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Mechanization in Ghana

Searching for Sustainable Service Supply Models

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Contents

Abstract	v
Acknowledgments	vi
1. Introduction	1
2. Agricultural Mechanization: Alternative Supply Models	3
3. AMSECs in Ghana: What Has Gone Wrong?	10
4. Conclusions: What Can Ghana Learn from the Bangladesh, India, and China Models?	17
References	20

Tables

2.1—Comparison of the three supply models of mechanization	8
3.1—Summary of Ghana’s current supply model for agricultural mechanization	16

Figure

3.1—Agricultural machinery imports	15
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ABSTRACT

Little has been written in recent literature regarding the role of mechanization in agricultural transformation in Africa. Government-led mechanization schemes in the 1970s and 1980s proved unsustainable after structural adjustment policies removed government support. However, demand for mechanized services by smallholder farmers has grown recently, with urbanization and agricultural intensification creating a power bottleneck for land preparation, especially in some regions. Against this background, the government of Ghana has increased its support for mechanization by establishing subsidized mechanization service centers since 2007. This paper assesses the sustainability of the current supply network for mechanization, given government policy. Stylized models of mechanization supply are developed based on experience in Bangladesh, China, and India during similar stages of agricultural transformation. Ghana's supply network is then analyzed in light of key lessons from the Asian experience. The analysis focuses on two policy issues: (1) whether the current model promoted by the government has left enough room for the private sector to develop the supply chain, including machinery imports and trade, and (2) whether this model can better link smallholders' demand for mechanized services to its supply, such that supply can further induce demand and mechanization can broaden its role in agricultural transformation. By addressing these questions, this paper aims not only to fill the knowledge gap in academic literature but also to contribute to policymaking by identifying an appropriate and sustainable model tailored to the current needs of smallholder farmers in Ghana. The study concludes that the government-subsidized mechanization service center model is neither appropriate nor sustainable at the current stage of agricultural transformation in Ghana, and hence government policy should focus on the private-sector leadership along the mechanization supply chain, in the mechanized service market, in the machinery market (including imports and domestic trade), and in the repair service market.

Keywords: agricultural mechanization; government policy; intensification; Ghana

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1. INTRODUCTION

The research on African agricultural transformation focuses on the adoption of modern technologies such as improved seed varieties and chemical fertilizer, and the policies required for promoting their adoption. Mechanization has received less attention in the recent years in academic literature, international policy dialogue, and program formulation (Pingali 2007; Mrema, Baker, and Kahan 2008). Most literature on mechanization, especially in Africa, dated to the 1970s and 80s and focused on evaluating various programs of government's direct provision of mechanization services to farmers. The consensus was that these programs were unsustainable due to a lack of real demand from farmers for such services and the heavy fiscal burden they created (see Pingali et al. 1987 and Mrema et al. 2008 for a full review).

While all the early government supported mechanization programs failed to sustain in Africa, demand for mechanized services by smallholder farmers has grown recently. Governments in countries such as Ghana and Nigeria have started to devote significant resources to promoting agricultural mechanization again. Many African countries have abundant agricultural land relative to labor, yet their agriculture is characterized by low productivity for both land and labor. However, in recent years, the pace of intensification in agricultural production has started to increase in Ghana. Erenstein (2006) defines intensification in two distinct but highly associated forms. Given that Ghana is a relatively land-abundant country, both forms of intensification have occurred simultaneously. Land-use intensification is identified as rising land-labor ratios, while technological intensification is measured by increased use of modern inputs such as fertilizer, herbicide, and improved seeds. Moreover, intensification in agricultural production is also an outcome of urbanization, as increased nonfarm opportunities in rural areas have been making labor more expensive. Additional agency costs of hired labor over family labor also make mechanization attractive as farm scale increases (Rosenzweig and Foster 2011). In Ghana, the average annual growth of the rural population from 1990 to 2010 was only 1.1 percent (World Bank 2012), while land area cultivated has increased by 3.9 percent on average annually (FAO 2012). Moreover, several rounds of the Ghana Living Standards Surveys (GLSS3, GLSS4, and GLSS5) show that nonagricultural employment increased by 3.8 percent annually between 1991 and 2006, compared to an agricultural employment growth rate of only 2.2 percent over the same period.

Agricultural intensification is understood to be a driving force for mechanization, which can help overcome the power bottleneck created by intensification (Pingali 2007). Demand for mechanization by small farmers in most African countries is concentrated in power-intensive activities, particularly in land preparation, indicating that mechanization is still at an early stage. Although labor still dominates most agricultural operations as the primary power input in Ghana, the emerging power bottleneck in land preparation can be explained by the seasonal peak in labor demand, the increased opportunity cost for such activity as non-farm activities become more plentiful (Kolavalli et al. 2011). Additionally, labor supply shortages are aggravated by the preferences of the younger generation of rural workers for an alternative urban livelihood as opposed to the perceived drudgery of farming activities.

Against this background, the government of Ghana has increased its support for mechanization by stepping up the subsidized mechanization service centers (Agricultural Mechanization Service Enterprise Centers, referred to as AMSECs) since 2007. Though the AMSECs are intended to promote private-sector-led mechanization, doubts have been raised regarding the program's sustainability due to the heavy subsidies on tractors and other equipment and the government's direct involvement in the importation and distribution of agricultural machinery.

This paper focuses on aims to explore the supply chain models which could be sustainable in an Africa context such as Ghana. Two questions are fundamental to assessing the sustainability of AMSEC: (a) has the AMSEC model left enough room for the private sector to develop the supply chain, including machinery imports and trade and (b) can this model better link smallholders' demand for mechanized services to its supply, such that supply can further induce demand so that mechanization can take on a broader role in agricultural transformation? By addressing these questions, this paper aims not only to fill the knowledge gap in the academic literature but also to contribute to policymaking by identifying an

appropriate and sustainable model tailored to the current needs of smallholder farmers in Africa. With economic growth and the increasing commercialization of agriculture, the role of mechanization in agricultural transformation will grow in importance (Pingali 2007). The policy issues addressed by the paper will be critical for developing an agricultural machinery supply chain led by the private sector in the long run.

The paper starts by structuring three models of mechanization supply in Section 2. The emphasis in this section is on the role of the private sector under alternative models of mechanization. The models are based on stylized facts drawn from the experience of successful Asian countries which faced challenges to agriculture development similar to those faced by Ghana today. We use them to explain how different countries have successfully mechanized parts of agricultural operations in their agricultural transformation process. Against the stylized models in Section 2, Section 3 analyzes the current model of mechanization supply in Ghana considering in particular challenges to the sustainability of the developing mechanization supply chain. Section 4 concludes by discussing the policy implications for Ghana, drawing on the lessons from the Asian experience.

2. AGRICULTURAL MECHANIZATION: ALTERNATIVE SUPPLY MODELS

Little attention has been paid to the supply side of agricultural mechanization in the literature, as it is commonly believed that demand is the driving force behind mechanization. When demand for mechanized services is present and high enough, supply from the private sector will come to meet the demand (Pingali 2007). Mrema et al. (2008) are among a few exceptions to emphasize the factors for mechanization beyond demand side constraint. In light of the lessons learnt from Asia's mechanization in 1970-80s, they emphasize the following factors necessary for mechanization development in Africa, that is, existence of effective demand for agricultural outputs; increasing machinery utilization rates through non-agricultural uses, rental markets and migration across climatic zones; and the attention needed to support sustainable machinery supply chains. While the early push for mechanization in Africa failed largely due to the lack of demand, such failure is also due to the government's direct intervention in the supply of mechanization services, which resulted only in low efficiency and high costs without sustainability (Pingali, Binswanger, and Bigot 1987). While agricultural equipment rental markets have played an important role across Asian countries in overcoming the lumpiness of investments in agricultural machinery (Feder, Just and Zilberman 1985), it failed in Africa. The inefficient machine rental markets in Africa relate to the high maintenance costs of tractors imported by the government without properly developing a repair market with right spare supply. The moral hazard issue in renting machinery is serious, particularly for machine used in farm operations with unpredictable weather conditions and difficulty in synchronous timing (Binswanger and Rosenzweig 1986).

To fill the knowledge gap in understanding alternative supply models of mechanization such that lessons can be learned by Africa from Asian countries' experiences, in this section we develop three stylized models based on the experiences of some Asian countries. Recognizing that demand is a necessary condition for mechanization, we show in this section that the mode of supplying mechanized services varies significantly across countries. Focusing on the private sector's active and sustainable engagement in mechanization supply, these three models will help identify a proper role for the government in mechanization.

Mechanization has evolved very differently in large-farm-dominant economies such as the United States and Brazil. Therefore, our stylized models are based on some Asian developing countries in which smallholders dominate, as the models need to be relevant to many African countries, including Ghana, with smallholder-dominant agriculture. In discussing Asian experiences under the stylized models, our attention is focused on the supply of mechanized services in land preparation, given that current demand for mechanized services in Africa is still concentrated in power-intensive farming operations, particularly land preparation.

Although we name the three stylized models after three countries, the models are actually highly representative of many Asian countries. However, it is not our intention to simplify the rich experiences of mechanization among developing countries, and in practice there are many other models that cannot be categorized or summarized by these three models. By providing three models that vary in the ways to develop a sustainable mechanization supply chain, we intend to broaden the range of options for Ghana to consider as the country looks to develop its own mechanization supply chain in parallel with the agricultural transformation process.

Small-Scale Farmers Owning Small Machines: The Bangladesh Model

As in many other rice-dominant South and Southeast Asian countries, Bangladesh has a long history of using animal traction in farming operations, particularly in land preparation. Evidence suggests that the adoption of mechanized service in such operations replaces animal traction. As draft animals are individually owned, ownership of power tillers by individual smallholders in rice production is only a small shift from the tradition of individual farmer ownership of animals for farm power. A similar transition has occurred in Vietnam and China, where individually owned smaller tractors have been replacing draft animals. The number of draft animals in China dropped from about 55 per 100 farmers in

1985 to only 20 in 2009 (Yang, Huang, and Zhang 2012). According to Viet (2011), 65 percent of tractors in Vietnam are less than 12 horsepower (hp) and only 8 percent are greater than 35 hp. Under this model, power tillers are production assets that are employed in the owners' own farming processes. However, mechanized services can also be provided to neighboring small farmers who do not own a power tiller, which generates additional income for the owners. This practice is a logical continuation of farmers borrowing animals from neighbors in exchange for various forms of in-kind compensation.

Government policy has played an important role in rapid mechanization in Bangladesh. In the late 1980s, the government liberalized the importation of agricultural inputs such as fertilizer, irrigation pumps and engines, pesticides, seeds, and also power tillers (Ahmed 1995). Up to 1988, the Ministry of Agriculture restricted imports to certain makes and models of equipment that met the certification standards for imported machinery, and importation and sales were carried out by a government parastatal (Gisselquist and Grether 2000). These restrictions were lifted in 1988 after a severe decrease in the draft animal population during a devastating flood (Roy and Singh 2008). Although the parastatal continued to import for several years, private traders took over the import market with cheaper power tillers from China, causing a 40 percent drop in the cost of machinery (Gisselquist and Grether 2000; Roy and Singh 2008). By 2007, approximately 400,000 power tillers were in use in Bangladesh, compared with only 12,000 four-wheeled tractors (Ziauddin and Ahmed 2010). This is a clear example of a situation in which the deregulation of machinery imports, combined with a reduction in trade tariffs, triggered mechanization adoption by small farmers and the simultaneous development of the private sector's active engagement in the mechanization supply chain. Because of the private sector's role in the supply market of machinery, including imports, the right machines have been brought into the country at affordable prices, which is the first necessary condition for small-scale farmers to invest profitably in power tillers.

Given that use of the power tiller as a power input in land preparation is seasonal, specialized machinery will limit the profitability of its owners, which will lead to a lack of demand for it. Again, the private sector's engagement helps individual small farmers broaden the utilization of tractors by developing local fabricators. Multifunctional machines have become the other important condition for incentivizing small farmers to own agricultural machinery. Indeed, it is common in Bangladesh and in many other Asian countries to see power tillers used to power a threshing machine during harvest season or as a transport tool in both agricultural and nonagricultural activities. Multifunctional operations make power tillers a more valuable investment for individual farmers. Roy and Singh (2008) show that power tiller owners in Bangladesh can repay their purchase cost after one or two years when they provide multifunctional paid services as well as servicing their own farms for land preparation. Although careful calculation of returns from different types of services (including serving the owner's own farm, providing paid service to other farmers, threshing, and transport) cannot be found in the literature, it is reasonable to expect that a power tiller is unlikely to be attractive for small farmers, given the small size of landholdings in Bangladesh, unless other functions beyond use for the farmer's own land preparation are exploited.

Discussion about how to finance power tiller investment is virtually nonexistent in the literature. Given that the prices of power tillers are low, they are probably affordable for many small farmers without the support of formal financial institutions. Chinese power tillers imported to Bangladesh in 1988 cost farmers only \$800 (Roy and Singh 2008). Also, it is well known that in rural areas of Asian countries, informal financial arrangements are common for many types of small investments (for example, World Bank 1996).

Though subsidy policies exist in some countries (see the India model below), such policies seem to have little effect on the capacity of the private sector in Bangladesh to lead power tiller importation and accelerate supply chain development. Manufacturing capacity in Bangladesh is limited to spare parts and other basic implements due to low expertise and high tariffs on raw materials (Roy and Singh 2008). However, this domestic capacity has led to the adaptation of imported power tillers to power other equipment (such as threshers) or to be used for transportation. Simple equipment, including threshers and haulers, can easily be produced locally. The mechanization supply chain also includes repairing and

maintenance service, which obviously has developed considerably alongside the increased use of power tillers and other agriculture-related equipment.

The Bangladesh model is a sustainable supply model in which the private sector plays the leading role throughout the entire mechanization supply chain. Critical to its sustainability is profitability for each player along the chain: when importation and the domestic market are operated by the private sector, profitability guides traders to import the right machines that are affordable to individual farmers. When local fabricators developed equipment that could attach to power tillers, multifunctional operations became possible for the owners of power tillers. These two conditions have made investment in power tillers profitable for small farmers. The active engagement of the private sector has created continuous interactions between supply and demand in the progress of mechanization.

The key lesson learned from this model is that once mechanization has become a business model that provides profit to each player along the supply chain, it will be able to develop rapidly and sustainably. While profitability is a general rule for any supply model, the Bangladesh model emphasizes the versatile use of power tillers beyond the initial demand for mechanized power-intensive agricultural operations. The second important lesson from this Bangladesh model is that small farmers can individually own agricultural equipment if this equipment is well tailored to small farmers' economic conditions. Demand for power-intensive mechanized services may be similar across countries, while models to supply such services can vary widely under different economic and policy conditions. Indeed, as in African countries in the 1970s and early 1980s, the Bangladeshi government tried to introduce larger tractors for tillage operations in the 1970s, but the program failed due to the equipment being unsuitable for small and fragmented landholdings (Roy and Singh 2008). Thus, the third lesson from the Bangladesh model is that government-led mechanization is unlikely to succeed. The critical role of government in the Bangladesh model was to liberalize imports of agricultural machinery.

Medium- to Large-Scale Farmers Owning and Operating Tractors: The India Model

As in Bangladesh, draft animals have been a major source of farm power for many decades in India. Adoption of mechanization began in the 1960s after high-yield seed varieties were introduced, irrigation was secured, and fertilizer use increased. The share of total farm power supplied by tractors and power tillers increased from 7.8 percent in 1970-71 to a projected 42.5 percent in 2000-01 (Singh 2000). The manufacture and sale of power tillers was attempted in the 1960s, under collaboration with Japan, but these enterprises failed because the machines were inappropriate for the soil conditions in India. Tractors were being introduced around the same time and were more suited to upland farming. In dryland areas, walk-behind power tillers created a dusty environment for the operator and were tiresome, as well as being difficult to manage on hilly areas (Singh 2000). At this early stage, the model for mechanization provision was established in India. Medium-size tractors (20–40 hp) were imported from the 1970s onward, replacing animal traction rather than agricultural labor. With the increase in domestic production and export, 65 percent of Indian tractor sales in 2000-01 were in the range 25-35Hp (Singh 2000). Adoption was initially highest among medium- to large-scale farmers with more than 4 hectares of farmland. A study by Singh (2000) showed that in 1982 62 percent of farms using tractors were larger than 4 hectares (ha). Although the population of draft animals fell from 80.4 million in 1960 to 56.4 million in 2004 (Kulakarni 2009), animal traction remains important for small and marginal farmers who may use tractor hire services but are not tractor owners. Animal draft remains the main source of power in hilly areas and for short-distance transport (Singh 2000).

The government of India is well known for its long-term support for agricultural productivity growth. Subsidies are a key component of this support, for both production and input use. On the output side, minimum price guarantees for rice and wheat, and other marketing regulations, contributed to India's Green Revolution during the 1960s and 1970s. This income support created incentives for farmers to invest in upgrading their agricultural technology, bringing considerable agricultural growth up to the 1980s (Von Braun, Gulati, and Fan 2005). Between 1970 and 1995, cereal production increased by 88 percent in India (Hazell 2009).

Price subsidies for machinery and agricultural tools such as animal-drawn implements, power tillers, and tractors have made their purchase less costly for farmers. For example, a 30 percent subsidy was offered directly to medium-size farmers (with 2.4–3.2 ha of land) for their tractor purchases (up to a certain ceiling amount). Most other implements were subsidized by 50 percent, and power tillers by 25 percent (Singh 2000). These subsidies were sustained over several years and were aligned with complementary public investments in research and development of agricultural machinery and other agricultural inputs. By providing subsidies for implements across human, animal, and mechanical power sources, the government allowed adoption to be demand driven rather than supply driven. Since 1981, the adoption of tractors has been increasing among small farmers. In 1991, 65 percent of farms using tractors were smaller than 4 ha (Singh 2000). Some argue that government input and output subsidy policies ensured that farmers would be profitable and thus stimulated their adoption of new technologies (Johnson, Hazell, and Gulati 2003). Subsidies continued into the 1980s, at which time open trade policies exposed distortions in domestic markets and subsidies ceased to be effective (Von Braun, Gulati, and Fan 2005). Importantly, they were combined with significant public investment in rural infrastructure and research and extension for agricultural machinery and other agricultural inputs (Hazell 2009).

In recent years, the government has begun to encourage the adoption of smaller tractors by smaller farmers by enabling them to own their own machines. For example, a 2008 subsidy policy document (India, Ministry of Agriculture 2008) lists only tractors under 40 hp, together with power tillers, self-propelled paddy reapers, and transplanters, as well as many other attachments, as qualified products for receiving subsidies. The document also describes how farmers can apply for and receive the subsidies. From this document, it is obvious that the private sector directly handles the tractor market, which is similar to any private business operation in the machinery and personal automobile markets.

As a part of the agricultural support policy in India, and similar to subsidies for other inputs, mechanization subsidies are financed by the government directly. The subsidies for agricultural machinery also seem to be provided in tandem with private investment. According to Singh (2000), US\$2.9 billion worth of long-term credit to agriculture (mostly for agricultural machinery) was provided by the financial sector in 1998–99. Rosenzweig and Foster (2011) show the strong link between bank proximity and farm investment in machinery in India, to explain the increase in mechanization use up to 2008. In addition, both national and state governments provide cheap credit to disadvantaged farmers who are less able to invest in technology, and also for some specific crops. With government subsidies, financing for purchases of machinery by farmers has come directly from the private sector. In early 1970s, government supported the creation of Agricultural Mechanization Service Centers in India which provided custom hiring services to farmers, supplied agricultural machinery on hire purchase basis, and also serviced machinery. However, these centers faced challenges including recovery of loans from farmers (Sharma, Singh and Panesar 2006). Private farmers and entrepreneurs have since taken up the supply of custom hire services for small-medium sized farms.

Demand for agricultural machinery has stimulated private investment in the manufacturing sector, and India has become the world's largest agricultural machinery exporter. In the late 1990s, 250,000 tractors were being manufactured in India every year by 13 manufacturers (Singh 2000). Moreover, agricultural machinery manufacturing ranges from small artisans producing basic implements and hand tools to large foreign direct investment enterprises exporting tractors to Africa and Asia. The role of the private sector in each aspect of the market—financing, manufacturing, and imports—has ensured that the appropriate machinery is available to farmers at affordable prices and with appropriate financing.

The India model of mechanization supply can be characterized as follows. Medium-size tractors rather than power tillers dominate the supply market for land preparation, reflecting the condition of the land and the preferences of medium- to large-scale farmers as owners. Also, larger farmers (with more than 4 ha) were the first to adopt machinery to service their own land, as well as hiring to other small farmers (Sharma, Singh and Panesar 2006). However, in recent years, the government subsidy policy has begun encouraging the adoption of smaller tractors to boost the incomes of small-scale farmers (tractors less than 40hp were identified in a 2008 document as qualifying for subsidies). Although tractor service provision is important for smaller farmers to adopt mechanization, animal traction use continues to

complement mechanical power for small and marginal farmers. The subsidy policy applies to many types of agricultural machinery to encourage local demand-driven adoption of mechanization technologies. The government also supports the manufacturing sector in the research and development of improved agricultural machinery for the local context. Agricultural machinery supply chains are operated entirely by the private sector. There is a fully developed tractor market including trade and financing. Doing business in this market is similar to doing business in other machinery and automobile markets. The private sector also takes the lead in developing various types of machinery to meet and induce local demand and for export. The domestic machinery industry arose from collaboration with foreign investors and strong local demand. Similarly, manufacturers from countries such as India could invest in Ghana's and other African countries' markets to combine their networks and capacity with local knowledge in order to develop tractors that are tailored to the local natural and economic conditions. For this to happen, there must be an active private sector in the importing countries.

Specialized Enterprises: The China Model

Mechanization in China has been deepening beyond power-intensive operations in recent years. Beginning in the 1970s, uptake of power tillers in China grew rapidly—considerably faster than adoption of four-wheeled tractors. In 1970, power tillers were rarely seen in the country. By 1981, the number of power tillers had increased more than tenfold, while the number of four-wheeled tractors, which is much smaller than the number of power tillers, seems not to have increased (Binswanger 1984). Chinese farm size is extremely small, and the land-labor ratio is lower than in almost all African countries, making power tillers the appropriate tool for tillage operations in the first phase of mechanization after reform (Li 2005). However, in recent years, rapid industrialization, led by export-oriented manufacturing growth, has significantly raised the wage rate, causing China to pass the Lewis turning point (Zhang, Yang, and Wang 2011). Although unskilled labor is still abundant, this labor is mainly absorbed by the manufacturing and urban service sectors, pushing up demand for mechanized control-intensive agricultural operations.

The use of individually owned power tillers for power-intensive operations such as plowing remains dominant and has similarities to the supply model found in Bangladesh. However, when mechanization diversifies to include control-intensive operations, individual ownership of agricultural machinery in such operations becomes impossible. Although combine harvesters for rice and wheat manufactured by Chinese firms are often much smaller than those seen in developed countries and Brazil, such equipment is a specialized tool, which limits multifunctional possibilities in either agricultural or nonagricultural activities. Without multifunctional possibilities, individual farmers are unlikely to purchase such machines for their own use on their small piece of land or for serving neighboring farmers in the same location, given that a combine harvester as control-intensive equipment, no matter how small, is much more costly than a power tiller. Consequently, the demand for control-intensive mechanization has quickly led to the development of a highly specialized business model in just a few years. The geographic scale of agriculture in China has enabled the development of this model. In this business model, individual entrepreneurs cluster together and travel long distances in a group to follow the harvest season province by province. With China's large territory, harvest season for the same crop varies significantly across the country, making it possible for the service providers to travel up to eight months per year (Yang, Huang, and Zhang 2012).

The China model described here is not unique. For example, specialized suppliers providing wheat and rapeseed harvest services as a business were developed in India in the 1990s. As in China, the private providers formed a team and traveled across the country to provide harvest services. Both China and India are large countries, and it is obvious that for this model to be sustained, the first necessary condition is that there must be a large agricultural area with diverse seasons. However, for long-distance service provision to become a reality, many social and institutional innovations are needed in order to help individual providers overcome the coordination difficulties inherent in such collective action. As documented by Yang, Huang, and Zhang (2012), local government has a role in this process to help the private provider clusters deal with many unexpected geographic, institutional, and technical barriers.

The key message of this China model emphasizes the scale needed in order to allow such relatively expensive and specialized agricultural machinery to be fully and efficiently used and become a profitable investment for the private sector. This model also emphasizes the role of local government in helping the private sector overcome barriers that are unlikely to be overcome by individual providers. For example, the government of China publishes dates for harvesting season across regions of the country. Making such information a public good enables the private sector to respond efficiently to changing demand.

Key Lessons Learned from the Three Models

We use these three models to demonstrate that there are various pathways for developing a supply chain for mechanization. The way in which mechanization is adopted varies due to agroecological conditions, existing agricultural practices, and economic conditions, while government policies have a role in the process as well. Some elements of the three models are common, which can provide insight to guide our analysis of mechanization policy in Ghana. Drawing from the stylized facts of the three models, we summarize the key players and their roles in mechanization service provision and machinery supply in Table 2.1.

Table 2.1—Comparison of the three supply models of mechanization

			Bangladesh model	India model	China model
Service provision	Ownership	Small farmers		<i>Early stages:</i> medium to larger farmers <i>Currently:</i> increasing ownership by small farmers	Private enterprises (individual persons)
	Type of machinery	Power tiller		<i>Early stages:</i> medium-size tractors (20–40 hp) used; <i>Currently:</i> introduction of smaller tractors (<40 hp) and power tillers	Small combine harvesters
	Type of operation	Multifunctional operations: self and paid services including land preparation, postharvest, and transportation		Self-service of multiple agricultural operations combined with paid services	Specialized service provision in harvest
Machinery supply	Market players	Private sector import machines and lead domestic trade		<i>Early stages:</i> private sector imported machines and led domestic trade <i>Currently:</i> most machines are domestically manufactured	Private sector manufacture domestically and lead domestic trade
Supply of attachments	Market players	Private sector imported attachments initially; some basic domestic manufacturing developed later		Private sector manufactured domestically	Private sector manufactured domestically
The key role of the government	Policy instruments	Trade liberalization and deregulation		Broad-based subsidies across human, animal, and mechanical power sources	Facilitative role in overcoming coordination failures common to collective action

Source: Authors' creation based on model summaries.

In addition to the information summarized in Table 2.1, the following observations seem relevant to the search for a sustainable supply model for Ghana.

1. Small farm size and high land fragmentation is not necessarily a barrier to private investment in mechanization.
2. Ownership of machinery by farmers is an important starting point for the successful and sustainable adoption of mechanization. When tractors are tailored to the farmer's economic conditions and when multifunctional operations are feasible, investment in tractors by small and medium-scale farmers can be made profitable by combining the provision of hiring services and servicing their own land. Tractor rental markets are widespread across Bangladesh, China and India (Reardon et al. 2012).
3. Adoption has been sustainable when the private sector actively engages in the machinery supply market, including importation. Although a liberalized trade policy is a must for private-sector engagement, a subsidy policy is sometimes necessary to stimulate demand. However, the subsidy policy should be broad and avoid narrowly targeting government-selected machinery items. Only through the market interaction of machinery supply and demand will suitable and affordable machinery be brought into the country.
4. When the supply chain is led by the private sector, local adaptation becomes possible even for a country without the capacity to manufacture tractors. Local fabricators will play a critical role in developing simple implements and attachments tailored to the needs of farmers. This is important in enabling multifunctional operations, which can both increase returns to the owners of machinery and boost demand for these services by farmers.
5. Specialized suppliers of mechanization services become profitable and hence sustainable only for more control-intensive operations using specialized equipment and in countries with large agricultural areas and diverse seasons. Even in such countries, collective action under this model is still a challenge, which means that either the local government's help or other coordination arrangements are necessary.

3. AMSECS IN GHANA: WHAT HAS GONE WRONG?

As discussed in the previous section under the three supply models of mechanization, the supply chain can be understood in terms of three key components. The first component is mechanization service provision. At this stage, service providers (which can be farmers) interact with farmers. The second component is the supply of machinery. When machinery is not produced domestically, importation, in addition to the domestic supply chain, is included. This component determines the relationship between sellers and buyers of machinery. The last component is repair services, which include supply of spare parts. Here machinery owners interact with repair service providers. Implements or attachments manufactured by local fabricators can be also part of the third component, as their demand often comes from existing tractor owners. This section analyzes the mechanization supply chain in Ghana according to these three components.

Mechanization Services in Ghana: A Competitive Market

Most farmers in Ghana access tractor services for land preparation through the tractor service market, where tractor owners provide hiring services to small-scale farmers. Service provision takes place through a fully competitive market, as the government withdrew from this market in the early 1990s after the structural adjustment reform. Supply of hiring services is guided by the market, and service prices are determined in the markets by supply of and demand for services. According to information drawn from a survey conducted by Benin et al. (2012), as well as from the authors' own observations, farmers reported similar service prices, with the only significant difference in price existing between south and north, as the south is more developed than the north and hence the wage rate is higher in the south than in the north.

Due to both historical reasons and recent policy, large tractors dominate Ghana's agricultural mechanization. Available data show that since 2003 the majority of tractors imported for agricultural use are in the range of 50–80 hp (Ghana, CEPS 2012). This is very different from the India model discussed above. In the India model, commonly seen tractors are medium size, with power of 20–40 hp. While power tillers are used in Ghana, they are seen only in some irrigated areas for paddy rice. Ninety percent of landholdings in Ghana are less than 2 ha per farmer, and land fragmentation is widespread (Ghana, MOFA 2011). There are similarities in farm size to Bangladesh, China, and Vietnam, although the machinery used for land preparation is much larger in Ghana than in these countries—even larger than in India. This pattern of mechanization is mainly the result of government policy and direct intervention, which will be discussed later in this section. We first focus on AMSECs.

AMSECs: Private Entities but Selected by the Government

The Agricultural Mechanization Service Enterprise Center (AMSEC) concept was initiated in 2003, based on the premise that government has a mandate to promote timely and affordable services to farmers who cannot afford to purchase agricultural machinery on their own. The centers are designed as private entities specializing in mechanization service provision. The initial proposal designed by the government for the AMSEC package included a broad range of agricultural machinery, such as tractors, harvesters, boom sprayers, planters, power tillers, seed drillers, slashers, ridgers, rice mills, and so on (see Ghana, MOFA 2003). The plan was ambitious and unrealistic, and in its implementation, tractors have become the focus. The first group of AMSECs was established in 2007/08. Twelve pilot AMSECs were selected by the government, with the Agricultural Engineering Services Division (AESD) of the Ministry of Food and Agriculture (MOFA) as the implementing agency. Each center received a package of seven tractors with basic implements (plow, harrow) and a trailer. The centers paid only 20 percent of the subsidized prices for the equipment allocated to them. A further 77 AMSECs were established in 2009 and 2010, with each center receiving a package of five tractors with plow, harrow, and trailer attachments. Again, all the centers paid only 20 percent of the subsidized prices for the package. According to our interviews with

AESD staff, the decision to provide five to seven tractors per package was not based on any economic or profitability consideration but was rather an engineering calculation: with an average size of 2 hectares for a small farmer, owning five to seven tractors allows an AMSEC to provide plowing services to 500–700 farmers in a season.

The subsidy on the AMSEC package of machinery is high, equivalent to more than one-third of the price actually paid by the government when the machinery was imported. Such high subsidies, together with a down payment of only 20 percent, present a potentially lucrative opportunity for enterprises or individuals who can quickly register as private entities. Unsurprisingly, application demand far outpaces the supply of tractors available to the government, and it has become difficult to ensure transparency in the selection process. Little information is available to document how allocations are decided. The repayment schedule after the first 20 percent down payment has not been followed by most AMSECs surveyed, a result that has failed to meet the government's expectations (Benin et al. 2012). While AMSECs paid only one-fifth of the heavily subsidized prices for tractors and other implements distributed to them by the government, these subsidies seem not to be passed on to farmers through a lowering of the service charge, as farmers paid the same for services provided by both subsidized AMSECs and non-AMSEC providers (Benin et al. 2012).

Profitability: Specialized Service Providers but Lack of Economies of Scale

Although the AMSECs are currently only a small proportion of the tractor service provision market, the program represents an important shift in government policy to change the supply model for mechanization services in Ghana. The AMSEC scheme was designed by the government with the expectation that mechanized service provision could become a specialized business for the private sector. Instead of farmers owning individual machines for their own use, supplemented by hiring services, an AMSEC is designed as a nonfarm private enterprise that operates a hiring service. From this point of view, the AMSEC model is attempting to emulate the China model, in which service providers operate as a specialized business, in contrast to the Bangladesh and India models, which emphasize farmers' ownership and provision of mechanized services. Unlike in China, where the specialized service is for harvesting—a control-intensive operation requiring specialized equipment—for AMSECs the main service provided is land preparation, a typical power-intensive operation using tractors that can perform multiple tasks.

A paper by Houssou et al. (2012) specifically focuses on assessing the poor performance of most AMSECs and the reasons for this outcome. Based on subsidized tractor prices and actual operational costs in Ghana, together with an assumption of a 10 percent capital depreciation rate, the paper calculates the minimum required plowed acres in order for the net profit from plowing service to be comparable to the interest earnings from a similar savings deposit in a bank account—a necessary condition for tractors to be a private investment. Recent survey data are then used to plot individual providers' profits and actual acres plowed against the profitability curve for this investment business model. The result shows that even after the government subsidizes more than one-third of the tractor price, capacity utilization of most tractors in Ghana is far below the threshold level for tractors to be a profitable investment. Drawing from field interviews, we discuss the reasons for this low capacity utilization.

Agricultural operations in land preparation, harvesting, threshing, drying, and transport are time bound for farmers, and a large amount of labor is hired for these operations. By introducing AMSECs and making various attachments available to farmers, the government expected that small farmers would increase their demand for mechanized operations beyond plowing. However, the recent survey by Benin et al. (2012) shows that in 2010, only 38 firms among 136 surveyed (including both AMSECs and non-AMSECs) provided other types of services such as threshing, boom spraying, or harvesting, and 80–90 percent of service revenue for these providers was from plowing. AMSECs often blame farmers for lack of demand for other mechanized services such as harrowing, but few providers actually own harvesters, threshers, dryers, and other machinery that can better meet demand for such timely operations, as these machines are not included in the subsidized package received from the government. Although combine

harvesters are much more expensive equipment, threshers, dryers, and other small equipment are often low cost, and some are produced locally. However, when an AMSEC can receive heavily subsidized tractors from the government, there is little incentive for it to invest its own money in other equipment. The Bangladesh and India models, discussed above, demonstrate that the profitability of machinery investments is augmented by the adaptation of power tillers and tractors with implements for other agricultural operations or use for nonagricultural purposes. Without multiple uses for tractors, the cumulative net income of tractor services is physically constrained by the cultivated area in a location.

South Ghana has two cropping seasons and the north has one, with the potential for 60 days of plowing in the south and 45 days in the north. If tractors can move between south and north, maximum operation could reach 90 days, in theory. Although this is still less than the operation time of harvesters in the case of the China model, a similar approach could make tractor investment profitable within a range of reasonable prices for tractors. However, experience from the China model shows that the risk for individual entrepreneurs is high, and without coordination between entrepreneurs on several aspects, most entrepreneurs are unlikely to operate such a specialized business across regions. Indeed, the survey results and field interviews both confirm that this practice is not being adopted by most entrepreneurs in Ghana today. Reasons for this include

1. the additional fixed costs of transporting equipment from one region to the other, and operator expenses for food and board;
2. the much higher direct and opportunity costs per acre for supervision of operators when moving to other regions; and
3. the lack of local market knowledge, which increases the transaction costs of finding customers and local repair services, for example.

Although the scale of tractor services provided is the dominant factor determining the returns to tractor investment, operational costs—including wage payment to hired operators and maintenance spending—are also important factors affecting profitability. Frequent tractor breakdowns are reported in Ghana, which further shortens operating time as well as increasing maintenance costs. This situation indicates that imposing five tractors on an AMSEC that is new to tractor operation is obviously problematic, given that newly established AMSECs are unlikely to have enough experience in service provision and managing a team of hired operators who drive the tractors (each tractor needs an operator and an assistant, who are hired labor for AMSECs). In the case of China, the harvesters are operated by their individual owners, who each only need to hire an assistant. In Ghana, although by law a special license is required for tractor operation, in practice this requirement has not been enforced. Lack of adequate training is reported as a main factor in low operating skill, which not only negatively affects tractor productivity but also increases the risk of damage to the tractor. Operators are paid by the number of acres plowed, bearing none of the variable costs that they control (for example, maintenance, fuel). There is little loss to the operator if the machine is damaged, which creates perverse incentives and leads to damage from overuse.

The form of contract between the owner and operator will have an impact on the quality of operation. A similar problem was investigated by Schneider (2010), who tests whether moral hazard can explain different driving outcomes under different types of leasing contracts in the New York City taxi industry. In 2005, long-term lessees of New York City taxis experienced 62 percent more accidents and 64 percent more driving violations per mile than did owner-drivers. The survey of AMSECs and non-AMSECs in 2010 (Benin et al. 2012) reported three breakdowns per tractor in a season. From our own interviews, we strongly suspect that this rate of breakdown is greatly underestimated. Tractor owners suggested that minor breakdowns can occur almost daily and more major repairs can take the tractor out of service for a month or longer while spare parts are sourced. Labor-management issues are a significant challenge to AMSECs' profitability. When a businessman or farmer owns only one or two tractors, oversight by the owner over the operator's actions is less costly and trust is more quickly built between owner and operators. Field observation indicates that in the case of ownership of individual machines, hired operators are often relatives of the owners. In contrast, most AMSEC owners are new to the tractor

service business and are immediately managing 10 hired operators and assistants in order to operate five tractors. The management capacity of the entrepreneur is not developed as the business grows from one or two tractors to five or more. Moral hazard in the contract between operators and owners is unavoidable in this case, which partially explains the poor operation of machinery and high frequency of breakdowns. The ownership model that is promoted through the AMSEC scheme appears to exacerbate this problem.

Machinery Supply: Direct Importation by the Government

The total stock of tractors in Ghana was estimated at 2,200 in 2002, and since then the government has been the main importer of new agricultural machinery. Through AESD the government has imported about 3,000 tractors and only 300 power tillers in the past 10 years (Ghana, AESD 2012). Tractors imported by the government have been allocated to both AMSECs and non-AMSEC applicants. Approximately 500 of the tractors imported in this period were provided to AMSECs, and allocation to non-AMSEC applicants, who are mostly individual farmers, fell considerably after 2008 when the AMSEC program began.

AMSECs are designed as private enterprises to provide mechanized services, while the supply of agricultural machinery to AMSECs is fully controlled by the government. All subsidized tractors are imported directly by the government. Although private companies have been appointed as agents, the key decisions regarding importation are made by the government. In all cases, agricultural machinery imported by the government is financed by either a grant received from a developed country (the Japanese government, for example) or a concessional loan from the government of an emerging economy (China, India, or Brazil, for example). Unlike the fertilizer subsidy policy and other agricultural support programs that are part of the government budget and expenditures, financing the support for mechanization seems to be rather ad hoc, depending on various sources from foreign countries. Without support for the program from the government's own budget, the foreign source of financing actually determines where tractors are to be imported from as well as which brands. This is particularly true for concessional loans, in which tractors must be imported from the lender countries. Therefore, different brands of tractors have been brought in from different lender countries by the government under different loan agreements.

The example of the importation of Farmtrac tractors illustrates the process of government-financed imports. The government of Ghana entered into negotiations with the Export-Import Bank of India, which offered a line of credit under concessional loan terms for the purchase of agricultural machinery. This resulted in the importation of about 500 tractors in 2007 and 2008. The choice of manufacturer was determined without an open tender process and appears to have been agreed between the government of India and the manufacturer. In this instance, it was Farmtrac that was chosen to provide tractors to the government of Ghana. Farmtrac tractors were manufactured in India, and a Ghanaian company was selected as an agent to handle the imports. Though this company had been present in Ghana for more than 10 years importing other nonagricultural machinery, it was this government deal that created a lucrative opportunity for the company to become a dealer for the government in handling agricultural machinery imports. For the company, it was a riskless business initially. Payment for the imports was made directly by the Export-Import Bank of India (as part of a concessional loan to the government of Ghana) to the manufacturer in India. This local Ghanaian company was responsible only for delivering the machinery to MOFA (arriving at the AESD office site) in Ghana. As part of the agreement requirement by the government of Ghana, the local company also had the responsibility to provide training and spare parts supply. With an expectation of future business opportunities from the government, the company invested heavily in its supply chain by constructing a large warehouse and building up stocks of spare parts ready to supply a much larger tractor market in the future. Unfortunately, for reasons unknown, the Ghanaian government switched to a different manufacturer under a new concessional loan arrangement with the Indian government. When John Deere, instead of Farmtrac, was selected in the following years, the company that had previously handled Farmtrac importation failed to secure this business opportunity, and a new local company was selected as the government's agent to handle the importation of John Deere machines. The local company that used

to handle importation of Farmtrac tractors was adversely affected not only because it did not secure the new business opportunity from the government but also because it had invested heavily in spare parts under an expectation that more Farmtrac machines would be imported by the government in the future.

Similar arrangements have been repeated for other imports, including Mahindra tractors from India and other brands from China and Brazil. Under each arrangement, a different local company was selected as the agent for the government. Obviously, local companies compete with each other to become the next agents for the government when new brands of tractors are brought in. Without the continuity of government contracts, these companies struggle to survive in this business environment. In fact, almost all these companies rely on business in other sectors, and field interviews demonstrate that for these local agents, it is unlikely that tractor importation could become a steady and profitable business while the government is the largest importer and frequently changes from one brand of tractors to another.

The example of Farmtrac is not unique, and it demonstrates that when importation is a decision made by the government under concessional loan arrangements with different countries' governments, it is almost impossible for the supply chain of machinery and spare parts to be developed by the local private sector. Although investing in basic machine assembly and stocks of spare parts is often a requirement of the government contract, such investments can be justified only when the private companies' expectation of growing future imports by the government for these tractors can be met. In reality, the local agents have often been left with excess capacity, as demand for the spare parts they imported has been volatile and failed to meet expectations. Demand for spare parts and maintenance services are dependent on the stock of a particular tractor brand. If a certain stock level is not present in the country, demand for auxiliary services associated with that brand will not be adequate to support private investment. Frequent shifts in the brand of tractor the government imports are making private investment either inefficient or high risk. This is in contrast to the importation of Ford and Massey Fergusson tractors by the private sector, discussed below.

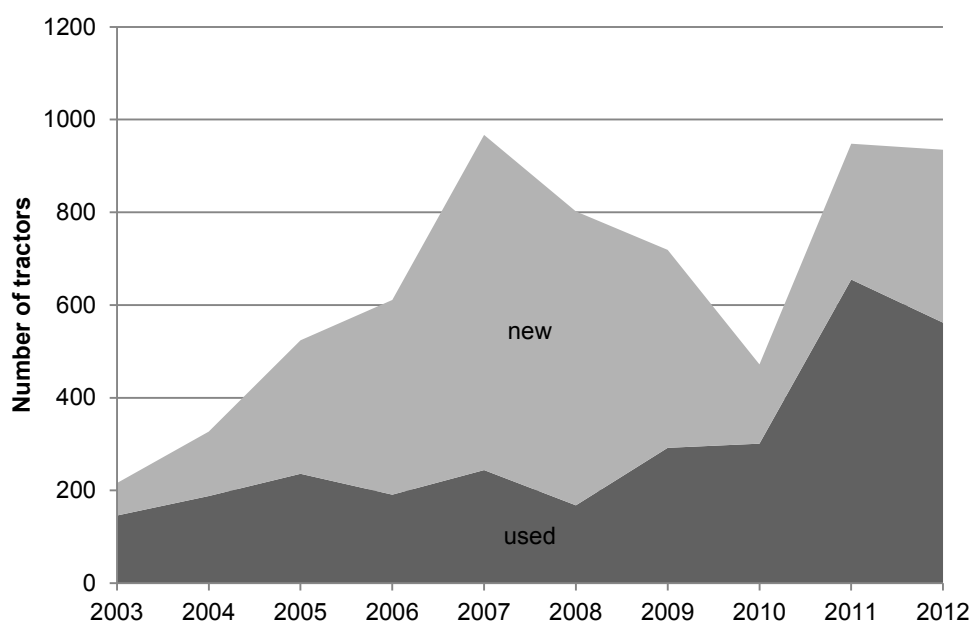
Direct importation by the government has created competition among local agents and foreign manufacturers for government contracts rather than for end users. The lessons from Asia demonstrate that appropriate and affordable machinery will be supplied when there is a competitive, private-sector-led market for machinery imports. Currently, local machinery suppliers in Ghana are not concerned with which machinery will meet the demand of farmers and tractor users, but instead are concerned with lobbying for government contracts. Recipients of new tractors from the government do not have a choice of machinery; therefore, local agents have no incentive to build up a good reputation to win customers. In addition, we saw in Bangladesh and Thailand that soon after private imports took off, domestic manufacturers began adapting imported machinery to suit the local market (Islam 2010; Rijk 1989). This is unlikely to take place under government imports in Ghana. Local agents for manufacturers who act only as agents for Ghana's government have little incentive to provide feedback to manufacturers in foreign countries, as their own profitability depends on having government contracts instead of local consumers (users) of the machinery they import.

The disconnect between local users of tractors and foreign manufacturers as suppliers blocks any possibility of developing demand for different tractor models that may better fit the current economic conditions of both farmers' needs and service providers' capacity. Indeed, most imported tractors are large (over 50 hp), and without subsidy the market prices have attracted little private investment interest, even from larger farmers. This partially explains why investment in tractors at the unsubsidized price is not profitable at current operational levels (Houssou et al. 2012). The government's belief that tractors are not affordable for farmers and that subsidies are necessary holds true when large tractors are considered for the Ghanaian context. Indeed, similar attempts to introduce large tractors in Bangladesh and Thailand failed, and it was only when smaller and cheaper machines were introduced that mechanization adoption became profitable.

The Secondhand Tractor Market: A Private-Sector Model

In the world tractor market, there are many different types and brands of tractors sold at many different price points. This is particularly true when secondhand tractors are included. In Ghana, the used tractor market is operated entirely by the private sector. As Figure 3.1 shows, a significant share of total imports of agricultural machinery is through this channel rather than the government. Imports of used agricultural machinery have remained steady, while imports of new tractors have been sporadic, as they are affected by changing government interventions. According to data from Ghana's customs department, used tractor imports have increased considerably since 2010. Most private importers are small businesses that have built a stable import channel from exporting countries through long-term business networks. In fact, the used tractor market has existed in Ghana for more than two decades, and tractor imports are often a routine part of business for importers. Given that there is a seasonality pattern in tractor demand and hence trade, most enterprises have a diversified business portfolio in which tractor imports are just one component. Buyers of used tractors are individuals and mostly larger farmers. Massey Fergusson and Ford dominate used imports; the tractors usually range between 50 and 70 hp and can be up to 30 years old. These two brands of used tractors have been imported into the country for many years and are the tractors most preferred by farmers. Prices for used machines in 2012 were quoted between US\$5,000 and US\$10,000, comparable to the prices of subsidized government imports. As in the market for personal automobiles, the price is negotiable and transactions are completed using cash, with no credit offered by the importer. Moreover, buyers are unlikely to take out a loan for such a purpose.

Figure 3.1—Agricultural machinery imports



Source: Customs, Excise and Preventive Service, Government of Ghana.

Note: Data for 2012 are to July 2012.

The existence of a private-sector-run secondhand tractor market indicates that this market would have growth potential if policies were implemented to develop private-sector-led import channels. A tractor purchase is a costly investment both for the users (farmers) and for traders (private entrepreneurs). The India model shows that available financing support can help the private sector expand business by stimulating demand from tractors buyers. In Ghana, private tractor importers in the secondhand market are currently unable to compete effectively with government imports because the government offers

interest-free financing and subsidies for the tractors it imports. Field interviews indicate that no financing for agricultural machinery is available through commercial banks, and private tractor importers are unable to expand their business because affordable financing is not available to buyers (farmers). Even when a farmer's decision to invest is economically rational, the financing that would enable the decision to be implemented is not available. This issue was overcome in India by the government providing support to commercial and cooperative banks to provide long-term credit for agricultural machinery. As discussed above, the availability of credit for agricultural machinery played an important role in the adoption of mechanization in India (Singh 2000).

Summary of Ghana's Mechanization Supply Chain

From our analysis of the supply chain for agricultural machinery in Ghana, we can see that government policy is having a significant impact on competitiveness and sustainability. The segregation of the supply of machinery between government distribution and the private market is reducing profitability for enterprises in machinery supply, service provision, and repair services. Corresponding to Table 2.1 in the previous section, Table 3.1 is developed for the case of Ghana. We consider two buyers of tractors in the market: AMSECs and private owners. There is little difference between the two groups in terms of which hiring services are offered, or the source of spare parts and attachments. Critical differences come in the source of financing, government support, and ownership type.

Table 3.1—Summary of Ghana's current supply model for agricultural mechanization

		AMSECs	Private tractor owners (non-AMSEC)
Service provision	Ownership	Nonfarm enterprises	Medium- to large-scale farmers
	Type of machinery	New tractors (50–80 hp)	Used tractors and some subsidized new tractors
	Hiring services	Hiring services: mainly plowing	Self-service and hiring services: plowing, tilling, harrowing, carting, some maize shelling
	Scale and type of operation	5–7 tractors	1–2 tractors
Machinery supply	Key supplier	Government imports of new machinery	Private-sector imports of used machinery, or individual new tractors from government
Supply of attachments	Market players	Private sector; most imported; some adaptation of other imported spare parts	Private sector; some imported; some basic implements manufactured domestically
The key role of the government	Policy instruments	Direct importation of new machinery; decisionmaking on who receives the subsidized new machinery and direct distribution; heavy price subsidy and no interest charge on late payment	Duty-free imports of new and used machinery and parts by the private sector; some farmers obtain individual machines from MOFA at the subsidized price
Source of financing	Government and end users	Grants from developed countries (rare) and concessional loans from emerging economies	No credit or loans available for either private importers or used machinery buyers

Source: Authors' creation based on fieldwork interviews and review of policy documents.

4. CONCLUSIONS: WHAT CAN GHANA LEARN FROM THE BANGLADESH, INDIA, AND CHINA MODELS?

Two supply models exist concurrently in Ghana. The first, which has dominated in recent decades, is the individual ownership of tractors by larger farmers, with the tractors either purchased secondhand or through MOFA allocation. These tractors are used to service the owners' farms and also those of small neighboring farms for a fee. This model closely resembles that of India, where tractors are purchased by large-scale farmers who provide services to other farmers in the early stages of mechanization. In Ghana, machinery supply is through both government importation of new tractors and a small but stable private-sector-led importation of used tractors. Under the newly developed AMSEC program, the government has started to promote an alternative model of machinery ownership and service delivery that attempts to establish a specialized service provision business, as is found in China. As government policy moves forward to support this second model by increasing the number of AMSECs, we assess this model in light of the lessons learned from the three stylized models discussed in Section 2, in order to identify a more sustainable mechanization supply model for Ghana.

A Successful Mechanization Process Begins with Ownership of Machinery by Farmers

At the early stage of mechanization development, tractors are better owned by farmers rather than nonfarm enterprises. Farmers can better manage tractors as their production assets and use them more efficiently. The examples from Bangladesh, India, and China demonstrate that it is when farmers begin to own and operate their own machinery that the mechanization process takes off. The incentive for a farmer to own a tractor is driven by the farmer's own use in farming. To be able to make investing in a tractor profitable, either farming itself must be profitable, taking into consideration the tractor investment, or it must be profitable to combine hiring service with own farming to generate income from owning a tractor. Houssou et al. (2012) show that current AMSECs are not profitable, while field interviews confirm that individual farmers are making investments in tractors using their own resources and through private imports. This indicates that tractor investment is profitable as part of the farming business, otherwise farmers would not be making these investments outside government support. The involvement of nonfarm enterprises in the provision of mechanized services may be profitable at more advanced stages of mechanization using more specialized machines.

Multitask use of machinery can increase the incentive for farmers to invest in tractors when the farm size is small and when the labor cost for land preparation is high. Again, multifunctionality is specific to the local context, and only farmers who own tractors can push diversification of the market for mechanization services. Indeed, according to our field visits in Ghana, in some places a few tractor owners have started to combine plowing services with other services in which the tractors are used to power other equipment, for example, for pumping water or threshing maize. As demand for a wider range of mechanized operations increases, Ghanaian farmers will have a greater incentive to invest in agricultural machinery, while government policies, including subsidies designed to encourage such investment, are necessary.

Machinery Imports Should Be Open to and Led by the Private Sector

The affordability of tractors is an economic concept. When broad options for different types of tractors at different prices are available to farmers, local demand will guide the importation of appropriate and affordable machinery. In Bangladesh, it was when trade restrictions were lifted that private-sector imports of power tillers grew considerably. In India, mechanization became successful when government allowed the private sector to fully operate the agricultural machinery markets, including imports and domestic trade. When importation is directly handled by the government, it is unlikely to bring in the right tractors at the right prices for farmers. Government attempts to promote certain machinery by direct importation have also failed in many other countries, including during the early stages of mechanization in

Bangladesh and India. The successful evolution of mechanization in these two countries, highlighted in Section 2, demonstrates that only when the private sector is allowed to operate the supply market will a sustainable supply model develop that is tailored to the country's special conditions.

Government Subsidies Should Encourage Private Investment

In the India and China models, government subsidies successfully encouraged private-sector investment. There is a crucial difference between these subsidies and the subsidy policy of the Ghana model, however. In the India model, subsidies were applied across an extensive menu of machinery, including animal-drawn implements, hand tools, power tillers, and tractors. In the China model, the subsidy targeted newly developed harvesters to encourage domestic private-sector investment in developing agricultural machinery adapted to China's conditions. In both models, the subsidies actually helped establish the link between machinery users and manufacturers to ensure that the most appropriate machines were made available in the local market. Under both models, removal of the subsidies after a sustained period did not interrupt the private investment that eventually developed a strong and sustainable private supply network.

When a government subsidy is financed through concessional loan arrangements, the lender country intends to promote tractor exports from its own country. Under such a situation, it is important for the importing country's government to realize the importance of directly connecting manufacturers from exporting countries to local demand through an open and competitive process. The machinery that is imported will thus be affordable and appropriate for the current economic conditions of farmers as tractor owners. Considering the burden subsidies place on government finances, it is not justifiable for the government to both fund direct importation and provide subsidies for machinery. Instead, subsidies should go directly to farmers as buyers of the machinery. The subsidized prices for a large range of machinery should be explicitly listed in a publicly available government document, as in the case of India's subsidy policy (see India, Ministry of Agriculture 2008). Importation and trade in subsidized machinery should be undertaken by the private sector, with only the price subsidy being administered by the government. Not only would such action make the subsidy policy more transparent, but market efficiency would be improved through private competition in tractor supply.

Financial Sector Involvement in Mechanization Should Be Promoted

A used tractor market, operated by the private sector without government subsidy, exists in Ghana. The development of this market is constrained by the limited financial capacity of private enterprises in importation and farmers as buyers. India's experience shows that through government support to financial institutions, domestic banks (particularly development banks) can provide longer-term lending to enable the private sector to invest in agricultural development, including in mechanization. Interest rate subsidies and any other policies that could lower the risk of banks in doing such business could be options. Without the active involvement of the financial sector, Ghana is unlikely to develop a strong supply chain led by the private sector.

In conclusion, there are several indications that the mechanization supply chain can become sustainable in Ghana. First, the private sector has been involved in the importation of used machinery for more than two decades. This is already a profitable business in Ghana, which, with the correct support from the government, could expand. Second, evidence suggests that urbanization and rising wages will continue to increase pressure to intensify farming and therefore increase demand for mechanization.

However, the government's promotion of the AMSEC model should be reconsidered. From the experience of other countries that have successfully mechanized, it is clear that a specialization model of mechanization service provision is only profitable at later stages of mechanization and with greater scale. Current AMSECs are unlikely to be profitable, as assessed by Houssou et al. (2012), and this is in large part because of a specialized supply model that has been imposed by the program. In contrast, it is profitable for some farmers to purchase their own used or MOFA-allocated tractors to offer hiring

services in addition to servicing their own farms. This is the model followed in Bangladesh and India, although the appropriate type of machinery has varied by country. This model of supply already exists in Ghana, and better policy could further promote its development.

Two other changes in policy should also be considered. First, tractor importation should be left to the private sector, which already has expertise in this business. Second, subsidies should try to avoid handpicking beneficiaries and should apply to a broader menu of machinery in order to transfer to tractor owners the decision of which machinery to import. In addition, the active involvement of the financial sector is crucial to the development of a sustainable mechanization supply chain, and proper policy is required to link the financial sector to mechanization.

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