiri Manyange for the invaluable support in collecting the data for this research.

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1 Introduction

With rapidly growing populations and urbanization rates on the African continent, there is a need for efficient, resilient and highly productive food systems to meet the increasing food demand and food insecurity challenges. Particularly the rapidly emerging urban middle class is expected to drive the demand for higher-value agrifood products (Tschirley *et al.*, 2015; de Bruin, Dengerink and van Vliet, 2021; Jenane, Ulimwengu and Tadesse, 2022). These changes will offer opportunities for the local food and beverage processing industry to tap into the growing market. To be competitive, the African agroprocessing sector will require cost-effective and efficient production methods that can generate a reliable supply of high-quality products. Globally, the food industry, particularly in higher-income countries, employ a myriad of technologies to meet these objectives, including power-driven machinery and more recently automation technologies, i.e. computer-controlled production systems.

The processing sector offers opportunities for the creation of jobs, which, albeit still small relative to other manufacturing sectors, have been growing rapidly over the past two decades. Evidence from Ethiopia, Ghana and Tunisia suggests that the sector can present high employment generation potential, both in absolute terms and compared to other sectors of manufacturing (Kubik *et al.*, 2022). Adoption of mechanization and automation in agroprocessing can also be expected to impact employment opportunities (Muro, Maxim and Whiton, 2019; World Bank, 2019). The technologies could displace and thereby reduce the demand for labour, but could also increase the demand either by reducing the cost of production or increasing productivity and thereby stimulate industry expansion and output growth overall (Acemoglu and Autor, 2011; Acemoglu and Restrepo, 2020).

Much of the research on the impact of mechanization and automation on employment in the manufacturing sector has focused on higher-income countries (e.g. Arntz, Gregory and Zierahn, 2016; Dauth *et al.*, 2017; Graetz and Michaels, 2018; Acemoglu and Restrepo, 2019). Changes in the structure of the workforce are expected across all sectors. In addition, automation in a given sector may also have important economy-wide effects (Autor and Salomons, 2018). Quantifying these impacts remains a challenge, however, and any attempts to do so have led to widely varying predictions (World Bank, 2019). But it is undisputed that mechanization and automation will change the nature of work and related skill requirements. While machines are not expected to entirely replace many jobs, they will change the tasks that the workers perform, in particular by taking over predictable physical and cognitive tasks (Muro, Maxim and Whiton, 2019). As a result, demand for technical skills to develop, operate and maintain the technology will increase, but also for so-called 'soft skills' such as critical thinking, management skills and teamwork (AfDB *et al.*, 2018; WEF, 2018; World Bank, 2019).

Little is known about the level of mechanization and automation in African agroprocessing and even less about related impacts on employment. In general, automation is not yet thought to be widespread due to a lack of necessary infrastructure and capital (Gaus and Hoxtell, 2019). UNCTAD (2017) points out that even if automation is technically feasible, it is not always economically profitable. For instance, among all manufacturing sectors, the food, beverages and tobacco sector exhibits the highest technical feasibility of automation because of high routine task intensity. Hence, it could be expected that the risk of job displacement would also be high compared to other sectors; however, due to low compensation, the sector uses much less automation than other sectors. Adoption of the technologies in the future may be driven by rising wage costs or low education levels where automation then becomes a substitute for missing skills or expensive labour (ibid). To date, the required technical and management skills for automation are often lacking (AfDB, OECD and UNIDO, 2017). Jobs in Africa may also be impacted through automation in other countries which may reduce the incentive to offshore certain jobs to low-wage countries (ibid).

To address these knowledge gaps, this study assesses the status of mechanization and automation in the food and beverage manufacturing sector and related implications for employment in four African countries (South Africa, Kenya, Nigeria and Ethiopia). It is the first do so empirically, based on a

nationally representative survey of formally registered food and beverage processing companies. The remaining article is structured as follows. Section 2 describes the data and methods. Section 3 presents the results, including an overview of the food and beverage processing sector in the four countries, the levels of adoption of mechanization and automation technologies, employment in the sector and implications of mechanization and automation for jobs and skill requirements. The concluding section provides a summary and analysis of the key findings, identifies policy implications and highlights limitations of this research.

2 Data and methods

This study was designed to (1) map the formal food and beverages manufacturing sector in four African countries, Ethiopia, Kenya, Nigeria and South Africa (referred to here as 'mapping'), and (2) assess the status of mechanization and automation and related labour impacts in the formal food and beverages manufacturing sector (referred to here as 'survey'). For each country, a list of all registered firms in the food and beverage manufacturing sector was established based on information obtained from public and private sources. This mapping exercise resulted in a sampling frame of 1585 registered firms, i.e. 267 in Ethiopia, 261 in Kenya, 572 in Nigeria and 485 in South Africa.

For the survey, a sample of firms was randomly selected using stratified sampling. Strata were defined based on company size[1], ownership[2] and type of industry[3]. In the case of Kenya, Nigeria and South Africa, a sample of 100 firms per country was targeted. Due to challenges to reach the target in Kenya and South Africa, additional firms were interviewed in Nigeria. In Ethiopia, attempts were made to interview all the listed firms. All mechanized firms where asked a series of basic questions about machinery use irrespective of whether the firms are also automated. Separate questionnaires were then administered to mechanized and automated firms in the more detailed survey.

The data collection process was implemented in a face-to-face interview format with high-level expert respondents within the firms, i.e. firm owner or manager, between September and early November 2020.[4] A total of 498 firms were interviewed, i.e. 215 in Ethiopia, 92 in Kenya, 110 in Nigeria and 81 in South Africa. The basic characteristics of the surveyed firms are presented in the Appendix. To account for the differences in sample size between countries, sampling weights were applied throughout the analysis. In the article, absolute numbers are provided as actual values while shares are computed using weights. The purpose of the analysis is to explore possible interactions rather than prove causalities. We therefore opted for presenting the results mainly in the form of a narrative analysis based on descriptive statistics.

Throughout this paper, *food and beverage manufacturing sector* (or agroprocessing) refers to activities classified under the Standard Industrial Classification (SIC) Code 20 - Food and Kindred Products (Manufacturing). Firms were categorized at the 3-digit level depending on the main food or beverage sector that they engage in. The European Skills, Competences, and Occupations (ESCO) classification was used to categorize the different skills mentioned by respondents in the survey.

Mechanization is defined as the process of changing from working largely or exclusively by hand or with animals to doing that work with machinery. *Automation* is defined as a system "in which a process is performed by a machine without the direct participation of a human worker. Automation is implemented using a program of instructions combined with a control system that executes the instructions. Power is required to drive the process and to operate the program and control system." (Groover, 2015, p. 4). In contrast to mechanization, automation implies the integration of machines into a self-governing system (Groover, 2023).

The survey took place during the Covid-19 pandemic. To account for changes that may have resulted from the pandemic, results in this article referred to the time before the pandemic. Impacts of the pandemic on business operations were analysed in a separate study (Baumüller *et al.*, 2021).

[1] Micro and small ($\leq$ 50 employees); medium (51-250 employees); and large companies ($>$ 250 employees).
[2] Private sector domestically-owned companies (including cooperatives); private sector foreign-owned companies; private sector share companies or joint venture companies; and government-/state-owned companies (including public-private partnerships).
[3] For this purpose, the study distinguishes between food and beverage sector.
[4] The exact dates of the surveys are: Ethiopia 13 October – 12 November; Kenya 7 September – 15 October; Nigeria 7 September – 15 October; South Africa 7 September – 15 October.

3 Results

1.1 Status of the formal agroprocessing sector in the study countries

1.1.1 Overview of food and beverage manufacturing firms[5]

The mapping of formal agroprocessing companies in the four study countries shows that food companies make up the majority of agroprocessing firms, with the largest share found in Ethiopia and the smallest in Nigeria (Table 1). Food companies operate in a wide range of sectors in the four countries. Only in Ethiopia one sector stands out (grain mill products) which accounts for over half of food processing firms. Other sectors that are more common in one country than the others (though not as substantially as grain mill products in Ethiopia) are processed fruits and vegetables (Kenya), fats and oils (Nigeria) and meat products (South Africa).

Companies of all sizes[6] can be found in all industries, with the exception of firms that produce multiple types of products which tend to be larger. The vast majority of companies are privately and mostly domestically owned. The share of domestically owned companies decreases with increasing firm size. The few government-owned companies operating in Ethiopia and Kenya are mainly large companies. Only Nigeria has a sizeable share of foreign (mostly medium-sized) companies among the surveyed companies. In South Africa, shareholder companies are more common than in the other three countries, more commonly medium and large companies.

Table 1: Status of food and beverage processing

		Ethiopia	Kenya	Nigeria	South Africa
Company size	Small (1- 50)	43	17	28	36
	Medium (51 - 250)	27	46	62	34
	Large (>250)	31	36	10	29
Company ownership type	Domestic private company	86	89	65	80
	Foreign private company	1	5	31	4
	Government-/state-owned	4	3	0	0
	Cooperative (member - owned)	1	2	0	1
	Public / Private Partnership company	0.4	0.8	0.5	0.2
	Shareholder company	8	1	3	15
Food or beverages	Food	93	80	67	82
	Beverages	7	20	33	18
Industry type (SIC)	Multiple types	0	1	1	2
	201 - Meat Products	2	2	5	14
	202 - Dairy Products	2	7	8	10
	203 - Canned, Frozen, and Preserved Fruits, Vegetables, and Food Specialties	2	14	5	7
	204 - Grain Mill Products	52	15	13	10
	205 - Bakery Products	12	8	8	6
	206 - Sugar and Confectionery Products	3	10	6	9
	207 - Fats and Oils	6	7	11	5
	208 - Beverages	7	20	33	18
	209 - Miscellaneous Food Preparations[7]	13	16	9	19

Share of firms within the respective country. N=see Table 1A. Source: Authors' compilation

[5] Based on the full list of companies.

[6] Information on annual turnover was also collected. Due to data gaps and likely inaccuracies, this analysis will only focus on size of the workforce.

[7] The key products in this category are seasoning in Kenya and South Africa, tea in Nigeria, and a mix of products in Ethiopia.

1.1.2 Level of mechanization and automation[8]

The survey results point to an almost universal adoption of mechanization in all countries and relatively high levels of automation in most. In light of the high prevalence of mechanization and automation technologies, the analysis distinguishes between two types of companies, i.e. 'mechanized' companies (i.e. using machinery, but not automation) and automated companies (using both machinery and automation).

Virtually all surveyed companies use some form of power-driven machinery. Most (75%) of the companies use more than one type of machine. The most common primary machines are used for grinding/crushing, packaging and baking/cooking while secondary machines are often used for packaging. Differences can be observed with regard to the number of machines. Kenyan firms have the highest number of machines on average and also the greatest variation in responses (Table 2). The average number of primary machines (and variation) also increases with firm size.

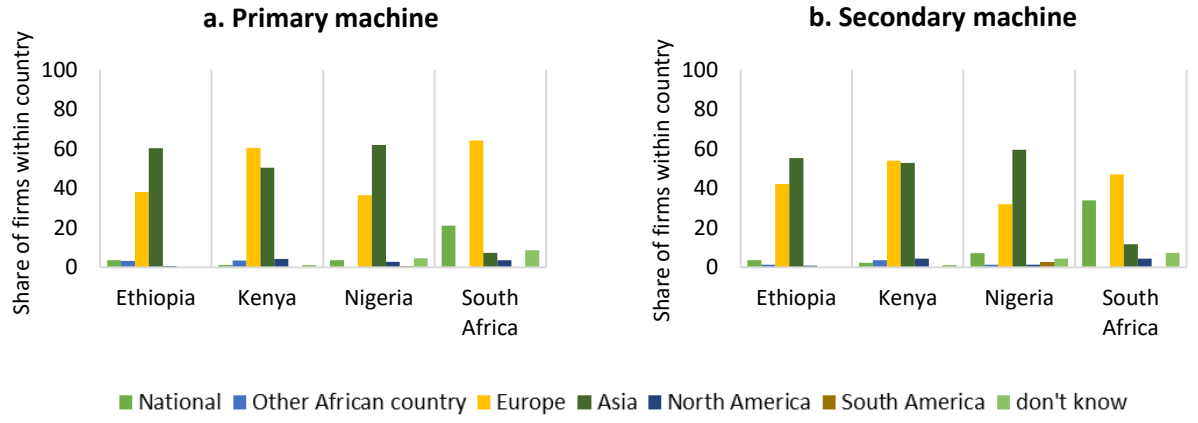
Table 2: Number of primary machines by country and firm size

		Mean	Minimum	Maximum	St. Deviation
Country	Ethiopia	5	1	70	8
	Kenya	9	1	100	18
	Nigeria	4	1	15	3
	South Africa	5	1	30	6
Firm size	Small (1-50)	3	1	26	4
	Medium (51-250)	5	1	70	7
	Large (> 250)	8	1	100	14

N=see Table 1A. Source: Authors' compilation

Most of the machines are imported from outside the continent (Figure 1). In Ethiopia and Nigeria, Asian machines are most often used, South African firms mainly rely on European technology and Kenyan companies commonly source machines from both regions. Only South African firm use domestically produced machines to a certain extent, mainly for their secondary machines. The share of firms sourcing their machines from Europe increases by firm size. While slightly more small firms buy their primary machines from Asia (43%) than Europe (39%), the share of firms buying European machines rises to 52% among medium and 58% among large firms (compared to 47% and 40% using Asian machines respectively).

Figure 1: Origin of machines by country of firm



N=see Table 1A. Source: Authors' compilation

[8] Based on the survey of a sub-sample of companies.

Just over half (52%) of firms also use automated control systems.[9] The share of automated firms is higher among foreign firms (68%) and shareholder companies (72%) than domestic private firms (46%). In particular in South Africa and Nigeria, adoption rates are higher among foreign firms (ca. 70%, compared to around half of domestic private firms) while in Kenya, automation is also widely adopted among domestic firms (84%). Automation rates increase with firm size (28% of small companies, 57% medium and 78% large). Large differences in automation can be observed between the four countries. The level of automation is lowest in Ethiopia (20%) and highest in Kenya (85%) while just over half of the companies in Nigeria (55%) and South Africa (52%) state that they are automated.

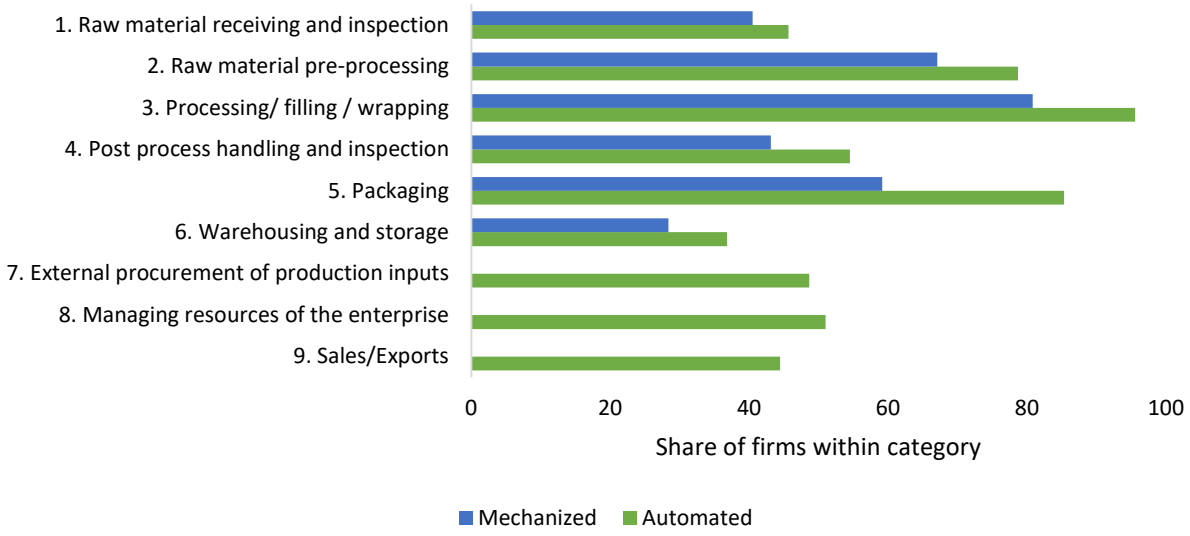
Regarding the industrial sectors, automation rates are higher among beverage than food companies, but not substantially so (57%, compared to 51% among food producers). Grain mill and bakery product producers are least frequently automated (36% and 41% respectively). The highest level of automation is found among producers of sugar & confectionary, meat and dairy products (72%, 68% and 63% respectively). No clear picture emerges with regard to export orientation. The lowest level of automation is found among those firms that sell only domestically (42%). However, automation does not necessarily increase with increasing level of export orientation, suggesting that automation is also used to service domestic markets.

Automated companies are better connected to the internet than mechanized ones. They more often have access to continuous broadband internet connection (94% mostly or always compared to 71% of mechanized companies). Ethiopia has the worst internet connection where 44% of firms do not have access to broadband und just 37% always do. Continuous connectivity is most common in Kenya and South Africa. A larger share of the staff use computers among automated firms (32% and 22% respectively), mostly with internet access (76% of staff using computers in automated firms compared to 58%).

Firms use mechanization and automation throughout the production process. The average number of stages of production (1-6 in Figure 2) that are automated is higher than those that are mechanized (4 compared to 2.3). Kenyan companies have the highest number of stages automated (5) and South Africa the lowest (3.4). Among automated firms, the number of automated stages increases with firm size while mechanization is similarly widespread among companies of different sizes. Both mechanized and automated firms most frequently use the technologies at the processing stages. The use of automated systems is also common in packaging. In addition, around half of the firms use automation technologies to coordinate the procurement of inputs, managing resources of the firm and sales (7-9 in Figure 2).

[9] For simplicity, the remainder of the analysis will distinguish between ‘mechanized’ (i.e. non-automated) and automated companies

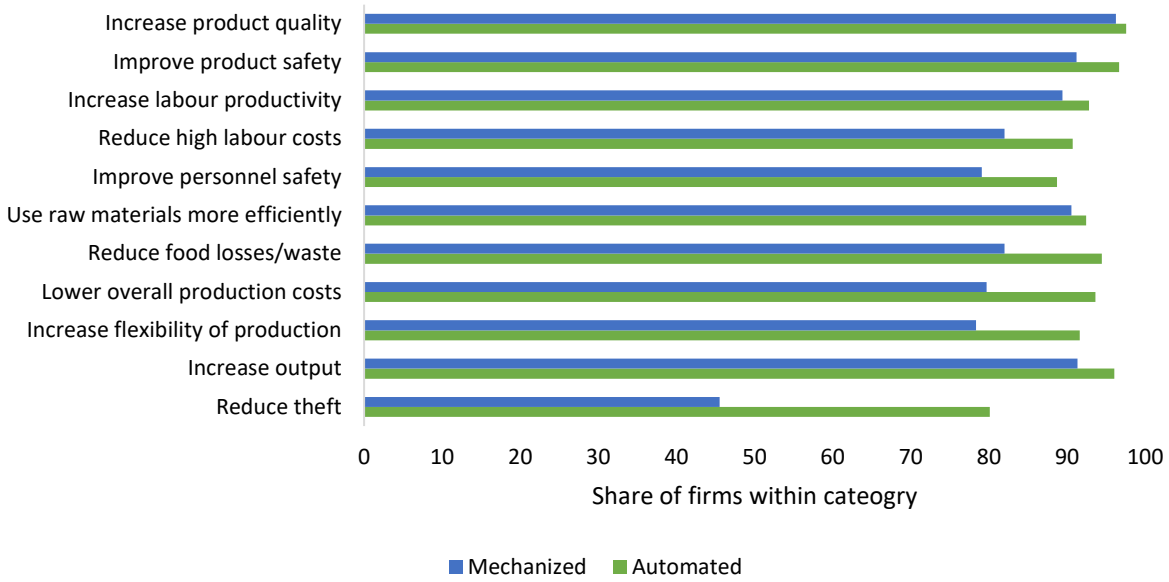
Figure 2: Use of mechanization / automation by stages of production



N=see Table 1A. Source: Authors' compilation

Mechanization and automation technologies are highly valued by the companies. Increased product quality and safety were cited among the main benefits, especially among large mechanized companies and automated companies of all sizes (Figure 3). The technologies were also seen to increase efficiency of production, notably the efficient use of raw materials. Among other efficiency gains, increased flexibility of production, lower overall production costs and reduce food losses/waste were also mentioned by both, but more frequently by automated firms. While both report that mechanization/automation increases the productivity of their labour (esp. mechanized firms who more often strongly agree), automated firms more frequently also see benefits in cutting labour costs and improving personnel safety. Reduction in theft is least frequently mentioned among both, but more often by automated firms.

Figure 3: Benefits of mechanization / automation



N=see Table 1A. Source: Authors' compilation

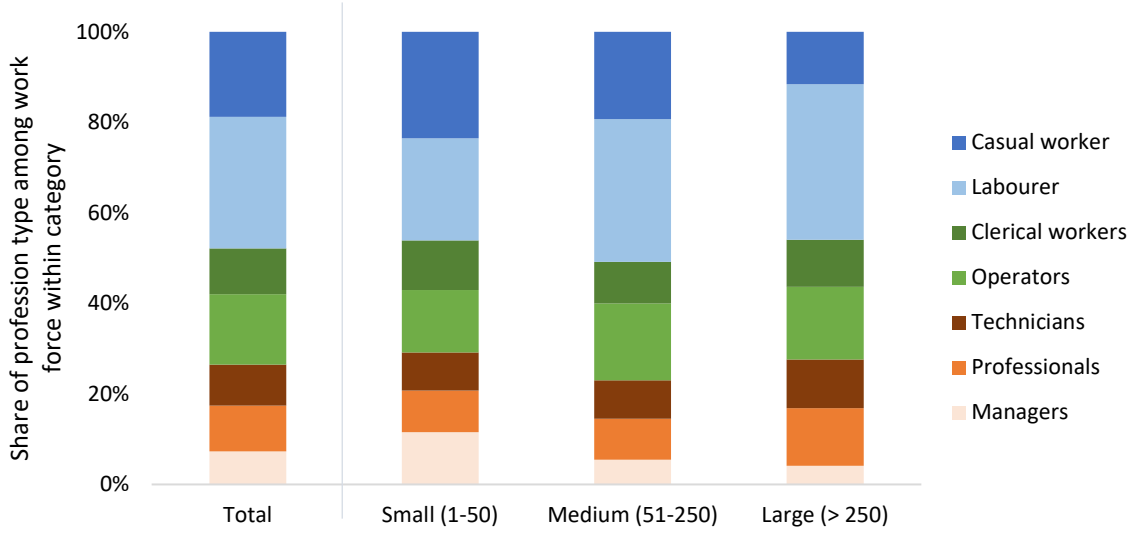
1.2 Employment in agroprocessing[10]

1.2.1 Staff composition and costs

Overall, around half of the staff employed in the agroprocessing firms in the four countries is performing low-skilled work while the remainder is equally spread between medium- and high-skilled jobs (Figure 4). The relative shares differ between the countries, however (Table 3). South African firms have the largest share of low-skilled jobs while Kenya has the largest share of high-skilled jobs. Some variation can also be observed between industry types, but not substantially so. The highest share of low-skilled jobs is found in the meat products sector and the lowest in the beverage sector.

The shares of different types of professions are broadly comparable across firm sizes. Smaller firms tend to have a larger share of casual labourers to perform low-skilled tasks while larger firms rely more on employed labourers (Figure 4). Professionals and technicians make up a larger share of the workforce among larger firms while the management share declines with increasing firm size. Among automated firms, a higher share of workers are high-skilled and a lower share is low-skilled.

Figure 4: Share of profession types in the workforce (on average)



Blue = low-skilled, green = medium-skilled, red/orange = high-skilled. N=see Table 1A.
Source: Authors' compilation

The share of women in the workforce[11] is by far the highest in clerical support work (51% on average) Within low-skilled jobs, female participation is higher among labourers (35% on average) than causal workers (25%). Women are also represented in high-skilled jobs, but more frequently among professionals (29%) than in management (26%). Women are underrepresented among technical staff, including technicians (11%) and operators (14%). Some differences between countries can be observed (Figure 5). The shares of women are among the highest in South Africa and to a lesser extent Kenya across profession types (with the exception of casual workers in South Africa). In Nigeria, women are more likely to work in clerical and low-skill jobs while in Ethiopia the picture is mixed.

[10] Based on the survey of a sub-sample of companies.
[11] This information was not available for 111 firms (86 in Ethiopia, 7 in Kenya, 1 in Nigeria and 17 in South Africa).

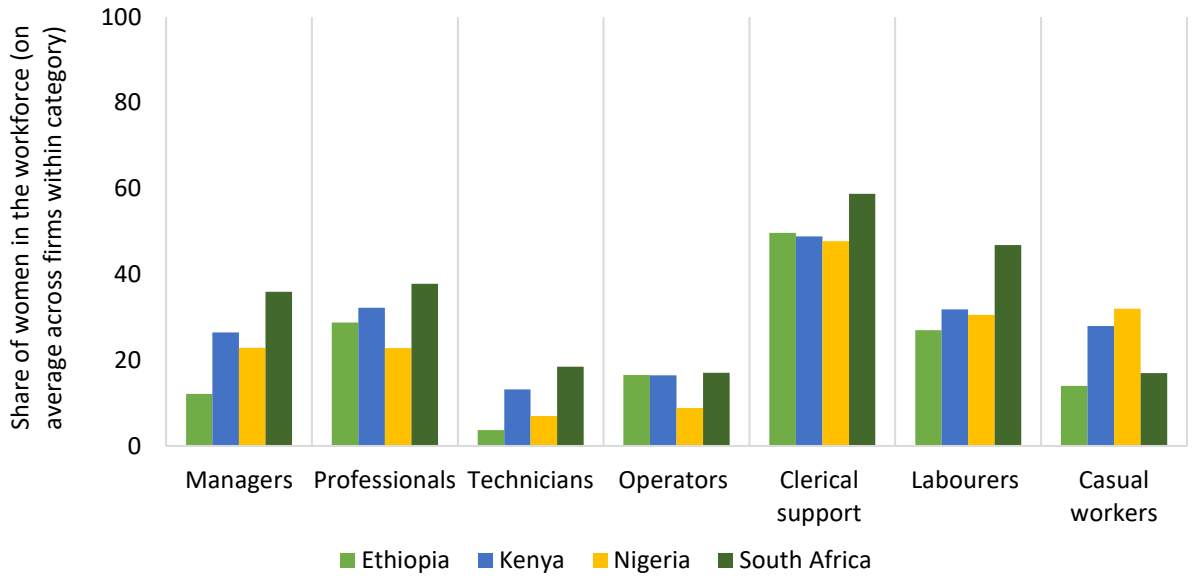
Averaging across all professions, the share of women is highest in the processed fruits & vegetables (34%), dairy products (32%), bakery products (31%) and sugar & confectionary (30%). The lowest shares of women are found in the grain mill (20%) and fats & oils (19%) sectors. The shares of women are broadly comparable across firm sizes. Some differences are found among small companies (i.e. a higher share of professionals and a lower share of clerical staff), but this might be explained by the fact that in small companies, small changes in staff numbers lead to larger changes in percentages than in larger firms.

Table 3: Share of the labour force by skill level

		High-skilled	Medium-skilled	Low-Skilled
Country	Ethiopia	21	33	47
	Kenya	43	23	34
	Nigeria	27	28	45
	South Africa	18	22	60
Company size	Small (1- 50)	29	25	46
	Medium (51 - 250)	23	26	51
	Large (>250)	28	26	46
Industry type (SIC)	201 - Meat Products	21	21	58
	202 - Dairy Products	23	28	49
	203 - Canned, Frozen, and Preserved Fruits, Vegetables, and Food Specialties	30	26	44
	204 - Grain Mill Products	24	27	48
	205 - Bakery Products	21	30	49
	206 - Sugar and Confectionery Products	28	17	54
	207 - Fats and Oils	25	26	50
	209 - Miscellaneous Food Preparations	28	27	45
Mechanization / Automation	Mechanized	24	26	50
	Automated	29	25	46

Share of firms within category. N=see Table 1A. Source: Authors' compilation

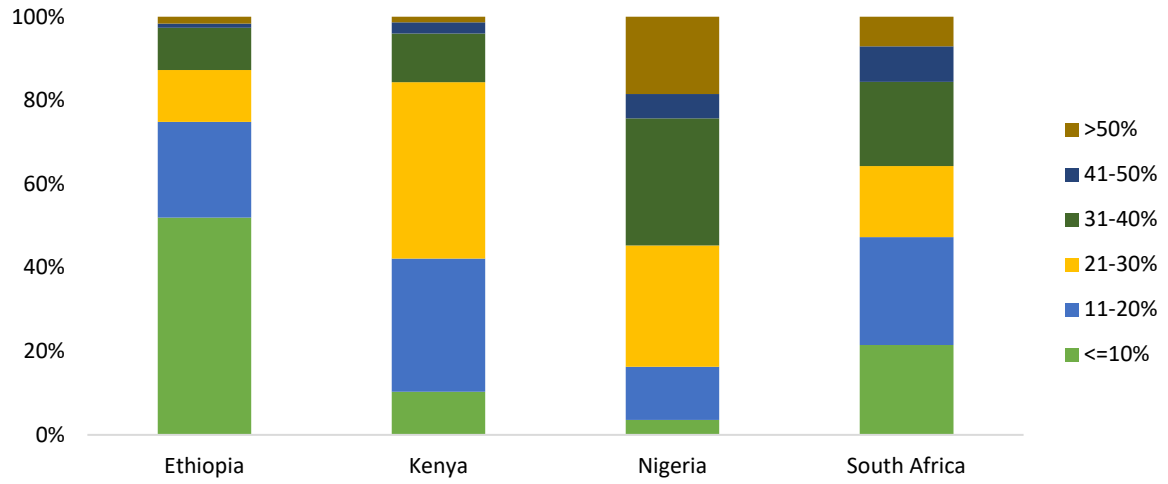
Figure 5: Share of women in the workforce by profession



N=see Table 1A. Source: Authors' compilation

Labour costs account for just over a quarter of total costs across all firms.[12] Nigerian firms spend more on average (36%) while Ethiopian firms report the lowest share (15%). Kenyan and South African firms allocate around a quarter of total costs to labour. Disaggregating the averages by ranges highlights variations between countries. Over half of Nigerian companies and over a third of South African companies spend 30% or more on labour costs compared to a quarter of Ethiopian and 16% of Kenyan firms. The highest labour cost shares on average are found among manufacturers of bakery products (32%) and the lowest in grain mill products and sugar & confectionary (around 21%). The average shares do not differ much by firm size. Among mechanized and automated firms, both the averages and disaggregated ranges are broadly comparable.

Figure 6: Share of labour costs by country



N=see Table 1A. Source: Authors' compilation

1.2.2 Staff-related aspects of mechanization/automation

Staff changes

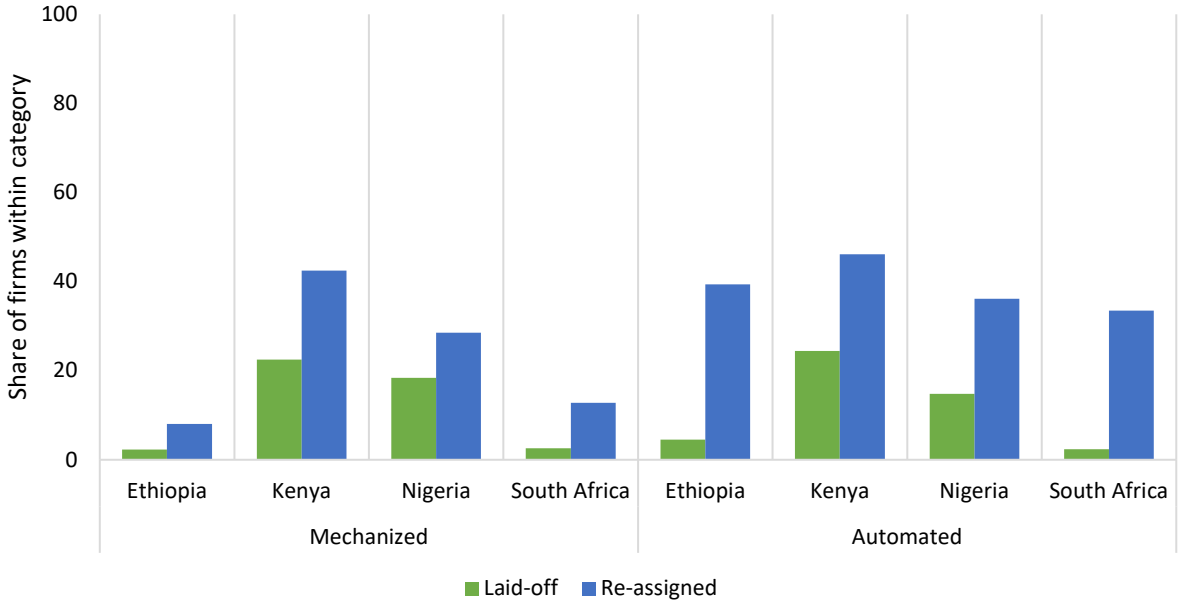
For the most part, the firms' last investment in mechanization / automation technologies had limited impacts on employment numbers.[13] Around 85% of all firms report that they did not lay off workers as a result of the last major investment. Lay-offs were most common in Kenya, followed by Nigeria while in the other two countries only a small share reported having dismissed workers (Figure 7). Lay-offs were more frequently reported by producers of beverages (19%) and bakery and dairy products (15% and 13% respectively), and among larger firms (16%, compared to 12% among medium-sized and 6% among small companies). Averaged across all firms and disaggregated by countries, lay-off rates are comparable between mechanized and automated firms.

Differences between mechanized and automated firms are clearly apparent when asked whether staff had been assigned to different tasks since the last major investment. Among automated firms, 38% stated that staff had been re-assigned, while only 18% did so among mechanized firms. The shares of automated companies that reassigned staff are broadly comparable, but slightly higher in Kenya (Figure 7). They also do not vary substantially by firm size. Among mechanized companies, the picture is more diverse. Thus, changes in tasks were most frequently reported by mechanized firms in Kenya (43%) and Nigeria (29%) compared to just 13% in South Africa and 8% in Ethiopia. The shares increase with firm size, from 11% among small companies to 31% among large ones.

[12] The data is missing for 64 firms (15 in Ethiopia, 14 in Kenya, 24 in Nigeria and 11 in South Africa)

[13] Due to recall constraints, respondents were only asked about impacts since the last major investment. To what extent staff were laid off as a result of previous investments is not known.

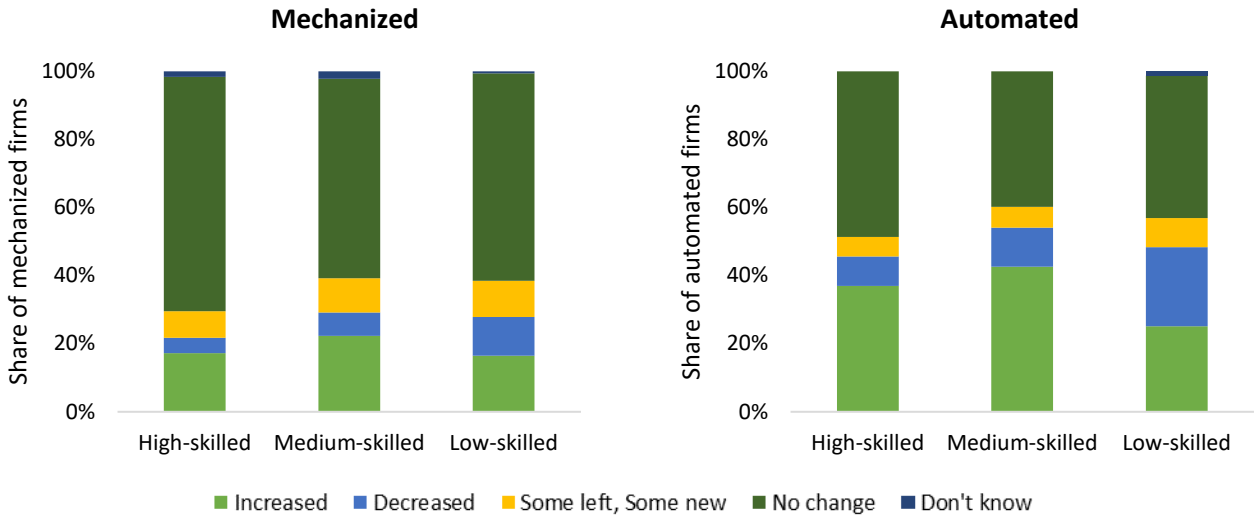
Figure 7: Staff impacts of mechanization / automation technologies by country



Share of firms that laid-off or re-assigend staff to different tasks after the last major investment in mechanization / autmoation technologies within country.
N=see Table 1A. Source: Authors' compilation

Reported impacts of the last investment in mechanization or automation on changes in the number of differently skilled workers are mixed. Among the majority of mechanized companies, staff levels did not change across all skill categories (Figure 8). Where changes occurred, they mainly led to staff increases (in particular among medium-skilled staff). While a sizeable share of automated firms also did not report changes, the majority saw both decreases and increases. Among medium- and high-skilled workers, the numbers mostly increased. For both mechanized and automated companies, changes in the numbers of low-skilled workers are most dynamic. In both cases, more companies reported reductions in low-skilled jobs compared to the other skill levels, but also more often reported increases in low-skilled than medium or high-skilled jobs.

Figure 8: Staff changes resulting from mechanization / automation by skill level

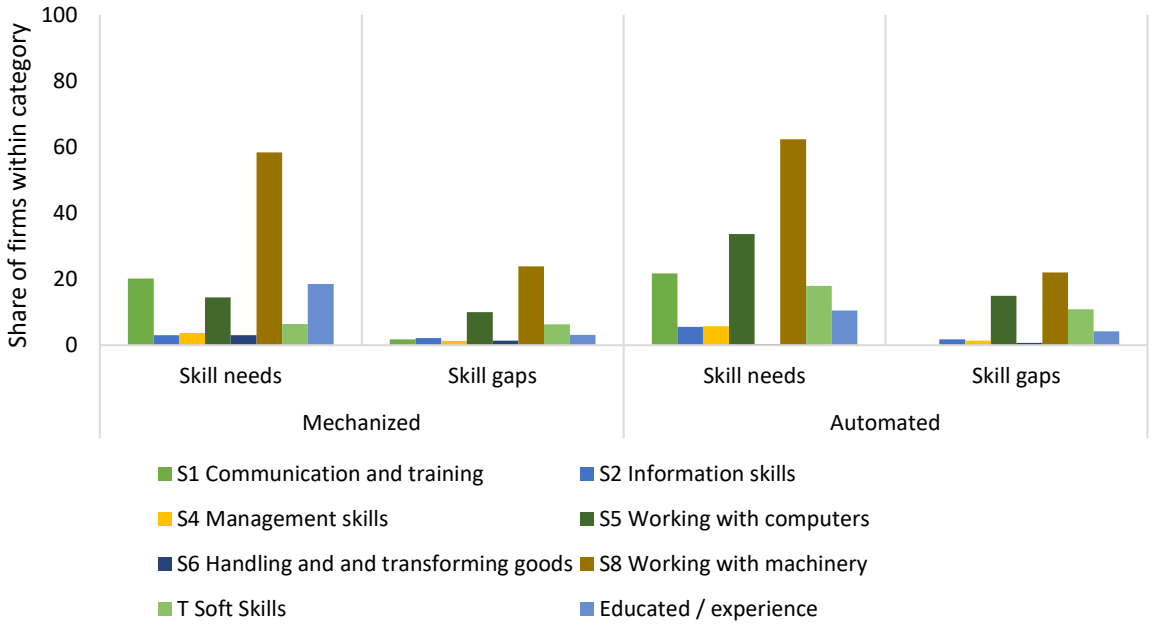


N=see Table 1A. Source: Authors' compilation

Skill needs and gaps

As expected, skills related to the operation of machinery are by far the most important skills required for mechanized and automated production (Figure 9). Skills to work with computers are more important among automated firms. Interestingly, three times as many automated companies point out the importance of soft skills (18% compared to 6%), e.g. willingness to learn, problem-solving, critical thinking or team work. In mechanized firms, general levels of education or experience (rather than specific skills) were seen as more important (by 19%) than in automated firms (10%).

Figure 9: Skills needs and gaps for automation and mechanization

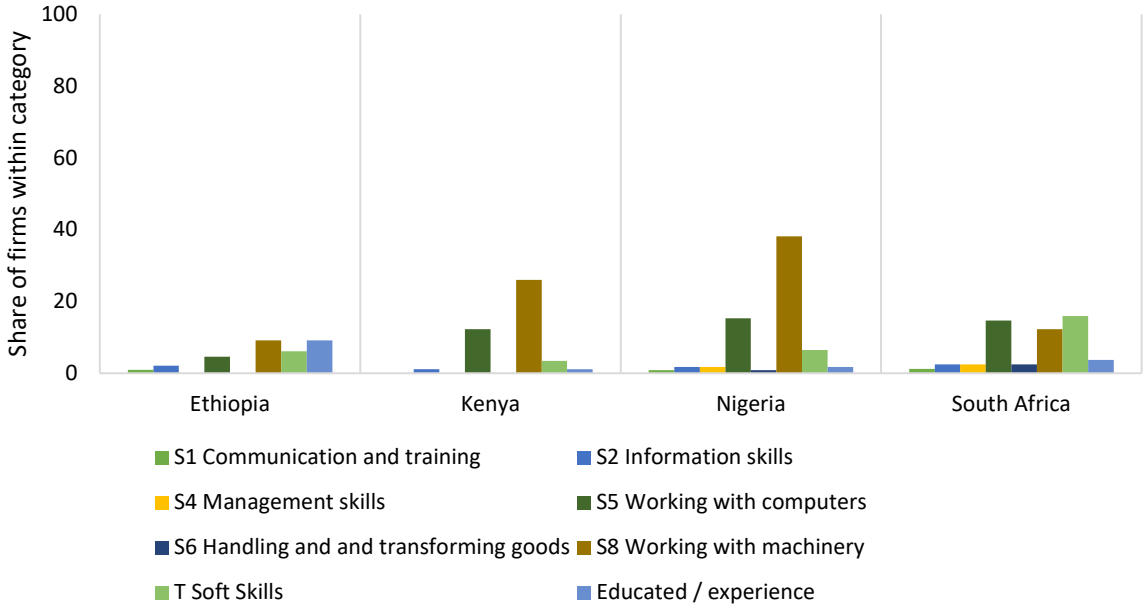


ESCO classification of skills. N=see Table 1A. Source: Authors' compilation

In general, reported skills levels among the work force are high. The large majority of firms state that all (54%) or most (28%) of their staff are qualified to work with machinery / automated systems. The lowest share of firms who feel that their staff are fully or mostly qualified is found in Kenya (67%) and the highest in Ethiopia (96%), while Nigeria (70%) and South Africa (85%) rank in between. Skills gaps are more often reported by automated firms (52%, compared to 40% of mechanized firms), in particular small ones. Where gaps are reported, companies mainly list one or two types of skills and more rarely three skills.

The most frequently needed skills are technical skills related to machine operations (slightly more so among mechanized companies) and computer use (slightly more among automated companies. Comparing countries, the main gaps in technical skills are found in Kenya and Nigeria, in particular skills to work with machinery (Figure 10). Soft skills are more often reported as missing by automated firms, especially in South Africa. A sizeable share of Ethiopian firms are missing a generally higher level of education or experience.

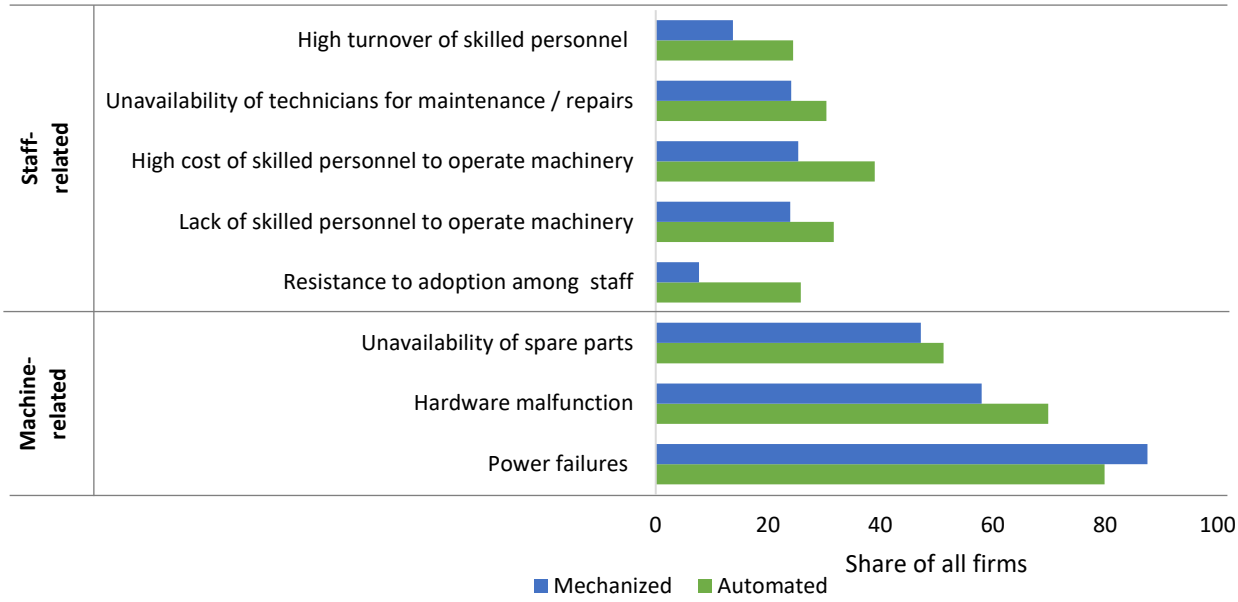
Figure 10: Skill gaps for mechanization / automation by country



ESCO classification of skills. N=see Table 1A. Source: Authors' compilation

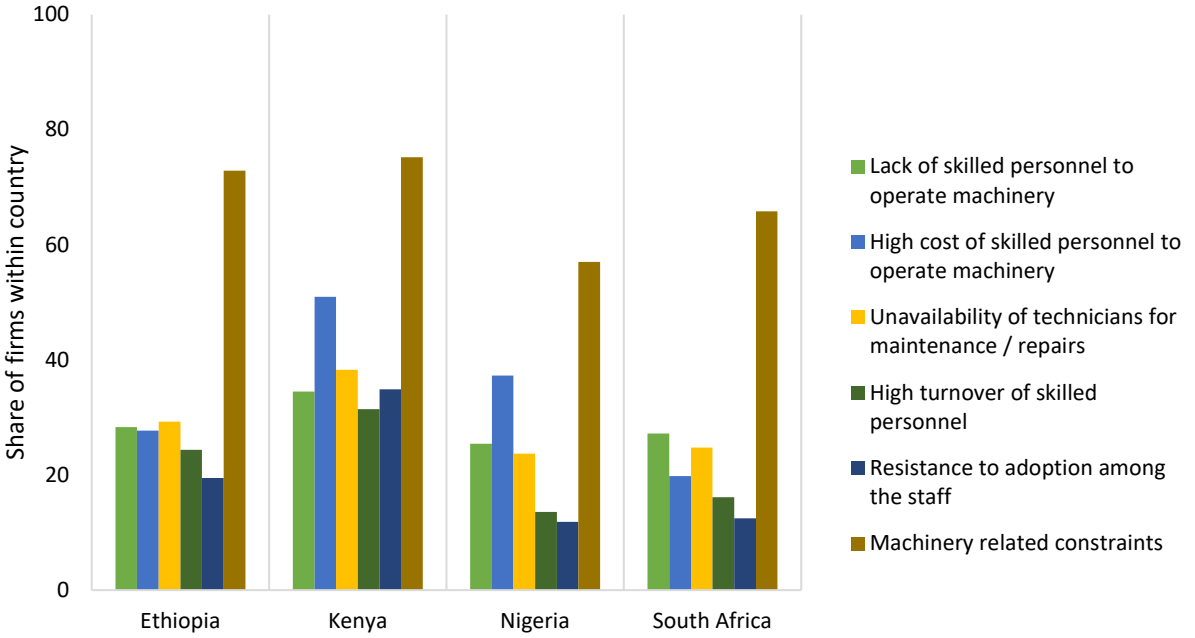
The main constraints identified by companies to the use of mechanization and automation also suggest that staff-related constraints may not be their main problem. Instead, machinery-related concerns are generally a larger concern, most notably power failures (especially in Ethiopia) as well as machine malfunction (especially in Kenya) and lack of spare parts (especially in Kenya and Ethiopia) (Figure 11). The frequency of reporting staff constraints increases with firm size (but not substantially so). They are also more often reported by automated firms. Kenyan companies most frequently mention staff-related issues, in particular staff costs (Figure 12). Resistance to adoption among staff is a more significant concern among automated firms, especially among larger firms and in Ethiopia and Kenya.

Figure 11: Constraints to mechanization / automation



N=see Table 1A. Source: Authors' compilation

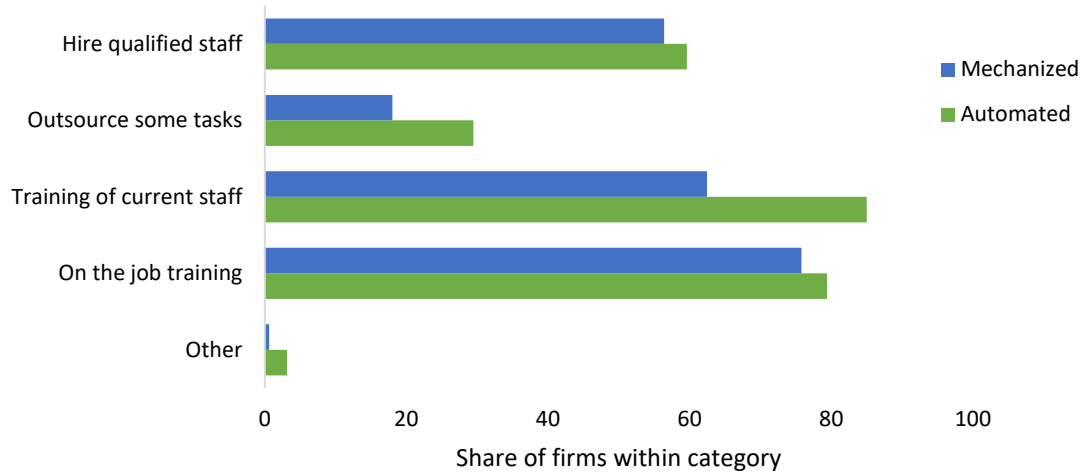
Figure 12: Constraints to mechanization / automation by country



N=see Table 1A. Source: Authors' compilation

To develop the necessary skills for mechanization and automation in the workforce, companies mainly rely on training existing staff and hiring qualified staff (Figure 13). In particular automated firms (62%), but also mechanized ones (52%) often employ both strategies (most frequently in Kenya) and around a third build skills only with training (most frequently in South Africa). Outsourcing is used less frequently, but more so among larger automated firms and primarily in Kenya. Automated firms also use the most diverse set of measures, i.e. around half of the firms that report skills gaps implement three or more measures of those listed in Figure 13 compared to just over a third of mechanized firms.

Figure 13: Skill development measures for mechanization / automation



N=see Table 1A. Source: Authors' compilation

4 Discussion and conclusion

This study provides an overview of the formal food and beverage manufacturing sectors in Kenya, South Africa, Nigeria and Ethiopia, including the structure of the sectors and the levels of adoption of mechanization and automation technologies by the firms. It also examines employment in agroprocessing with a focus on current staff composition and costs as well as staff changes and skill needs related to mechanization and automation. Domestic private companies dominate the sector in all four countries, albeit to varying degrees. All of the surveyed companies use power-driven machinery and around half also employ automation technologies. The aggregated and country-specific results suggest that a number of factors influence the adoption of automation, including firm size, labour costs, skills, infrastructure and access to machines and their spare parts. In line with the literature, the results also confirm that automation is likely to change the nature of rather than replace jobs and points to the need to strengthen in particular technical and soft skills.

Looking at the findings in more details, the results show that automated companies are more often larger and owned by foreign investors or shareholders than mechanized companies. They have better access to the internet and computers, both of which are essential ingredients for automation. Given that automation functions as a system, related technologies are more ubiquitous in the production process than single machines. Both mechanization and automation are mainly used for processing, but automation also plays an important role in packaging e.g. in bottling plants. Mechanization and in particular automation are seen to bring numerous benefits, in particular to ensure product quality and safety and efficient use of raw materials. The staff in automated companies are higher-skilled (and presumably more expensive) while the share of labour costs in total costs are comparable to mechanized firms. This could be due to lower staff numbers or reduced costs in other areas than labour as a result of using automation technologies

Mechanization and automation have not led to substantial job losses, at least since the firms' last major investment in the technologies. Instead, staff were often assigned to different tasks, in particular those working in automated companies. Where staff changes occurred, they mainly translated into job gains, in particular among medium- and high-skilled staff and among automated companies. For all companies, the impacts of investments in the technologies are felt most among low-skilled workers with both job gains and losses. Technical skills to work with machines and computers are most needed and also most lacking while soft skills become more important with the adoption of automation. Women are clearly under-represented in the technical professions. The staff are generally willing to use machines, but some automated firms report resistance to the use of the technologies among their employees. Skill gaps are more pronounced among automated firms, possibly due to the demand for higher-skilled labour and the specific requirements of the job. To address these gaps, automated companies employ more diverse strategies of hiring, training and outsourcing than mechanized firms. Formal training is mainly used to build automation-related skills while machinery skills are most commonly provided through on-the-job training.

Looking at the different countries provides further insights on possible drivers and impacts of mechanization and automation. The Kenyan agroprocessing sector is characterised by larger companies with the highest level of automation and good internet access. Automation is most extensively used along the entire production process. The firms also have the largest share of high-skilled workers. The downside of this trend is that workers in Kenya where most frequently laid off or assigned to different tasks as a result of adoption mechanization or automation. Moreover, Kenyan firms report the largest skill gaps, in particular technical skills, and most often experience staff constraints, notably high costs of machine operators. Resistance to automation among staff is also a concern. To address these gaps, Kenyan firms implement the most diverse skill development strategies and are the only country were a sizeable share of firms outsources tasks to close skill gaps.

Ethiopia is found at the other end of the automation spectrum where firms have the lowest level of adoption and the worst internet access. One reason could be low labour costs which account for the smallest share of total costs among the four countries. For the current level of adoption, the existing skills seem to be sufficient, but unavailability and cost of skilled personnel as well as resistance among staff are listed among the obstacles to adoption of more advanced technologies. In addition to specific skills, general education levels are also a concern. However, rather than skills, access to power is by far the main barrier to adoption.

In Nigeria and South Africa, the adoption of automation technologies is mainly driven by foreign companies (and in the case of South Africa shareholder companies), but not exclusively so. Nigeria stands out for its high labour costs as a share of total costs which is also cited as the main obstacle to mechanization and automation. Skill constraints are also a serious concern in Nigeria, in particular technical skills. South African firms have a particularly high share of low-skilled workers which could partially explain lower adoption rates. While they struggle to access skilled staff to operate and maintain machines, their main skill gap relates to soft skills. In general, power and machine functioning are much more substantial concerns in South Africa and Nigeria than staff constraints.

To advance the adoption of automation technologies, governments will need to invest primarily in the development of technical skills, but also soft skills. Automation needs to be an integral part of related vocational training and university curricula to introduce potential employees to the technologies and thereby reduce resistance. In addition to tertiary education, continuous training programmes are needed to build a flexible workforce that can use the fast-changing technologies and adapt to the resulting changes in tasks. Particular attention should be paid to low-skilled workers to enable them to take advantage of opportunities that arise. At the same time, social safety nets and retraining opportunities are needed in particular for low-skilled staff that are more likely to be affected by job losses that may result from introducing the technologies. In addition, more focus needs to be placed on bringing women into the technical professions. In light of the diversity reflected in the country-specific findings, governments will need to adapt their strategies to the national context and the specific constraints and opportunities.

The research is subject is a number of limitations which point to areas for future research. The survey only covered the formal agroprocessing sector. Additional research should also investigate the status and mechanization/automation adoption in the informal sector and related labour impacts. Moreover, the research only a snapshot of the current situation. Follow-up research with the same companies could help to monitor changes over time. With regard to the methodology used in the study, this article relies on descriptive data. Additional research could statistically explore the determinants of adopting automation technologies and the impacts of mechanization and automation on employment.

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Appendix

Table 1A: Basic characteristics of the surveyed firms (not weighted)

		Ethiopia	Kenya	Nigeria	South Africa	Total
Main sub-sector of operation	Food	203	75	82	69	429
	Beverages	12	17	28	12	69
Main sub-sector of operation (SIC code)	201 Meat Products	6	2	2	9	19
	202 Dairy Products	4	7	14	10	35
	203 Canned, Frozen, and Preserved Fruits, Vegetables, and Food Specialties	6	11	4	8	29
	204 Grain Mill Products	113	12	13	11	149
	205 Bakery Products	27	6	8	3	44
	206 Sugar and Confectionery	8	10	7	7	32
	207 Fats and Oils	14	7	14	6	41
	208 Beverages	12	17	28	12	69
	209 Miscellaneous	25	20	20	15	80
Company ownership	Domestic private sector	181	60	69	58	350
	Foreign private sector	9	10	36	7	62
	Government-/state-owned	3	3	2	0	8
	Cooperative (member-owned)	2	0	0	2	4
	Public / Private Partnership	4	3	0	2	9
	Private sector, share company	16	16	3	12	65
Firm size (number of employees)	Small (1-50)	114	12	37	32	195
	Medium (51-250)	66	28	47	32	173
	Large (> 250)	35	52	26	17	130
Firm size (annual sales)	<USD 15'000	10	0	9	2	21
	USD 15'000-50'000	7	3	9	2	21
	USD 50'000-200'000	18	3	19	4	44
	USD 200'000-1m	125	23	35	21	204
	USD 1m-5m	20	9	14	11	54
	USD 5m-10m	13	37	12	10	72
	USD 10m-25m	11	10	6	15	42
	>USD 25m	0	0	3	5	8
	no data	11	7	3	11	32
Level of export orientation	domestic	182	31	73	35	321
	>75% domestic	8	22	18	25	73
	50-75% domestic	3	24	12	8	47
	25-50% domestic	3	6	6	8	23
	<25% domestic	18	9	1	5	33
Mechanization/ automation	Mechanized	212	92	110	81	495
	Automated	43	78	61	42	224
	Total	**215**	**92**	**110**	**81**	**498**

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