CHAPTER 5

Policies for Competitive and Sustainable Agricultural Production Systems: A Case Study of Ghana's Recent Mechanization Interventions

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Africa south of Sahara (SSA) has witnessed steady economic growth and transformation in the agricultural sector in recent decades, involving significant changes in underlying economic conditions that affect both the demand and the supply of mechanization. After periods of relatively less attention, interest in agricultural mechanization has resurged in SSA in the past decade. Mechanization has been integrated into the mainstream Africa-wide agenda, including the African Union's Agenda 2063, the United Nations' Comprehensive Africa Agriculture Development Programme (CAADP), and the Malabo Declaration, all of which have urged countries to commit to making significant progress on agricultural mechanization by 2025 (Malabo Montpellier Panel 2018; Diao, Takeshima, and Zhang 2020). Recently, the Food and Agriculture Organization of the United Nations (FAO) and the African Union Commission (AUC) developed the Sustainable Agricultural Mechanization in Africa (SAMA) framework, an approach to further mobilize regional and global support for this effort (FAO and AUC 2018).

Governments and international communities have faced steep learning curves in attempting to meet the growing demand for mechanization in SSA, yet gradually they have improved their approaches by drawing on lessons learned over time. Despite the resurgence of medium- to large-scale farmers in SSA in recent years, smallholders remain the dominant players. The demand for mechanization began expanding among a broad class of farmers, including smallholders, in SSA countries before most of these smallholders fully transitioned into the nonfarm sector, and SSA governments have had to face the challenge of meeting the growing demand for mechanization among these smallholders. The indivisibility and the knowledge intensiveness of mechanical technologies such as tractors have led to significant market failures that could not be overcome easily in the short term. In recent decades, developing countries in Asia have been able to accomplish mechanization goals in land preparation, such as primary and secondary tillage, and such experiences have inspired SSA governments. However, unique conditions in SSA, including the dominance of rainfed farming systems and preferences for higher-horsepower tractors, have complicated the challenges faced by SSA governments.

This chapter highlights the emerging areas of market failure associated with agricultural mechanization and how SSA governments, including the Ghanaian government, have adapted their strategies over the years in attempting to overcome these market failures. The chapter focuses more on Ghana, rather than SSA as a whole, while also discussing how Ghana's experiences are still relevant to other SSA countries. To retain clarity on the policy dynamics aspects, the chapter limits its focus to tractors in the crop subsector, as well as mechanization-*specific* policies, while leaving other types of mechanization technologies or subsectors, or other broader mechanization-*sensitive* interventions and policies, to future studies.

General Patterns of Emerging Policy Needs on Mechanization in Africa

Social, Political, or Macroeconomic Factors and Historical Reasons That Explain the Current Mechanization Policy Choices

Recent decades have seen noticeable changes in the demand for and use of mechanical technologies, particularly among smallholders.[2] Key supply-side factors have also evolved through external forces as well as endogenously in response to the nature of the demand.

Demand-Side Factors

The demand for mechanization in SSA appears to have grown in peculiar ways that have affected the choices made in policy responses. The overall demand grew in aggregate, with strong seasonality and in an atomistic way. In addition, higher-horsepower (HP) tractors have generally been preferred over lower-HP tractors. Furthermore, governments have faced pressure to speed up their responses to meet time-sensitive goals on mechanization.

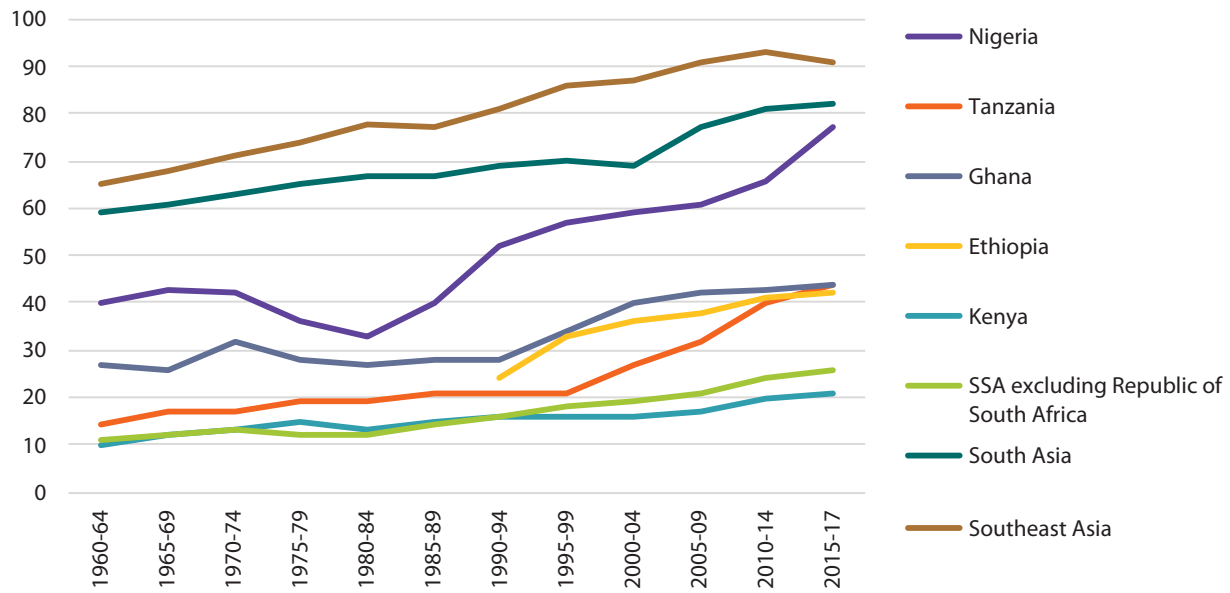
2 For example, the share of farms adopting animal traction, which had been low until the 1990s, increased significantly by the 2000s–2010s, to about 60 percent in northern Nigeria (25 percent for the whole of Nigeria) (Takeshima and Lawal 2018), 80 percent in Burkina Faso (Gray and Dowd-Uribe 2013), 70 percent in Mali (Fonteh 2010), and close to 40 percent in Niger (Sheahan and Barrett 2014). Similarly, by the mid-2010s, about 30 percent of farm households in Ghana were using machines for land preparation (Diao, Takeshima, and Zhang 2020).

Demand Expansion Due to Farming System Intensification and Structural Transformation

The intensification of farming systems and the broader economic transformation in SSA in the last few decades are likely to have expanded the demand for mechanization to a broader class of farmers, including smallholders.

The literature on farming system evolution (Pingali, Bigot, and Binswanger 1987) suggests that growth in demand for mechanization among a broad class of farm households is linked with the process of farming system intensification—characterized by more frequent land preparation and a shortened fallow period—driven by population growth and market development.[3] SSA countries have experienced significant intensifications of their farming systems in recent decades, based on the "R-value," which measures cultivated area as a share of total agricultural land (Ruthenberg 1980) and has been particularly applicable to SSA and Asia. Since the 1990s the farming system has intensified significantly in Nigeria, as well as in countries such as Ethiopia, Ghana, and Tanzania (Figure 5.1). Some African countries have been catching up to Asia in the past two decades, although R-values have been higher in Asia than in Africa, consistent with the faster growth of mechanization in Asia in earlier decades. While R-value is an aggregated indicator and does not capture in-country variation, a recent set of more location-specific evidence also suggests rising demand for mechanization in SSA (for example, Baudron et al. 2019). The specific evolution patterns of mechanization technologies hypothesized in farming system evolution theory is also partly consistent with the prediction of induced innovation theory. While mechanization had appeared to be suitable for land-abundant Africa during the 1960s, shifting cultivation and long fallow periods were more likely to have been suitable complementary technologies to land instead of mechanization (Diao, Takashima, and Zhang 2020).

FIGURE 5.1—R-VALUES IN AFRICAN COUNTRIES, 1960–2017



Source: Authors' calculations based on FAO (2019).
Note: R-value = (Harvested area of all crops summed) / (Arable land + Permanent pasture and meadows) * 100.

3 Importantly, some demand had existed in Africa in the 1960s and 1970s, among a fraction of relatively modern, large farms in the formal sector, and guiding strategies such as those in FAO (1981) had been instrumental in meeting demand among these sectors. Pingali, Bigot, and Binswanger (1987) had complemented such efforts by expanding the framework to understand the demand among a broader class of farms, including small businesses and smallholders in SSA, which had constituted a larger share of the agricultural sector (for more discussion, see Diao, Takeshima, and Zhang [2020, Chapter 1 Online Appendix]).

Increasing farming system intensity has raised the demand for overall farm power inputs, which can be supplied by human, animal, or mechanical power. However, this process is also accompanied by economic transformation, which raises the relative price of rural laborers, who have higher opportunity costs and significant aversion against drudgery, leading to an increased demand for mechanical technologies that can substitute for labor. The growth of a rural nonfarm sector has drawn rural labor away from farming. This shift has been evident particularly among the youth (Mueller and Thurlow 2019), who are key suppliers of on-farm heavy-duty manual labor for tasks such as land clearing and preparation. Recent empirical evidence suggests that, in Africa, the substitution of physical labor with mechanical power has been one of the important processes of rising agricultural labor productivity (Diao, Kweka, and McMillan 2019; Diao et al. 2019).

Seasonality and Atomistic Nature of Demand for Mechanized Land Preparation

In many SSA countries, agriculture is largely rainfed, whereas irrigation can help extend land preparation and other seasonal activities in Asian agricultural production. Crop yields are sensitive to planting timing, leaving only a short window for land preparation. When demand for mechanization services concentrates on tractors for plowing, the seasonable demand can constrain tractor services from the supply side.

Much of the mechanization demand for land preparation has remained atomistic because demand has grown considerably among smallholders. The gradual rise of medium to large farms (Jayne et al. 2019) has been associated with the growth of tractor ownership in various SSA countries. However, while these medium to large farms have grown in relative terms, they have not yet dominated the sector. Consequently, a significant share of mechanization demand has arisen on farms managed by smallholders who hire mechanization services from farmers with medium to large farms (Jayne et al. 2019; Diao, Takeshima, and Zhang 2020). Because of these patterns, SSA governments' mechanization support remains centered around smallholders. Support for custom-hiring services faces challenges, including high transaction costs for increasing machine utilization rates by aggregating demand and uncertainty caused by smallholder constraints.

Seeming Preferences for Higher-Horsepower Tractors

In some SSA countries such as Nigeria and Ghana, farmers appear to prefer higher-HP tractors than those demanded in other comparable regions such as Asia. Even for four-wheel tractors, the typical power of tractors operating in SSA countries is more than 50 HP, compared with a typical power of 30 HP in Asia (Diao, Takeshima, and Zhang 2020). Because higher-HP tractors tend to be more expensive, the consequence of credit-market failures has been more severe, and policies in SSA countries often focus more on reducing tractor prices. This relative dominance of higher-HP tractors affects the types of market failures that emerge, as is described in later sections.

Time-Sensitivity of Regional Commitments

At the global and regional levels, SSA governments continue to face pressure to meet time-sensitive development goals, which also include goals on mechanization. For example, the African Union's Agenda 2063 Aspiration #1, Goal #5, commits countries to banish the hand hoe by 2025 (Malabo Montpellier Panel 2018; Diao, Takeshima, and Zhang 2020), although the viability of this goal remains unclear. In Ethiopia, concerns over imminent climate change and interest in the green economy have induced the promotion of mechanization to substitute draft animals, which officials regard as a contributor to global warming (Berhane et al. 2017; FAO and AUC 2018).

Supply-Side Factors

Some of the earlier literature on agricultural mechanization (see Pingali, Bigot, and Binswanger 1987) hypothesized that the private sector might be able to meet the rising demand for mechanization in SSA even without direct government intervention. This approach remains feasible, but SSA governments have increasingly recognized that private-sector responses alone can be insufficient in the short term to meet the aforementioned time-sensitive goals. Some of SSA governments' mechanization policy options seem to be associated with perceptions of various types of market failures. These failures can largely be categorized as risk and uncertainty in private investment in agricultural machinery, and insufficient information and knowledge (Diao, Silver, and Takeshima 2017; Diao, Takeshima, and Zhang 2020).

Risk and uncertainty, particularly in private investments, arise primarily because of the aforementioned nature of demand, including seasonality and

the atomistic characteristics of smallholders. As described above, the number of medium-scale farmers has increased in many African countries in recent years, but most have comparatively small farms, and their tractors do not reach sufficient utilization rates from their own-farm use alone. To reach the break-even level of machine utilization rates, such farmers have needed to earn additional revenue by hiring out their services. As a result, returns from hiring-out services significantly determine the returns to machine investments. Uncertainty in the returns from hiring-out services can arise because rainfall uncertainty can make smallholders' demand for plowing at a specific time period a highly volatile prospect. Further, smallholders' inability to group themselves to approach service providers makes it risky both for smallholders to find service providers and for service providers to find profitable customers. The consequences of such uncertainty may be magnified because of the lack of credit markets that potential tractor owners are able to access, and lump-sum cash investment often is needed up-front (Takeshima et al. 2015). These factors are expected to lead to underinvestment in agricultural machinery in the absence of effective public policy support.

African countries' various stakeholders also may lack sufficient information and knowledge on many mechanization-related issues (Daum and Birner 2017). Modern mechanization technologies have developed rapidly and often are knowledge-intensive. Farmers will require basic knowledge of their equipment for machinery operation and efficient maintenance and repair. To improve the efficiency of their investments, they will need further knowledge about different brands and types of machines, their functions, and their suitability for different soils and agroclimatic conditions. Such information and knowledge are similar to public goods, and the private sector alone cannot generate and accumulate enough of such knowledge.

SSA governments also often perceive that the market alone fails to achieve inclusiveness and equality, with smallholders more likely to be excluded from access to mechanization services (for example, in Ghana [Diao et al. 2018]). Where such inclusiveness is part of a public good, the private sector alone may undersupply it. The following section focuses on such issues.

Key Lessons from Past and Recent Policy Interventions

Agricultural mechanization policies and government programs in SSA generally have consisted of promotion policies, as well as trade and import policies; licensing policies; and policies affecting financial support for machinery purchases and inputs, domestic manufacturing, and regulation/testing, among others.

Earlier Interventions and Lessons

1960s–1980s

Starting in the 1960s, African governments and international organizations provided support for agricultural mechanization. However, this support was largely unsuccessful in raising the level of mechanization in SSA agriculture, and in the mid-1980s, many African governments were forced to abandon these support programs under the loan terms of the Structural Adjustment Programs (SAPs) provided by the World Bank and International Monetary Fund. A number of factors explain these initial failures.

Approaches taken by different SSA countries between the 1960s and early 1980s were fairly diverse. Many SSA countries typically increased direct support for tractorization during this period, but several Sahelian or highland francophone countries, including Burkina Faso, Burundi, Niger, and Rwanda, given their ecology more suitable for draft animal technologies (DAT), focused support on DAT (Pingali, Bigot, and Binswanger 1987). Even among countries promoting tractorization, some, such as Ghana (and some lusophone countries), followed a more socialist approach (Twum and Gyarteng 1991), where mechanization was promoted as part of state farms, while other countries such as Nigeria focused on supporting more large-scale commercial farms (Diao, Takeshima, and Zhang 2020). Consequently, the share of government support for tractorization was much higher in Ghana compared to other SSA countries. Similarly, in the 1970s, mechanization support in Ghana and Nigeria was implemented by military regimes, unlike in some other SSA countries. Some SSA countries such as Cameroon, Democratic Republic of the Congo, and Nigeria also financed these programs through resource export revenues (Diao, Takeshima, and Zhang 2020, Appendix 1C), while other countries relied more heavily on international support.

However, despite the diversity of approaches taken by different SSA countries in the 1960s through the early 1980s, there were common lessons. One lesson from these early interventions was that mechanization support can be successful at a broad scale if it is provided in response to sufficient demand

among a broad class of farmers (FAO and AUC 2018, 36). In many countries promoting tractorization, the interventions targeted the relatively more formal, modern sectors that were connected with the government. The guiding strategies for mechanization developed, such as those of the FAO (1981), were instrumental in informing these formal, modern-sector approaches. However, it was also acknowledged that field-level information on small businesses, including smallholders, which constituted the majority of the farm sector, had been scarce (FAO 2008). Pingali, Bigot, and Binswanger (1987), among others, contributed to analyses of the demand among such broader segments of farm populations. As mentioned above, in the earlier period, mechanization demand for the majority of farmers was likely to have been low if judged based on farming-system intensification. Even in countries where DAT had been promoted more, field-level economic returns to and demand for DAT were mixed until the 1990s, suggesting that realizing effective interventions is difficult without sufficient demand (Diao, Takeshima, and Zhang 2020, Appendix 1C).

Another lesson was that even when demand is sufficient, the government's direct involvement in machine supply development and financing or the provision of hiring services tends to have limited effects (FAO and AUC 2018, 36), and if these approaches are to be used, they need to be used carefully. The experiences in the 1960s–1980s suggested the general inefficiency of direct government involvement in certain activities such as tractor hiring schemes, associated with low utilization rates and insufficient attention to spare parts and repair and maintenance knowledge and skills. At the same time, the need for the long-term development of and investment in relevant institutions, such as those envisaged by the FAO (1981), remained relatively ignored. These institutions included CGIAR and the Centre for Sustainable Agricultural Mechanization, which have conducted engineering research and development (R&D) and facilitated cross-country learning in Asia, or in institutions that could harmonize relevant policies at the regional level and build capacity in both engineering and economics to identify key market failures and appropriate interventions that could reduce government failures (Diao, Takeshima, and Zhang 2020; FAO and AUC 2018), as has been showcased in more recent experiences in Ghana and Nigeria, as described below.

1980s–2000s

Between the 1980s and the 2000s, direct government interventions to support tractor-based mechanization decreased significantly, in part because of the aforementioned lack of success and the effects of the SAPs, which led to currency devaluation and a significant increase in the price of imported tractors in many SSA countries. In addition, due in part to studies such as Pingali, Bigot, and Binswanger (1987), some of the earlier mechanization support was replaced by support for intermediate technologies such as DAT.

The lessons learned during these DAT interventions were largely consistent with earlier lessons, indicating that mechanization interventions are generally more successful if demand is sufficient. Similar to support for tractorization up to the earlier 1980s, support for DAT increased post-1985 until the mid-2000s (FAO and AUC 2018). However, unlike tractors, DAT achieved much more extensive diffusion; while tractor adoption rates had stagnated despite the earlier support, DAT adoption rates rose to around 25 percent in Nigeria, 30 percent in Ghana (Fonteh 2010), and up to 80 percent in Burkina Faso and Mali (Diao, Takeshima, and Zhang 2020). Support for DAT might have been more effective because the demand for DAT in the late 1980s was likely rising more than the demand for tractors, as predicted by the farming system hypothesis; the level of intensification had risen enough for DAT to be more profitable than human power only, while at the same time DAT was sufficient to meet the needed frequency and timeliness of tillage, and the labor wage was still relatively low so that DAT (which was relatively more labor-intensive than tractors) was more profitable than tractors.

Recent Policy Interventions

Since the 2000s, interest in mechanization has revived. SSA countries have modified their support approaches based on their earlier experiences. These modifications have led to some improvements, although challenges remain.

Concessional Loan Support

In recent years, emerging countries including Brazil, China, and India have promoted policies and programs through concessional loan (CL) facilities. These approaches have featured prominently as major instruments for recent public support for mechanization by SSA governments. Typically, low-interest loans are extended on the condition that the borrowing country import the agricultural

machines from the lending country. Such exports and imports of machines through CL facilities have helped recipient countries to import a large number of tractors and exporting countries to sell this equipment and potentially create markets abroad.

The precise nature of the agreements varies. In recent years, Ghana has received CL arrangements from India and Brazil. Lusophone SSA countries, including Mozambique, have also imported tractors through CLs from emerging countries such as Brazil (Cabral 2019). Brazil also has signed memoranda of understanding and technical cooperation agreements with Kenya, Senegal, and Zimbabwe (Veiga and Rios 2017). Benin and Gambia received tractors from India through donation and purchase credits and received assistance to set up a tractor assembly unit (Kragelund 2008). Similarly, in 2009, Cameroon received US$37.65 million in credit from the Exim Bank of India to import made-in-India tractors (Sneyd 2014). Tanzania obtained $40 million in concessionary credit from the Indian government between 2010 and 2011, which was used to import and distribute 1,800 four-wheeled tractors to farmers (Mrema, Kahan, and Agyei-Holmes 2020). The effectiveness of these government programs has not yet been widely evaluated. In countries such as Cameroon, the distribution of tractors under the aforementioned government program reportedly has been less than timely and relatively inefficient (Sneyd 2014).

While these CL-based arrangements have provided opportunities, issues have also emerged over time. Countries offering CLs may not have similar farming systems and practices or similar tropical agroecological conditions to the countries receiving the equipment. As in older programs, the machines themselves have often remained the focal point of these new loan programs, with less attention placed on the supply of complementary resources, including attachments, spare parts, and operation and maintenance skills. The switch from one round of CL agreements to another has sometimes led to the breakdown of the supply network as well as the loss of brand-specific operational skills and knowledge (Diao et al. 2014). Importantly, SSA countries such as Ghana have learned lessons from the earlier phases and have improved their program designs (see the Ghana case study in the next section for a more detailed example).

Private-Sector-Run Custom-Hiring Service Centers[4]

One of the models recently promoted by SSA countries has been private-sector-run custom-hiring service centers using the equipment obtained through the aforementioned CLs. These centers include Ghana's agricultural mechanization service enterprise centers (AMSECs), which are described in greater detail in the next section, and agricultural equipment hiring enterprises (AEHEs) in Nigeria. The Nigerian government, under its Agricultural Transformation Agenda, set up 80 AEHEs in 2011, an additional 31 in 2015, and another 80 by 2018 (Hatzenbuehler et al. 2018).

Recently, Mozambique launched agrarian service centers that have been equipped with agricultural machinery to improve mechanization service offerings for farmers. By 2018, 96 of these centers had been established across the country, consisting of public agencies, private enterprises, and individual farmers (Cabral 2019). Similarly, in Rwanda, the government adopted an Agricultural Mechanization Strategy in 2009 and set up 16 government-led hiring services and training centers called village mechanization service centers, as well as six power-tiller centers (Malabo Montpellier Panel 2018). Under this program, between 2009 and 2013, the Rwandan government also acquired 81 tractors, 250 power tillers, 35 rice planters, five combine harvesters, and farm implements including plows, moldboards, harrows/rotavators, water pumps, and trailers, which were sold to farmers, individuals, and cooperatives (Malabo Montpellier Panel 2018).

Information and Communication Technology Applications for Mechanization Service Provisions. Private-sector-run custom-hiring service centers have been one area where new information and communication technologies have been increasingly integrated. In particular, various SSA countries have promoted "Uber-type" provider-user matching services, as well as other functions such as machine tracking. These services include Hello Tractor in Nigeria and Kenya, Trotro Tractor in Ghana, and "Rent to Own" in Zambia

4 This chapter covers the case of tractors primarily, but the challenges of insufficient utilization rates are a common problem for mechanization in SSA, including postharvest processing. For example, countries such as Nigeria continue to modernize the rice milling sector by promoting large-scale industrial processing facilities. However, these large rice mills are less economically viable owing to an insufficient supply of paddy, unlike more resilient small- to medium-scale processing enterprises that can cope with an uncertain supply of paddy (Gyimah-Brempong, Johnson, and Takeshima 2016).

(Daum and Birner 2019). These innovations have significant potential, though one key challenge is how to scale them up. For example, Hello Tractor currently covers several hundred tractors (Birner and Daum 2017), which is less than 5 percent of all tractors used in both countries (FAO 2019). Moreover, few studies have investigated in detail the economics of these new services, which is important in identifying specific areas of support that can enhance their economic viability.

Challenges for Custom-Hiring Service Provision. These government-supported, private-sector-run programs should be monitored and evaluated formally in future research, as experience suggests that challenges remain. For example, in Nigeria, anecdotal evidence suggests that many government-selected service providers (to whom the governments have provided tractors with subsidies) may be less efficient than service providers that operate in purely competitive markets, in terms of keeping fuel consumption low per unit of area plowed (Takeshima et al. 2015; Hatzenbuehler et al. 2018). If AEHEs observe similar patterns, the government should reconsider the selection of beneficiaries and perhaps make subsidies available at lower rates but for wider groups of tractor owners and tractor brands, so that subsidies are better used in more competitive, market-based mechanisms. Over the years, in parallel with AEHEs that are promoted by the Nigerian federal government, some state government mechanization programs (for instance, the Kaduna state program) have completely withdrawn from providing any financial support for tractor acquisitions and shifted toward linking farmers and tractor vendors in the state (Hatzenbuehler et al. 2018). Some of these changes have been made for financial reasons (for example, lack of budget allocations or the high cost of collecting outstanding loan repayments from tractor owners), but states also have become aware of growing evidence of the relative inefficiency among government-selected beneficiaries.

Similarly, the experience in Ghana suggests that because of the aforementioned risk and uncertainty, and the transaction costs associated with custom-hiring services, the recovery of the full cost of tractor investment relies on sufficient use of tractors for service provision in addition to owners' own-farm use (Diao, Takeshima, and Zhang 2020, Chapter 1). Therefore, more support should be provided for the promotion of farmer-to-farmer service provision by medium-scale farmers, instead of (nonfarmer) specialized service providers on which the earlier public supports often focused. Similar observations have been made in countries such as Mozambique, where farmer-to-farmer service providers have been more effective than larger nonfarmer service providers, with lower prices and more flexible payment terms (Cabral 2019).

Other Mechanization-Related Policies and Programs

Importantly, many of the recent CL-based interventions described above have been implemented in conjunction with other mechanization-related policies and programs.

Trade and Import Policies. Tariffs and tax policies have been typical government trade considerations related to mechanization (Diao, Silver, and Takeshima 2016). In Nigeria, for example, import duties of approximately 5 to 25 percent have typically been applied to tractors, though value-added tax (VAT) has been less common (Takeshima and Lawal 2018). Similarly, SSA countries have often eliminated import duties and VAT for imported tractors but have subjected completely and semi-knocked-down parts and other spare parts to full tariffs (Diao, Silver, and Takeshima 2016). In some countries such as Ethiopia, machine imports have been constrained because of stringent restrictions on access to foreign exchange (Berhane et al. 2017).

Licensing, Registration, and Testing. Licensing requirements for operating, importing, and distributing tractors, and registration requirements for owning tractors, have been in place in various SSA countries. For example, in Nigeria, since the mid-1980s, the law has required tractor operators to be at least age 18, to have passed a trade test (often equivalent to a technical college certificate), and, more recently, to hold a professional license for "agricultural machines and tractors" (Takeshima and Lawal 2018). Nigerian laws also require that tractor importers and distributers be licensed. In Nigeria, importers and distributors of new tractors are typically authorized as sole agents by the foreign companies, which are all licensed (Takeshima and Lawal 2018). Similarly, many countries apply motor vehicle licensing and registration requirements to agricultural tractors. For example, in Nigeria, the Federal Road Safety Commission office and the relevant state motor vehicle registration office license and register tractors (Takeshima and Lawal 2018). The tasks of inspecting the quality of machines, particularly of imported ones, are assigned to relevant bodies in various SSA countries, including the Center for Agricultural Mechanization and Rural Technology in Tanzania and the National Center for Agricultural Mechanization in Nigeria. Enforcement rates in Nigeria, however, have

generally been unclear. In Nigeria, despite the federal government's 1993 directions to establish motor vehicle administration departments in all states, to date only a few states appear to have complied (Takeshima and Lawal 2018).

Financing. Various SSA countries have introduced financing facilities aimed at supporting machine acquisition through deferred payments. In Ghana and Nigeria, such facilities have been tied to government-promoted hiring enterprises such as the AMSECs and AEHEs. Other facilities for general machine purchases include credit facilities within parastatal institutions (for example, Adama Agricultural Machinery Industry in Ethiopia [Berhane et al. 2017]), agricultural windows at investment banks (for example, Tanzania Investment Bank [Mrema, Kahan, and Agyei-Holmes 2020]), agriculture-related trust funds (for example, the Agriculture Inputs Trust Fund in Tanzania [Mrema, Kahan, and Agyei-Holmes 2020]), de-risked support for banks through the provision of guarantees (for example, Nigerian Risk-Sharing Agricultural Lending), and revamped agricultural development banks. However, in Ghana and Nigeria, tractor owners often report that personal savings remain the predominant source of financing for tractor purchases (Takeshima et al. 2015; Diao, Silver, and Takeshima 2016), suggesting that coverage of government financing facilities should be monitored.

Research and Development. SSA countries also have often sought to develop domestic machine manufacturing capacities. In Nigeria, joint ventures were pursued as early as the 1970s between Nigeria Truck Manufacturers and Fiat, and between Steyr Nigeria Ltd. and Steyr tractors (Takeshima and Lawal 2018). Similar joint venture interests considered adapting tractor designs to local conditions, including the Kabanyolo tractor in Uganda and the Tinkabi tractor in Swaziland (FAO 2008). These earlier joint ventures generally were not successful. In Nigeria, the joint ventures faced challenges in using the required amount of locally sourced raw materials due to their low quality (Diao, Silver, and Takeshima 2016). SSA governments' efforts in establishing local assembly plants have also faced challenges, but some plants have remained operational, including Ethiopia's Nazareth Tractor Assembly Plant, which accounted for almost half of the tractors entering the country between 2005 and 2010 (World Bank 2012).

Similarly, many SSA countries have assigned local institutions general R&D tasks for the engineering and development of new designs for machines and attachments. In Nigeria, mechanization units of the Agricultural Development Projects, state and federal governments, and the National Centre for Agricultural Mechanization have been mandated to coordinate R&D conducted by various local organizations (Takeshima and Lawal 2018). International organizations such as the United Nations Industrial Development Organization and the United Nations Economic Commission for Africa have actively contributed to similar R&D efforts. Governments also recognize the need for R&D on other mechanization technologies such as rippers, shredders, and levelers for effective land development and obstacle clearing, as well as the importance of improving the local fabrication and research capabilities of artisans and promoting the local fabrication of basic farm power and postharvest equipment. However, monitoring systems for these R&D efforts generally seem weak and need to be strengthened.

Potential areas for further R&D also include environmental issues. Concerns have long existed that the mechanization process can have considerable environmental impact. Such environmental issues have become more relevant in recent years as tractor adoption has grown in SSA. In October 2018, after intensive expert consultations with a broad range of stakeholders, the AUC and FAO launched the SAMA framework, which has been integrated into CAADP and the Malabo Declaration (FAO and AUC 2018). However, it is generally agreed that more evidence is needed to integrate mechanization policy and environmental sustainability, including in the area of conservation tillage (Giller et al. 2009; Sithole, Magwaza, and Mafongoya 2016; FAO and AUC 2018, 97).

Case Studies from Ghana

As described in the previous sections, over the past few decades Ghana has experienced changing conditions that have affected the demand for mechanization. This section illustrates how the Ghanaian government has tried to fill perceived market failures in farm mechanization services, how it has improved its approaches, and what other challenges remain, with particular focus on AMSECs. As noted, AMSECs have been in operation for more than a decade, and they offer suitable cases that allow us to assess short- to medium-term experiences. They are also relevant to other SSA countries that are increasingly adopting similar institutional models. While future studies will need to provide assessments of other alternative models (for example, block farming), lessons from the AMSECs can offer some guidance.

Experiences before the Introduction of AMSECs

As in many other SSA countries, before the SAP in the 1980s direct government supports for mechanization in Ghana included state-supported tractor-hiring schemes. Unlike many other SSA countries, however, the Ghanaian government promoted more state farms, and the state-supported tractor-hiring schemes accounted for a greater share of the country's tractor fleet than in many other SSA countries (Twum and Gyarteng 1991). The then Ministry of Food and Agriculture typically owned and operated about 1,500 tractors in its 32 district mechanization stations in the Savannah Zone. Plowing services were largely provided for farmers irrespective of their locations and often at rates that were subsidized between 30 and 100 percent (Diao, Takeshima, and Zhang 2020, Chapter 1). These state-run tractor-hiring schemes suffered from high machine breakdown rates (often as high as 40 percent), strong political interference, and a weak management structure, leading to low machine utilization rates compared to the private tractor owners who provided similar hiring services (Diao, Takeshima, and Zhang 2020).

Experiences from AMSEC Phase I

By the mid-2000s, the aforementioned perceptions of a supply-demand gap for mechanization had grown to the point where the Ghanaian government launched Phase I of the AMSEC mechanization support program. Utilizing CLs and donor grants as well as its own budget, between 2004 and 2008 the government imported tractors and basic implements for sale to farmers, private entities, and other institutions under subsidy and hire-purchase arrangements. In 2007, some of the stock of equipment was used to support the establishment of 12 AMSECs in some parts of the country (Diao et al. 2014). In 2009–2010, the government established an additional 77 AMSECs across the country through a similar process and under the same financing arrangement.

Recognizing the challenges experienced under the earlier state-run tractor-hiring schemes arising from direct government management and operation of mechanization services, the AMSEC program was designed to be managed by private agents selected by the government to own and operate the machinery services centers. The government provided a subsidy of about 30 percent on the equipment sold to farmers and AMSECs. It further provided hire-purchase arrangements based on about 20 percent down or up-front payment for the fleet of equipment allocated to an AMSEC, with interest-free repayment on a quarterly installment schedule over a five-year period.

AMSEC Phase I appears to have had mixed effects in the short term; where the centers were successful, they somewhat improved the timely availability of mechanization services and reduced drudgery, but their presence had relatively limited impact on service fees and total area ploughed (Benin 2015). Elsewhere, they faced greater challenges to stay operational. Many AMSECs suffered from low profitability and incurred losses in the first few years of operation, and many defaulted on their repayments, leaving the government responsible for repaying the CLs (Diao, Takeshima, and Zhang 2020). Many AMSECs still suffered from low machine utilization rates, often below the hypothetical break-even points based on subsidized tractor prices, actual operational costs, the typical capital depreciation rate, and interest earnings from a similarly sized savings deposit in a Ghanaian bank account (Houssou et al. 2013).

Various factors contributed to these outcomes. AMSECs, which were selected by the government, often failed to achieve utilization rates that were similar to those of the purely private-sector service providers who mostly used secondhand tractors. At the same time, each AMSEC was equipped with five to seven new tractors, which turned out to be too large a fleet to manage efficiently. For many AMSECs, the plowing season, which was largely dependent on rainfall, turned out to be too short in their localities for sufficient utilization rates. Migration to regions with different plowing seasons could have increased these rates, but the high transportation costs caused by poor road infrastructure and the transaction costs associated with the fragmented nature of customer farmers meant that few AMSECs could explore such options. Similarly, AMSECs often did not do better than the private sector in using tractors for multiple purposes (Benin et al. 2012), further limiting utilization rates. Lastly, the program could not effectively solve the problems of tractor operators' limited operational and maintenance skills, and poor access to repair services and spare parts; moreover, AMSEC owners and operators did not have sufficient managerial skills to manage the large number of tractors in each center (Diao et al. 2018).

Experiences from the Ongoing AMSEC Phase II

In 2016, the Ghanaian government secured a CL facility to import Brazilian agricultural machinery. The government, aware of the aforementioned

perceptions of market failures in mechanization hiring services and farmers' poor access to equipment, chose to continue with the second phase of AMSEC. Reflecting on the lessons from AMSEC Phase I, as well as recommendations made by various organizations and studies (Diao et al. 2018), AMSEC Phase II has made a number of modifications. First, whereas AMSEC I restricted the offer to centers that would purchase at least five tractors, AMSEC II dropped that restriction and opened the offer to all would-be buyers at the same price, reducing the risk of government failures in beneficiary selections. This appears to have been effective at least in the short term; of the first tranche of 549 tractors imported from Brazil by 2017, 379 (69 percent) were purchased by individuals who bought only one tractor with accompanying implements. Second, the program incorporated greater support for maintenance; 1,000 engine-hours or one year (whichever comes first) of free scheduled tractor maintenance servicing has been included as part of the support for all tractor beneficiaries. The program identified and included mobile workshop vans in the list of equipment available to beneficiaries for on-field repair work. More concrete arrangements have been made with the Brazilian manufacturers, so that they are required to provide spare parts for two years while the supply network is developing. Third, the program paid more attention to enhancing maintenance knowledge and skills. First-time buyers, including operators, are now required to participate in the training provided by the agriculture ministry's engineering staff. Fourth, the AMSECs expanded support for exploiting multiple uses of the tractors, both on and off the farm. Various implements and equipment have been imported for purchase and demonstrations, including maize shellers, multicrop threshers, pneumatic and mechanical planters, cassava planters and harvesters, seed drills, boom sprayers, and maize/soya/rice harvesters that can be attached or mounted to tractors. The government also has expanded the tractor brand options by importing three different class "A" brands of tractors: Massey Ferguson, the most popular brand in Ghana's secondhand tractor market (most over 20 years old); New Holland; and Valtra. Three private companies selected as local agents provide after-sales support for each brand of tractors.

While the outcomes (particularly in the medium to long term) of these modifications should be formally evaluated through further research, these modifications in AMSEC II are generally promising. At the same time, field observations by Diao et al. (2018) suggest that some challenges remain, which can be addressed through further improvements in the program. Notably, it remains unclear how the program has improved smallholders' access to mechanization services. As has been observed in the private sector, including in Ghana, farmers' main motivation for tractor purchases has been primarily for use on their own farm, and hiring out is only a secondary use. This pattern suggests that AMSEC II has yet to achieve the government's intended goals of improving access for smallholders. The relatively limited mechanization service offered through hiring out, owing to the aforementioned transaction costs, appears to have persisted under AMSEC II. These challenges suggest a potentially important role for complementary government efforts to reduce transaction costs, such as encouraging smallholders to aggregate their demand for services and stimulating demand at intensive margins (such as the second plowing or harrowing in addition to the first plowing). Furthermore, Diao et al. (2018) also have suggested that knowledge of machine operation remains insufficient. For example, tractor owners and operators frequently have insufficient operational and tillage skills. In many cases, operators skip proper pre-inspection of fields for stumps and stones, which means that these obstacles can damage crucial parts of the machines, such as the transmission or hydraulic systems. These incidents often lead to the premature breakdown of machines, since repairs and spare parts are often expensive and not readily available. Although AMSEC II incorporates training as a new program component for first-time buyers, a broader set of beneficiaries will need to access such training.

Concluding Remarks

Agricultural mechanization has significant potential to further transform the agricultural sector in SSA, most notably through direct effects on labor productivity. Now that mechanization of farming activities has spread across Asia, SSA is the last frontier, and significant agricultural mechanization growth is expected to continue in the near future.

SSA governments will remain critical players in supporting the growth of agricultural mechanization, though they will need to take care in this delicate process. This chapter has focused on identifying the areas of market failure where the public sector has a role to play, but the private sector also has substantial potential to lead the growth of mechanization, particularly in comparison to some other agricultural technologies for which the public sector remains the dominant player. At the same time, the risk is also high that improper government actions could negatively affect this growth potential. It is therefore

important for SSA governments to effectively mitigate market failures even as they minimize the risk of government failures. Appropriate involvement of the government is also important to ensure the socioeconomic and environmental sustainability of business models in the mechanization sector, as envisaged in recent initiatives such as the SAMA framework (FAO and AUC 2018).

In conclusion, it is also important to note that, overall, the mechanization process has been affected more profoundly by broad economic policies than pure mechanization policies (Binswanger and Donovan 1987), and this remains largely the case today. In terms of the number of agricultural machines operating in any given SSA country, the share of machines handled by the governments either directly (for example, through state-run tractor-hiring schemes) or indirectly (for example, through hiring-service enterprises) has remained small. In Africa's spatially diverse agroecological and socioeconomic conditions, implementations of blanket policies and interventions have faced challenges in realizing effective outcomes. For mechanization support policies, SSA governments and the international community must have realistic expectations about the domain of influence of direct mechanization policies, and they must continue to identify policy spheres that have greater multiplier effects, including the generation of information and knowledge relevant to mechanization.