

An Evolving Paradigm of Agricultural Mechanization Development

How Much Can Africa Learn from Asia?

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In recent decades, urbanization, increased food demand, rising rural wages, and seasonal labor bottlenecks have sparked a growing interest in agricultural mechanization among policymakers and development stakeholders in Africa south of the Sahara (SSA). Despite intensification of farming, a combination of market failures and detrimental government interventions have prevented the supply of mechanization options in SSA from meeting demand. In contrast, the significant growth of mechanization in Asia offers lessons that are becoming increasingly relevant to SSA. But exchange of such South-South knowledge has so far been limited by the lack of empirical information about the development of mechanization in both regions.

An Evolving Paradigm of Agricultural Mechanization Development: How Much Can Africa Learn from Asia? aims to fill this knowledge gap. Using a framework based on farming system evolution and induced innovation—the paradigm developed by Pingali, Bigot, and Binswanger (1987)—expanded to include supply-side market failures, the book assesses the Asian and African experiences with adoption of tractors and other farm machinery. The authors emphasize the divergent patterns of mechanization between the two regions, assess market and government failures, and identify challenges specific to SSA and their policy implications.

Thirteen case studies—covering eight Asian countries and five African countries—document the evolution of mechanization. The detailed overview of mechanization in these developing countries allows for easy comparisons across countries and regions. National policymakers and the development community can adapt this knowledge to local contexts and use it as a foundation for further research.

Mechanization in Africa and Asia

Demand for mechanization has grown unevenly across Africa. Where demand has developed, market failures have largely prevented supply from fully responding. By contrast, in a wide range of Asian countries, hiring markets for tractors and other agricultural machinery have developed rapidly to respond to

emergent demand (Figure 1). Obstacles facing development of Africa's tractor hiring markets, including government policies, help explain this divergence.

Asian Mechanization

In all eight Asian countries studied—Bangladesh, China, India, Myanmar, Nepal, Sri Lanka, Thailand, and Viet Nam—there was already a tradition of mechanization using draft animals. The key change in recent years has been a shift to machine power—replacing these animals with tractors and power tillers for plowing and adopting engine-powered machinery, such as combine harvesters or threshers, for harvesting or postharvest processing. This shift was a response to a broader economic transformation in Asia: mechanization accelerated with industrialization as labor-intensive manufacturing and the rural nonfarm economy put upward pressure on wage rates.

Physical and market conditions in Asia favored the development of machine-hiring markets that serve smaller farmers. In addition, government subsidies and public goods have contributed to the success of mechanization development in most Asian countries. Small and relatively low-cost tractors, power tillers, and harvesters, typically manufactured domestically or imported from China, India, Thailand, or other nearby Asian countries, are among the most commonly adopted agricultural machinery. Power tillers are widely used throughout Bangladesh, Myanmar, and Sri Lanka and in rice-producing areas elsewhere in Asia.

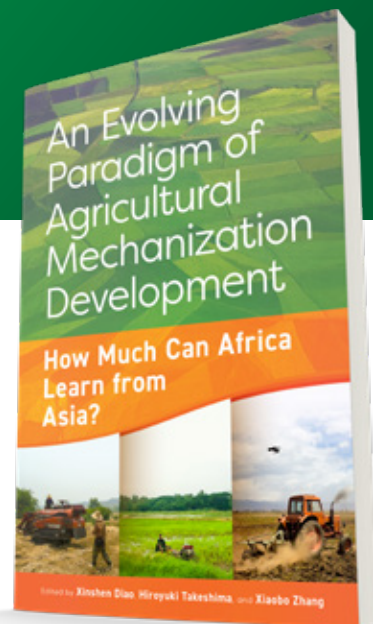
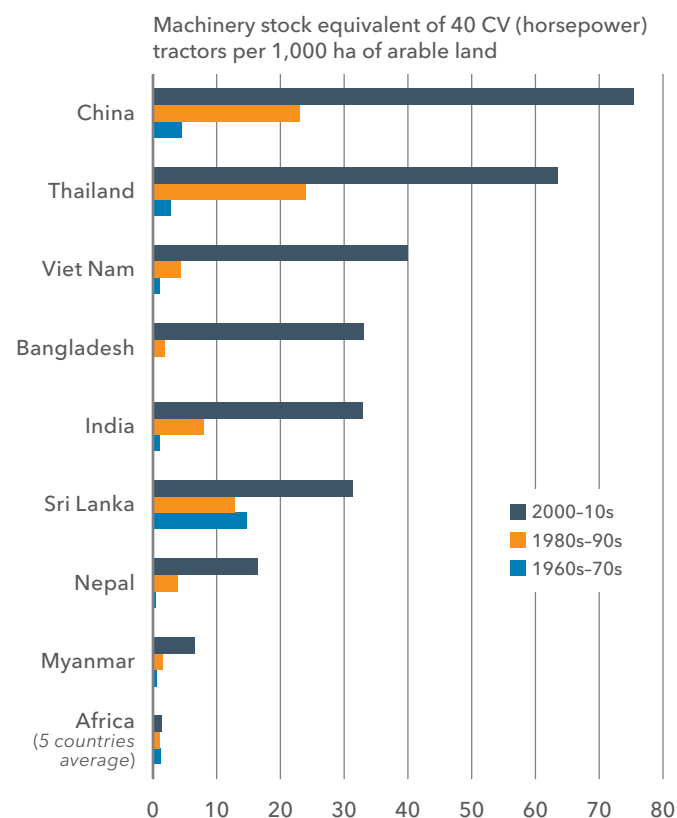


FIGURE 1 Agricultural machinery stock by countries / regions



Source: Authors' own calculation using data from USDA ERS (2018).

Note: The total stock of farm machinery in "40 CV tractor equivalents" aggregates the number of two-wheel tractors (2WTs), four-wheel tractors (4WTs), and combine harvesters. For weights, we assume 2WTs average 12 CV; 4WTs, 40 CV; and combine harvesters, 20 CV. Data for each category are from FAO, except for the data for 2WT, which were compiled from national sources.

With rising rural incomes, the cost of machines has been low enough that some small- and medium-scale farmers could afford to buy them and become service providers in the hiring market. Moreover, subsidized credit was widely available in a few countries, and farmers in some countries were able to use their land as collateral to acquire machines.

Climate and planting systems in Asia reduce the scale issues associated with providing mechanization services for small farms. In irrigated cereal systems, farmers plant their crops simultaneously, allowing for sharing of equipment. In larger Asian countries, climate patterns and infrastructure enable migratory service provision, increasing opportunities for agricultural machinery use.

African Mechanization

Theory on farming system evolution has provided plausible explanations as to why mechanization had been low in Africa in the beginning despite the continent's land abundance, and also why intermediate mechanization through animal traction has grown over the last few decades. Induced innovation theory has partly explained how the growing relative scarcity of labor has induced mechanization growth in Asia and pockets of Africa in recent years. However, the African mechanization pattern has increasingly taken on new characteristics, shaped by a continuously evolving paradigm.

As of 2005, tractors were used to prepare only 10–20 percent of African farmland. While tractor adoption has grown somewhat since then, that growth has been slow in some major countries,

including Nigeria, which has the largest area of arable land in Africa. The five African countries covered—Ethiopia, Ghana, Kenya, Nigeria, and Tanzania—are relatively mechanized compared to other low-income African countries. But even these five countries face constraints to mechanization, on both the demand and supply sides.

DEMAND-SIDE CONSTRAINTS. Much of Africa has not experienced an Asian-type Green Revolution. Adoption rates of improved seeds, fertilizers, pesticides, and other inputs remain relatively low and opportunities for irrigation development are limited and underexploited. Growth in crop yields has been extremely modest, and increased agricultural production primarily comes from land expansion.

Urbanization and economic growth in Africa have been accompanied by a shift of labor out of agriculture, involving both migration to cities and farming households diversifying into nonfarm activities. The rapid exit of youth from agriculture, together with food demand shifting to higher-value and more labor-intensive crops, may increase demand for agricultural labor and mechanization, but has not yet sparked broad rural transformation.

Mechanization demand varies across Africa. Despite limited experience with use of animal-powered mechanization, in some areas farming systems and labor scarcity have induced significant demand for tractors, combine harvesters, or both. Where demand for mechanization has emerged, however, market failures hamper the supply response, which justifies public sector interventions.

SUPPLY-SIDE CONSTRAINTS. Anecdotally, African farmers appear to generally prefer large tractors, which may be better suited to regional soil conditions than smaller machines. Large tractors are expensive, however, and the small number of farmers able to invest in such tractors limits the supply. Further, African private banks are reluctant to lend to farmers, because of the difficulty of using land as collateral and doubts about the profitability of agricultural production.

Heterogeneity of soil types and diverse cropping systems, with different planting and harvesting calendars, make it difficult for small farmers with fragmented plots to coordinate tractor hiring. For example, farmers within the same area may plant either a variety of root crops or use mixed crop systems that combine root crops, legumes, and maize. These differ from many Asian cropping systems, which tend to be dominated by grains and have more homogeneous calendars, allowing for shared tractor use.

Effective tractor hiring services depend on a functional road infrastructure and trucking industry. Such conditions, along with local government capacity to support them, are often lacking in African nations. Information and communication technologies show potential to help smaller farmers to coordinate future tractor hiring, however. Some companies in Ghana, Kenya, and Nigeria have developed platforms that make tractor hiring services more easily accessible through SMS and mobile apps.

African nations also lack large-scale manufacturing of agricultural machinery. Moreover, distance and a lack of overall demand impose significant transaction costs on African nations importing machinery.

Role of Government Policy

Even when mechanization demand emerges, supply may not spontaneously respond, and government intervention may be required. In many Asian countries, governments helped create

an enabling environment and provide public goods to support mechanization. By comparison, many African countries rely heavily on tractors provided by bilateral donors. However, the models often vary by year and donor country, disrupting the domestic private supply channels.

Rather than emphasizing direct interventions, such as subsidies, many Asian governments focused their efforts on research and development (R&D): developing machinery and implements or new seed varieties that make mechanization more efficient. Public and private sector training and extension in some countries also helped familiarize farmers with different types of machinery, helping to create demand.

Where restrictive government policies were reformed, mechanization rapidly accelerated as markets opened. For example, Myanmar's 2011 land reforms and liberalization of its banking system unleashed nascent demand for mechanization that led to a majority of farmers in surveyed regions adopting mechanization for land preparation and 40 percent doing so for harvesting.

IMPORT POLICIES. Because tractors and combine harvesters are not manufactured in Africa, options for importing machinery are critical. Few African countries charge import duties on agricultural machinery, but many do tax imported spare parts. Given the limited potential to manufacture spare parts in most African countries, such taxes only impede the spare parts market.

PROMOTION POLICIES. Where demand was insufficient to drive increased supply, a number of governments attempted to induce intensification by supporting entities to manufacture, distribute, and hire out tractors. At least 11 African countries have supported government-run or subsidized tractor hiring services this century. Such services face inherently higher barriers to profitability than private-sector services, both because of operating costs and because private tractor owners reduce costs by using the equipment on their own farms as well as offering a hiring service. Government efforts also risk crowding out potential private service providers, especially when government service charges are below market rates.

PUBLIC GOODS POLICIES. Agricultural R&D can be an important spur to mechanization. For example, improvements in rice varieties appear to have stimulated demand for tractor plowing in Nepal, Thailand, and Viet Nam. Improved varieties that respond better to more intensive tillage, are suitable for mechanical reaping, or permit more frequent cropping, as well as yield increases that promote further intensification, made mechanization feasible. But in most African countries, investment in broader agricultural R&D, including the development and commercialization of a new generation of improved seed varieties, has been slow, thus limiting opportunities for intensification and mechanization.

Investments in soil mapping in Africa could help in adapting machinery to local conditions and determining optimal tractor sizes. Soil mapping could also help countries move from a blanket promotion of fertilizer to integrated soil fertility strategies that would support intensification. Public investments in smallholder productivity are also important. If raising productivity increases the returns to more intensive land preparation and thus demand for custom hiring mechanization services, then public investments to raise smallholder productivity can complement private investments in machinery by medium-sized farmers in Africa.

INSTITUTIONAL DEVELOPMENT AND CAPACITY ENHANCEMENT POLICIES. In Asian countries, national governments and national agricultural research institutes often played key roles in monitoring

WHY HIRING SERVICES?

Custom hiring services have become the most common mode of mechanization among smallholders in developing countries. In developing countries dominated by smallholders, most farmers cannot afford a tractor or other large machinery. Even those with medium-sized farms cannot recoup the expense of a tractor. Thus, tractor and combine-harvester owners offer hiring out services to make their investments profitable.

Hiring services from private owner-operators are almost invariably the most efficient method of supplying mechanization services for smaller farms. The viability of mechanization service provision depends on the ability of owners to make a substantial lump-sum investment in a machine and achieve efficient use rates.

The use rate of a tractor—and hence opportunities for profitable tractor ownership in rainfed systems—greatly depends on the length of the planting window. A short planting window, common in semi-arid regions, makes it extremely difficult to reach a break-even point in investment and magnifies the cost of any tractor breakdown or other delay. Therefore, opportunities for hiring out tractors for other uses, such as water pumping, crop processing, or transport, can be vital.

Likewise, migratory service provision in plowing allows tractor owners to use their machines for more of the year by exploiting geographical variation in seasons. Migratory services rely on government investment in road infrastructure, as transporting tractors over long distances can be prohibitively costly where physical infrastructure is poor.

progress in agricultural mechanization. Asia also had more advanced educational institutions for agriculture, including state agricultural universities, as well as professional bodies of agricultural engineers, agricultural economists, and commercial farmers. The capacity of similar bodies is relatively weak in Africa and needs to be strengthened, including through greater regional efforts and enhanced analytical capacity to generate required evidence on mechanization issues.

The information generated by Asian national organizations has been extensively exchanged at the forums offered by international and regional organizations such as the Regional Network for Agricultural Machinery. CGIAR centers, including the International Rice Research Institute and the International Crops Research Institute for the Semi-Arid Tropics, also contributed to R&D on machine designs and performance and to knowledge transfers across countries. These institutional efforts in Asia have been complemented by significant private-sector R&D and innovations. Mechanical innovations by the private sector in Asia likely provided regional institutions with more knowledge and relevant information about technologies, information that can be transferred across countries. Strengthening similar institutions to support African mechanization will similarly require private sector innovations, including those that originate from traditional small businesses.

Africa's Path Forward: *Lessons from Asia and the Past*

Expansion of mechanization in Africa is likely to continue to be constrained in the near future, in part by supply-side market failures. Significantly greater efforts are needed to overcome these market failures while judiciously avoiding the distortionary effects of past interventions. Africa's mechanization needs are not uniform, and no solution can apply in all countries.

Nevertheless, the following recommendations are relevant across different contexts:

CLOSELY ASSESS DEMAND. Many Asian countries' experiences suggest that substantial public R&D in biological technologies, as well as investments in infrastructure such as roads and irrigation, preceded and contributed to mechanization demand in land-scarce, smallholder-dominated environments. Where such investments have been made, mechanization may be used for widely grown African crops such as sugarcane, maize, and cassava and other root crops.

While rising farm wages are observed in various pockets across Africa, public R&D and infrastructure investments have remained insufficient to promote mechanization. As a result, potential hiring-service providers may regard mechanization demand as volatile and risky, even as demand rises. Further efforts are needed to investigate whether and where it is beneficial to enhance public investment in technologies that are complementary to mechanization technologies.

PRIORITIZE MARKET-LED HIRING SERVICES. Private hiring services are generally the most efficient method of supplying mechanization services to smaller farms. Hiring markets enable relatively large-scale farmers to profitably invest in machines and smaller farmers to access services. Efforts to make ownership and services provision more viable could include widening available machinery options, addressing coordination failures between hiring services providers and consumers, and promoting access to agricultural finance.

Emphasizing the benefits of market-led hiring services for African countries remains important. Many African governments feel pressure to intervene directly in the selection of program beneficiaries, including choosing hiring service businesses to promote, which has been shown to be detrimental to the development of hiring service markets. Nevertheless, the public sector can play an important role in coordinating functions, such as linking service providers and customers; providing information on when machines will be needed in different areas for harvesting; encouraging the involvement of other service providers, such as mobile communications companies; and waiving highway tolls for trucks transporting tractors or combines.

ELIMINATE MARKET DISTORTIONS. Programs that arbitrarily select beneficiaries, limit technology choices, and do not provide incentives for proper use and maintenance of machines are likely to exacerbate existing market failures and encourage rent-seeking behaviors. Duties on imported machinery have been largely removed, but exempting spare parts is also important. Any subsidies should be wide-ranging and aim to increase exposure to new brands, types of machinery, and implements.

IDENTIFY APPROPRIATE TECHNOLOGY. Governments can influence the adoption of new, more efficient machinery and mechanization practices through demonstrations, experiments, and other incentive-promoting interventions. With proper policy and public funding support, local R&D institutions can adapt imported mechanization models to local conditions, develop new designs, and educate engineers and offer extension programs, often in collaboration with the private sector. Appropriate government policies, including financial and technical support, can allow small local manufacturers to play a key role in Africa as they did in Asia. Developing complementary technologies, such as irrigation and rural infrastructure, can also be important for mechanization development.

While past policy failures show which interventions are unlikely to succeed, relatively little is known about how government interventions can effectively complement the private sector in Africa. An effective government mechanization policy requires both identifying market failures in mechanization and recognizing how inappropriate government interventions may create market distortions that deter the private sector from developing mechanization supply chains.

A deeper understanding of the suitability of different sizes and types of machines under different conditions, hiring market dynamics, better mechanization practices, and alternatives for overcoming credit constraints are much needed. Because solutions will be highly localized, effective public sector support requires accounting not only for different climatic conditions and factor endowments but also for differences in the broader economic transformation pathways that affect agricultural transformation, and requires use of experimental knowledge exchanges and mutual learning among African countries.

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