



INTERNATIONAL FOOD POLICY
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IFPRI Discussion Paper 01255

March 2013

Agricultural Mechanization in Ghana

**Is Specialization in Agricultural Mechanization a
Viable Business Model?**

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PARTNERS AND CONTRIBUTORS

IFPRI gratefully acknowledges the generous unrestricted funding from Australia, Canada, China, Denmark, Finland, France, Germany, India, Ireland, Italy, Japan, the Netherlands, Norway, the Philippines, South Africa, Sweden, Switzerland, the United Kingdom, the United States, and the World Bank.

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ABSTRACT

Since 2007, the government of Ghana has been providing subsidized agricultural machines to private enterprises established as Agricultural Mechanization Services Enterprise Centers (AMSEC) to scale up tractor-hire services to smallholder farmers. Although farmer's demand for mechanization has increased in recent years, most of this demand concentrates on land preparation (plowing) service. Using the firm investment model and recent data, this paper quantitatively assesses whether AMSEC as a private enterprise is a viable business model attractive to private investors. Even though the intention of the government is to promote private sector-led mechanization, findings suggest that the AMSEC model is unlikely to be a profitable business model attractive to private investors even with the current level of subsidy. The low tractor utilization rate as a result of low operational scale is the most important constraint to the intertemporal profitability of tractor-hire services. Our findings further support the argument of Pingali, Bigot, and Binswanger (1987), who indicated that mechanization service centers supported through government's heavy subsidy are not a policy option anywhere in the world, even in the current situation in Ghana. Although the tractor rental service market is a proper way of mechanizing agriculture in a smallholder-dominated agricultural economy such as Ghana, this paper concludes that the development of such a market depends crucially on a number of factors, including increased tractor use through migration across the two very different rainfall zones (north and south), increased tractor use through multiple tasks, and use of low-cost tractors. The government can play an important role in facilitating the development of a tractor service market; however, the successful development of such a market depends on the incentive and innovation of the private sector, including farmers who want to own tractors as part of their business portfolio, traders who know how to bring in affordable tractors and expand the market, and manufacturers in exporting countries who want to seek a long-term potential market opportunity in Ghana and in other west African countries.

Keywords: agricultural transformation, mechanization, tractor-hire service, firm investment, government policy on mechanization, Ghana

ACKNOWLEDGMENTS

We would like to thank the regional and district staff of the Agricultural Engineering Services Directorate (AESD) of the Ministry of Food and Agriculture for facilitating field interviews. Particularly, we express our gratitude to Eng. Joseph Kwasi Boamah (director— engineering) and Eng. George K. A. Brantuo (deputy director—engineering) at the AESD for providing useful comments. We also thank Eng. Gerald Kojo Ahorbo and Dr. Victor Owusu for collecting the data on which this work is based. We acknowledge the farmers, tractor owners, and numerous stakeholders who participated in the field surveys. This work greatly benefited from comments from the participants of the 2013 Allied Social Sciences Association meeting in San Diego, California, United States; and discussions with Xiaobo Zhang, Hiroyuki Takeshima, and Alejandro Nin Pratt at IFPRI headquarters. We would also like to thank one anonymous reviewer.

1. INTRODUCTION

Since 2007, the government of Ghana (GoG) has embarked on a bid to transform agriculture under its Medium Term Agricultural Investment Plan and Accelerated Agricultural Modernization Policy. This effort has led to the establishment of private enterprises known as Agricultural Mechanization Services Enterprise Centers (AMSEC) and to the provision of subsidized agricultural machines to these centers. Although the government's subsidy on tractors for individual farmers (mainly medium and large farmers) has been the policy since the late 1990s, the focus of such subsidies shifted to AMSECs after 2007. Even though different types of agricultural equipment have been imported and distributed to AMSECs under subsidized prices, observed mechanization services provided by AMSECs concentrate primarily on land preparation, especially plowing. As a result, tractors are usually parked and remain unused after the plowing seasons in the country. This pattern of demand for mechanization services raises the questions of whether the current AMSEC policy is a practical model for agricultural mechanization service provision and whether such enterprises can be a business model attractive to private investors.

Historically, tractor-based mechanization often has enjoyed popular support among policymakers across Africa south of the Sahara because it is seen as vital to increasing production and relieving drudgery in agriculture. From 1950 to 1980, many developing countries established state-run, subsidized tractor-hire schemes to extend tractor-based mechanization to small farmers (see, for example, Food and Agriculture Organization of the United Nations [FAO] 2008; Li 2005; Eziakor 1990; Akinola 1986; Kolawole 1972; Chancellor 1969).¹ These previous attempts to mechanize agriculture in Africa south of the Sahara failed to induce sustained adoption of mechanization after the end of the initial government support (see, for example, FAO 2008; Pingali 2007). A major lesson learned from the past is that successful development of farm mechanization has rarely been driven by the government's direct involvement in machinery supply, development, and financing or by offering mechanization hire services (FAO 2011; Pingali, Bigot, and Binswanger 1987). Yet, a few African countries support mechanization today with similar policies, including tractor purchase (imports), tractor distribution, and tractor subsidies. Using firm investment theory and survey data collected from tractor service providers in Ghana, we examine the intertemporal profitability of agricultural mechanization services with a focus on land preparation. This research is intended to contribute to the current policy debate on agricultural mechanization in the country. Findings suggest that AMSEC as a specialized service provider is not a viable business model, even with the current level of subsidy in the country. Furthermore, our results indicate that underutilization of tractors as a result of low operational scale is the most important constraint to the profitability of investment in specialized agricultural mechanization service provision. This paper is organized as follows. Section 2 describes the current organization of the tractor service provision market. Section 3 presents the theoretical framework applied, and section 4 presents the results. Section 5 offers our concluding remarks.

¹ See Obi and Chisango (2011), Binswanger (1978), and Hayami and Kawagoe (1989) for a review of the theories and evidence surrounding the massive state involvement in agricultural mechanization in the 1950s and 1960s.

2. ORGANIZATION OF THE AGRICULTURAL MECHANIZATION SERVICE PROVISION MARKET

In Ghana, the first boost to agricultural mechanization took place after independence in 1957 when the new government offered highly subsidized mechanized services to farmers (Boamah 2006). The GoG withdrew from direct service provision in the early 1980s. Today's unmet demand for mechanized services in farming is perceived by GoG to be the result of a shortage of domestic tractor stock—a belief that has significantly shaped GoG's agricultural mechanization policy. Mechanization service provision now is dominated by individual tractor owners and AMSECs set up with the support of GoG.

The AMSEC concept was initiated in 2003 to provide timely and affordable mechanized services to farmers who cannot afford agricultural machinery on their own (Agricultural Engineering Services Directorate, 2003). Initially, the proposed AMSEC package included a range of agricultural machinery, such as tractors, harvesters, boom sprayers, planters, power tillers, seed drillers, slashers, ridgers, and rice mills. However, during AMSEC implementation, this package changed. On average, each AMSEC was allocated a package of five tractors with basic implements (plows, harrows), plus a trailer. According to the Agricultural Engineering Services Directorate of the Ministry of Food and Agriculture, this decision to allocate five tractors was based on the expectation that each AMSEC could serve in a season about 500 small-scale farmers with average landholding of 2.0 hectares (ha). A total of 89 AMSECs have been established to date (see Table 2.1).

Table 2.1—Package and allocation terms of agricultural machinery to Agricultural Mechanization Services Enterprise Centers, 2008 to 2011

	2008	2009	2010	2011	Total
Number of agricultural mechanization services enterprise centers established	12	57	15	5	89
Package—average number of tractors	8.2	5.1	4.3	3.0	472

Source: Compiled from Agricultural Engineering Services Directorate (2011) data.

More than 90 percent of Ghana's farming population consists of small-scale farmers, farming less than 2 hectares on quite widely distributed farms (Statistics, Research, and Information Directorate 2011). Farming is mostly a rainfed activity, and the timing of plowing is critical. "If there is no rain, there is no business for a mechanization service provider," said one of our interview respondents. The seasonal pattern of demand for plowing service is strong. This demand pattern was confirmed by the 2011 survey results (see Benin et al. 2012), which show that in 2009 and 2010 plowing revenues both for AMSEC and for non-AMSEC providers amounted to 88 percent and 90 percent of their total revenues, respectively. Of the revenues, 10–12 percent came from carting farm products and transportation.

The peak demand period spreads from June to July in the north, where a single cropping season dominates as a result of a single major rainy season. This pattern allows for about 45 effective days of plowing (April through September). In the south, two cropping seasons are possible, and the peak demand period spreads from April to June during the major rainy season (March through July) and from September to October during the minor rainy season (September through November), allowing for 60 effective days of plowing in total.

Although the demarcation between seasons makes it possible for tractor service providers to migrate from the north to the south (and vice versa) to offer plowing services (for a maximum of 45 days) in either region, in practice, migratory service providers are rare. Information gathered for this study indicates that few AMSECs and individual tractor owners migrated across the two rainfall zones between the north and south. A number of factors may explain the limited migration of tractor service providers across regions, including providers' lack of knowledge and limited networks outside their own regions, additional costs imposed by operators' oversight, and lack of support in making the necessary logistic arrangements. With a constraint on tractor utilization beyond the local plowing seasons, it is important to

assess whether a specialized tractor service provider can survive, given the initial investment necessary to run such a business. The high price of imported tractors has led to the strong belief that the state should subsidize the provision of agricultural machinery services to farmers. Although it is true that such machines are not affordable to many individual farmers, any subsidy should be designed in such a way that it does not create a barrier to developing a sustainable supply chain for agricultural machinery in which the private sector can play a leading role in this aspect of the transformation of agriculture in the country.

3. METHODOLOGY

General Considerations

This research uses data from several sources. In April 2012, we interviewed both various stakeholders along the agricultural machinery supply chains and service beneficiaries across the country. Information gathered from these interviews was combined with the 2011 AMSEC survey data collected by a team of consultants with assistance from the International Food Policy Research Institute.² This survey was conducted as part of the evaluation of the Ministry of Food and Agriculture's four special initiatives, which aim at accelerating the modernization of agriculture and increase the productivity of Ghanaian farmers. These four special initiatives include (1) the subsidization of agricultural mechanization services via support to the establishment and operation of AMSECs, (2) the subsidization of fertilizers via the National Fertilizer Subsidy Program, (3) the establishment and management of block farms that benefit from subsidized mechanization services and inputs (fertilizers, improved seed, and pesticides) and extension services, and (4) the stabilization of output prices via the establishment and operation of the National Food Buffer Stock Company.

A combination of purposive and random sampling of service providers and corresponding districts was used to select the sample. First, a random selection of about 50 percent of the AMSEC service providers operating or located within each of the relevant regions was performed. Then, for each selected AMSEC service provider at least 2 non-AMSEC service providers in the same area were selected. In total, 48 AMSEC and 88 non-AMSEC service providers were interviewed, depending on providers' availability and willingness to participate in the survey (see Benin et al. 2012 for further details on the AMSEC survey). Given that both providers' businesses are expected to be profitable, we treat them as individual firms without distinction in our analysis.

Using firm investment theory and field-based assumptions on various costs, revenues, and tractor efficiency, we first estimate the profitability of the provision of specialized plowing services under a normal situation. Since rainfall patterns and service price levels differ between the north and south, separate models were estimated for the two regions. Furthermore, we determine the actual profitability of the AMSECs. This assessment implicitly considers the current functioning of the service rental market, which is characterized by several constraints and weaknesses that, in combination, affect the overall profitability of such businesses. Our analysis was informed by previous research on the profitability of tractor hire services, including that of Paman, Uchida, and Inabaz (2010); Mahama et al. (2008); Jayasuriya, Amanda Te, and Herdt (1986); and Chancellor (1969).

Theoretical Framework: Firm Investment Theory

To model investments in agricultural mechanization services, we adopted a modified version of the firm investment theory described in Diao, Yeldan, and Roe (1998), who adapted it from Barro and Sala-i-Martin (1995). Mechanization service provision is considered a business run by a firm. The firm's goal is to maximize its intertemporal net profit π , taking existing service provision technology; market prices for service provision, fuel, and other inputs; and labor wage rates as given. The firm as an investor decides between a plowing service business by investing in a tractor and saving in a bank to earn interest. The firm will invest in a tractor only when the returns to such investment are higher than the interest earned on saving the same amount of capital in a bank. This comparison is critical here as investing in a tractor is riskier than saving in a bank. If the capital is convertible, that is, the money invested in tractor can be taken back easily by selling the tractor, such investment has little risk for the investor. We first assume that this is the case; that is, the tractor owner can easily sell his or her used tractor without any risk on the

² We would like to thank Gerald Ahorbo and Victor Owusu, who conducted the survey of service providers, for numerous and fruitful conversations and for sharing the survey data.

used tractor market, which does exist in the country. We show later that relaxing this assumption does not affect our conclusions.

Furthermore, we did not consider inflation in the discount and interest rates. We also assume that both rates are constant over time to simplify the model. Since a credit market for financing tractor purchase does not exist in the country, we assume that the investor invests its own money instead of borrowing. In Ghana, market-based lending rates are much higher than the saving rates of 7 percent used in the model. Such a low saving interest rate increases the profitability of investing in a tractor. As shown later in our analysis, however, even at such a low interest rate, investing in a tractor is not a viable option for the investor. We further assume that once the firm invests in a tractor, the latter lasts for a certain period (10 years in this case). With the required annual maintenance, the productivity of the tractor is not affected by its depreciation. After 10 years, the old tractor will be replaced by a new one, the cost of which is covered by the accumulated depreciation as part of the investment profit. To simplify the issue, we further assume that the firm will always purchase the same tractor at the same price—that is, we ignore the possibility that the firm may grow through increased capital accumulation.

Mathematically, this firm's investment decision in any one 10-year period can be modeled as maximizing the value of the following equation:

$$\pi = \sum_{t=1}^{10} R_t G_t - I, \quad (1)$$

$$R_t = \frac{1}{(1+r)^t}, \quad (2)$$

where π is the total discounted net profit over 10 years (as the tractor's lifetime is assumed to be 10 years), R_t is the annual discount factor, r is the annual saving interest rate, and I is the actual tractor cost paid by the firm initially, assuming that the firm invests its own money and ignoring the cost of borrowing. G_t is the gross margin for the firm (that is, annual service provision revenue minus variable costs). The gross margin in year t can be estimated as follows:

$$G_t = P * A_t - A_t(F + L) - M, \quad (3)$$

where P is the market-determined plowing service charge per acre, A_t is the acreage plowed, F represents the fuel and lubricant costs per acre, L represents the labor costs per acre, and M represents the maintenance and repair costs, including other fixed operating costs per year. P , F , L , and M are assumed to be constant over time.

Although equation (1) defines π for only one investment cycle (10 years), we assume that the firm will reinvest in the same type of tractor, and the investment cycle will restart at the end of each cycle so that the business is sustained in a natural fashion. Thus, the intertemporal decision for this firm can be analyzed as an infinite time horizon problem, which allows us to ignore termination issues for this firm.

Solving this intertemporal profit maximization problem by taking into consideration capital depreciation yields the following nonarbitrage condition:

$$G - \delta I = rI, \quad (4)$$

where δ is the capital depreciation rate. Equation 4 indicates that the nonarbitrage condition requires that the gross margin G minus the annual depreciation cost of the tractor investment equals the interest earned from saving the same capital at a bank. At this equilibrium point, the investor is indifferent between investing in a tractor and saving. Given that once the investment in the tractor is made, the firm cannot sell it and save the capital, equation (4) needs to hold over the entire time horizon of 10 years, although it may not hold in each of the 10 years. To simplify the analysis, however, we assume that $A_1 = A_2 = \dots = A_{10}$ and δ and r are constant, so that equation (4) holds for each year. In other words, to make tractor investment more attractive than simply earning annual interest from savings, the profits from tractor

service provision minus tractor annual depreciation cost must be higher than the returns (interest) from saving the capital (tractor investment cost) at a bank in each year.

Let $N = G - (r + \delta)I$ define the annual net profit from investing in a tractor—that is, the profit minus the interest earned from saving the capital. Substituting the right-hand side of equation (3) for G yields

$$N = P * A - A(F + L) - M - (r + \delta)I. \quad (5)$$

Given P, F, L, M, r , and δ , the net profit N depends on two key factors: the acreage plowed, A , and the initial investment, I . We illustrate the relationship between N and A at different levels of I in the following section.

Calibrating the Model to the Ghanaian Situation

We calibrate equation (5) using actual data or information for parameters P, F, L , and M with the assumption of $\delta = 0.1$ and $r = .07$. Parameters were estimated using field-observed information on costs, prices, and tractor efficiency. For I , we consider three types of tractor prices: a normal business model in which the tractor (and plow) price is not subsidized, a subsidized business model in which the subsidized tractor price is similar to the price offered by the government, and a used tractor business model in which a nonsubsidized price for used tractors found on the local market is considered.

The main reason for considering the third model is that the used tractor business has existed in Ghana for a long time, and demand remains strong despite the government's subsidy on new tractors. Moreover, information collected from our field visits shows that the field efficiency of used tractors is comparable with that of new tractors. Used tractors are much cheaper than new tractors; they are purchased on the private market and do not enjoy any government subsidy or financial-sector credits support.

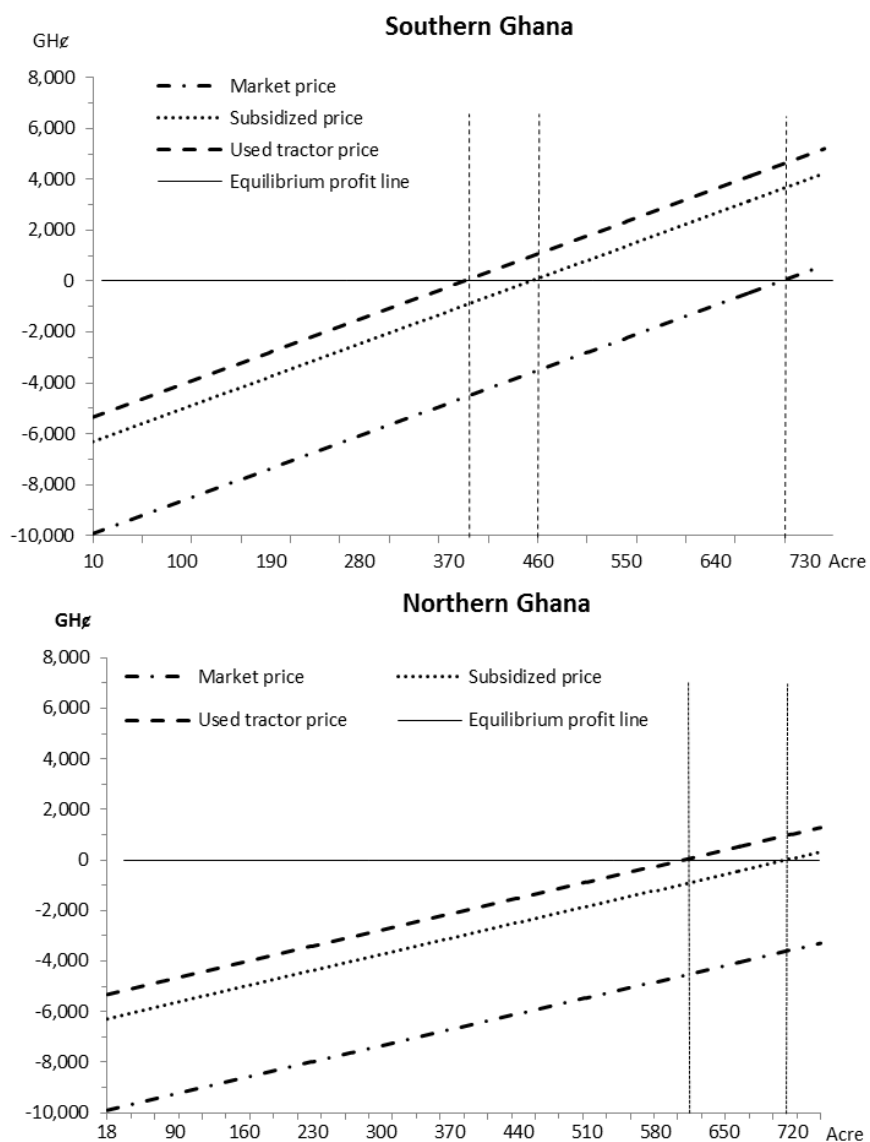
Appendix Tables A.1 - A. 3 summarize the main assumptions regarding costs and revenues made for our analysis.

4. PROFITABILITY OF AGRICULTURAL MECHANIZATION SERVICE PROVISION: MAIN RESULTS

Is Specialization in Agricultural Mechanization a Viable Business Model?

As mentioned earlier, we assess the profitability of specialized agricultural mechanization service provision based on various cost and revenue assumptions. The graphs in Figure 4.1 illustrate the relationship between the numbers of acres plowed and the net profit per tractor for the south and north of Ghana, respectively. In all of our theoretical models, the tractor operational efficiency is assumed to be the same.

Figure 4.1—Net profit per tractor investment—model for southern Ghana (top) and model for northern Ghana (bottom)



Source: Authors' estimations.

Note: GH¢ denotes Ghanaian Cedi. GH¢ 1.50 = US\$1.00 in June 2011.

Profitability is monotonically increasing with the number of acres plowed. The horizontal zero-profit line represents the nonarbitrage condition displayed in equation (4). It represents the equilibrium in which investing in a tractor yields the same return as saving the money in a bank to earn interest. Below the equilibrium (or nonarbitrage) point, an investor prefers to save at a bank, whereas above this point, an investor has an incentive to invest in a tractor, and mechanized service provision can be a rational investment. This equilibrium point shows the minimum number of acres that must be plowed for accumulated profits over 10 years (discounted by the interest rate on savings) to cover the tractor investment cost, accounting for depreciation.

Given a tractor field capacity of 10 acres per day, 60 effective plowing days in the south, and 45 days in the north, the maximum number of acres that can be plowed by a tractor in the two seasons is about 600 acres in the south and 450 acres in the single major season in the north. As indicated in Figure 4.1, both used and subsidized tractors are likely to be profitable in southern Ghana, as their equilibrium points are at 380 and 460 acres, respectively—below the maximum number of acres that can be plowed in southern Ghana. In northern Ghana, about 600 acres and 710 acres are required to reach the equilibrium point for used and subsidized tractors, respectively, whereas the maximum number of plowed areas possible is only 450 acres. This is because the service charge in northern Ghana is about 25 percent lower than in southern Ghana. As a result, the gross margin is lower in the north, even though labor costs are lower in this region of the country and fuel and maintenance costs are comparable between the regions. Taking into consideration the differences in gross margin and effective plowing days between the north and the south, the results suggest that none of the three models in the north is profitable at the maximum effective plowing days—45 days to plow 450 acres in total. These results are not comparable with findings from the West African Rice Development Association discussed by Pingali, Bigot, and Binswanger (1987), who suggest that in the 1960s, with an average of 300 acres in a season, tractor-hire services were profitable in northern Ghana. This result can be explained by the much lower tractor prices and operating costs in the 1960s compared with those used in our analysis.

As mentioned earlier, if a used tractor cannot be easily sold on the used tractor market, investing in a tractor would be more risky than simply saving at a bank. There are also other risks associated with investing in a tractor, which we did not consider in our model. For example, service fees, fuel prices, and maintenance costs are exogenous factors to tractor owners, and their changes can negatively affect the returns to tractor investment. Likewise, weather-related risks such as a decrease in the number of effective plowing days (due to erratic rainfalls) can reduce total revenues. In the Ghanaian case, falls in service fees (per acre) are unlikely, and as observed during our field interviews, rises in fuel and other costs have been passed on to farmers because demand for mechanization services is high and supply is the major constraint to mechanization in the country. Nonetheless, we considered an additional scenario in which certain risks associated with tractor investment are taken into account. Under this scenario, we simply increased the interest rate from 7 percent to 10 percent, implying a risk premium of 3 percent. This change results in higher acreage numbers at the equilibrium. For example, under the subsidized business model, the numbers of acres at the equilibrium increase to 480 acres (from 460 acres) for the south and 760 acres (from 710 acres) for the north. These results further strengthen our conclusions and made investment in tractor service provision more unattractive to the private sector.

Agricultural Mechanization Service Provision: Modeled versus Actual Profitability

In this section, we first examine the actual profitability of the providers across tercile groups and regions using 2010 providers' data. Table 4.1 presents the summary statistics across terciles as well as the model estimates.

Table 4.1—Relationship (average) between profitability, cost efficiency, and operational scale among providers by region

Region/Tractor Price		Terciles of Net Profit ^a	Tercile Size	Tractor and Plow Price (GH¢)	Maintenance Costs (GH¢)	Number of Acres Plowed	Revenue (GH¢)	Operational Profit (GH¢)	Investment Profit (GH¢)
North	Model	Market	—	—	34,222				−5,999
		Subsidized	—	—	12,969	4,243	450	11,250	−2,387
		Used tractor	—	—	7,300			4,061	−1,423
	Actual profit	1	12	16,439 (7,000; 19,667)	6,168 (100; 19,400)	221 (28; 580)	5,001 (700; 11,600)	1,845 (294; 4,686)	−7,118 (−21,440; −2,526)
		2	12	13,304 (5,600; 18,000)	928 (150; 3,500)	139 (18; 280)	3,316 (365; 8,400)	1,319 (110; 4,200)	−1,871 (−2,261; −1,078)
		3	10	9,968 (1,400; 18,000)	948 (260; 2,511)	138 (19; 251)	4,153 (380; 8,790)	2,082 (114; 4,897)	−466 (−1,064; 262)
South	Model	Market	—	—	34,222				−1,510
		Subsidized	—	—	12,969	4,243	600	19,800	2,103
		Used tractor	—	—	7,300			8,550	3,066
	Actual profit	1	18	15,912 (2,400; 30,000)	6,222 (635; 13,660)	245 (27; 705)	7,263 (1,060; 17,629)	3,235 (300; 7,930)	−5,692 (−14,776; −2,813)
		2	18	14,096 (11,000; 20,000)	1,441 (51; 5,750)	143 (11; 510)	4,181 (375; 15,300)	1,833 (190; 6,885)	−1,925 (−2,755; −1,283)
		3	18	10,167 (1,300; 20,000)	2,085 (100; 5,667)	230 (23; 567)	7,558 (900; 17,000)	3,665 (495; 8,580)	−148 (−1,133; 3,575)

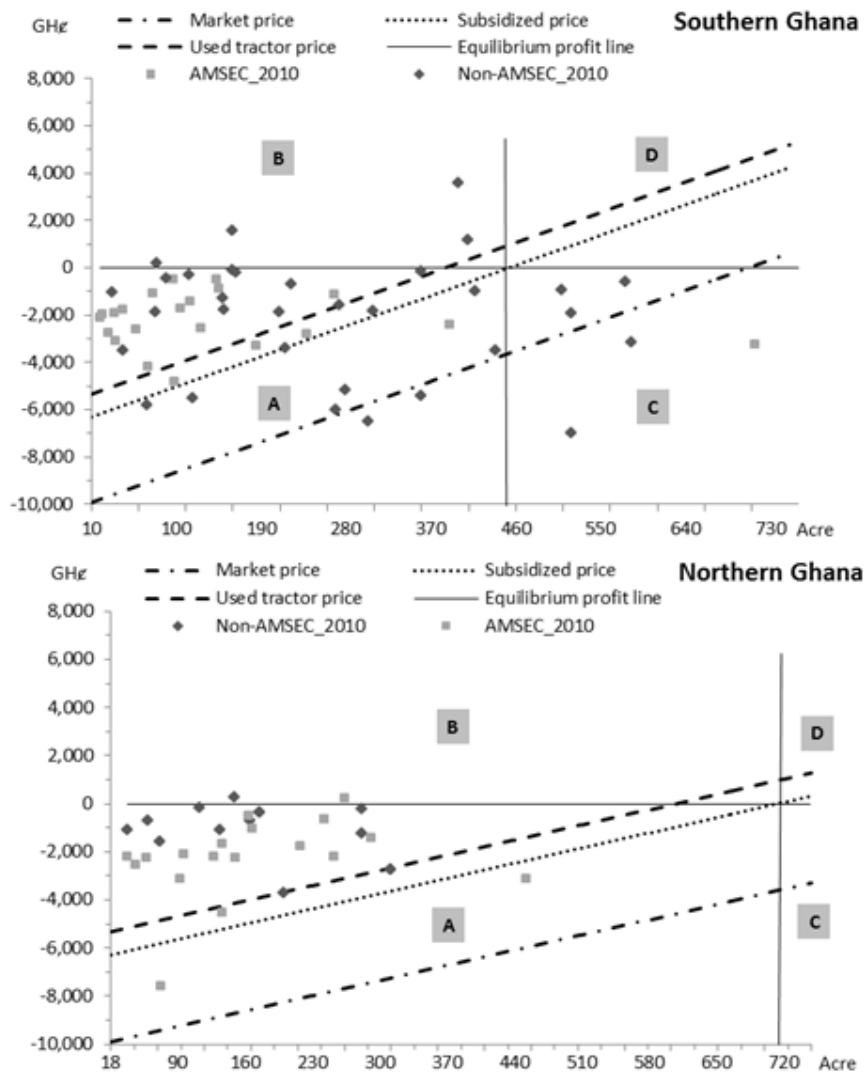
Source: Authors' estimations based on 2011 Agricultural Mechanization Services Enterprise Center survey data by Benin et al. (2012).

Notes: Only six firms in the total sample (two in the north, four in the south) made positive net profits. GH¢ denotes Ghanaian Cedi.

^a Terciles of increasing net profits from 1 to 3. Tercile ranges are in parentheses.

Table 4.1 suggests that across terciles of net profitability operational profits are positive, whereas investment profits are negative. Likewise, as investment profits increase across terciles, tractor and maintenance costs decrease, with some exceptions. After a sharp drop between the first and second terciles, maintenance costs remain steady in the second and third terciles. Plowing revenues and operational profitability for incomes are lower in the second tercile but higher and comparable between the first and third terciles, indicating a similar operational scale between these two terciles. Table 4.1 also indicates that the surveyed providers display on average a low operational scale compared with the limit allowed by the seasons in both regions. We provide in Figure 4.2 a full picture of model outcomes and actual profitability by plotting net profitability in the provider sample against the model curves.

Figure 4.2—Net profit of per tractor investment—actual for southern Ghana (top) and for northern Ghana (bottom)



Source: Authors' estimations based on 2011 Agricultural Mechanization Service Enterprise Center survey data and field-based assumptions.

Note: GH¢ denotes Ghanaian Cedi.

The graphs are divided into four zones: A, B, C, and D, which are delimited by the curves and the zero-profit line for the nonarbitrage condition in the firm's investment decision.

- Zone A is characterized by low operational scale and negative investment profitability (although without considering tractor investment cost the operational profit is positive). Most surveyed firms in both the south and the north are unfortunately located in this zone (86 percent of valid observations). This pattern indicates that most firms are not able to fully operate their tractors to the maximum 45 days (north) or 60 days (south). That most providers in zone A are located in areas above the profitability curves of the three models indicates that it is the low operational acreages rather than the high operational costs that explain the nonprofitability of these firms' investments.

- Zone B is characterized by a low operational scale with positive investment profits. A few firms in the south are located in this zone, and almost no firms in the north are located in this zone. This result indicates that although they operate at low scale, the extremely low operational costs observed (lower than the average situation used in the models) make their investments profitable. Assuming that there is no reporting error, two factors can explain the profitability of these firms: low maintenance costs and low tractor prices. The low tractor price indicates that these are used tractors with low maintenance costs. Enterprises in this group may be owned by experienced farmers.
- High operational scale but negative investment profits characterize zone C. A few firms in the south are located in this zone, indicating that although their operational scale is high enough potentially to yield positive returns, they still did not make any profits from their investments. Further analysis shows that the high maintenance cost incurred by the firms is the main factor behind their nonprofitability. The average maintenance cost for firms falling into zone C is estimated at GH¢ 6,200, about 40 percent higher than the model assumption of GH¢ 4,200.
- Zone D is the zone with high operational scale and high profit. Unfortunately, none of the firms in either the south or the north are found in this zone. Overall, all firms in the north and about 90 percent of firms in the south plowed fewer acres than are required to break even. The average number of acres plowed by a firm was 168 and 206 in the north and the south, respectively, and both are well below the equilibrium break-even points.

In summary, the low operational scale observed for most providers is the main factor behind the nonprofitability of investing in specialized tractor service provision in the country. The results here are based on data from 2010, a year with good rainfalls. According to Statistics, Research, and Information Directorate (2011), average rainfall for 2010 is estimated at 12,000 millimeters, which is higher than the 10-year average (11,606 millimeters) for the period 2002–11. Our field interviews provided information and anecdotes that may explain why most firms cannot fully operate. The most important reason is the frequent breakdown of the tractors, including new tractors. Poor maintenance or lack of skilled operators result in frequent breakdowns. Likewise, delays in repairs due to the unavailability of spare parts and lack of qualified mechanics are contributory factors. Indeed, these constraints are not new to the sector. A few decades ago, research by Kolawole (1972), Akinola (1986), and Eziakor (1990) identified the same problems in Nigeria, and recently Paman, Uchida, and Inabaz (2010) reported similar issues in the Riau province of Indonesia.

Although in theory specialized agricultural mechanization service provision is a profitable investment in the south, in practice, there are numerous constraints that private enterprises have to overcome along the supply chain of mechanization services. Therefore, it seems fair to say that a specialized agricultural mechanization service provision model is not a realistic model that can be operated and sustained by the private sector in Ghana, even with the current subsidy policy.

5. CONCLUDING REMARKS

This paper assesses whether the recent promotion of specialized AMSECs by GoG is a viable business model attractive to the private sector. Findings suggest that specialization in agricultural mechanization service provision at the current stage of agricultural development in Ghana is not attractive to the private sector. Underutilization as a result of low operational scale is the most important constraint to the profitability of investment in tractors for specialized agricultural mechanization service provision. Making tractor-hire services profitable under current conditions requires either encouraging service providers' migration across rainfall zones to increase their utilization rate or lowering the tractor investment cost. Indeed, different rainfall patterns across agroecological zones in Ghana make possible migratory services that can be promoted to increase the operational scale of tractor owners.

Reducing the tractor cost by further increasing the tractor subsidy seems not to be an option given that the tractor price paid by AMSECs is only about 62 percent of the imported price and an AMSEC pays only 20 percent of the subsidized price upfront. Thus, to lower the tractor cost, it is essential to consider various options for introducing lower-cost and smaller tractors into the Ghanaian market. For example, in Indonesia, Paman, Uchida, and Inabaz (2010) found that owners of low-cost and small tractors have been able to realize the full operational capacity of the tractors and to achieve profitability in their use. The used tractor model is one of the options as the used tractor market is fully operated by the private sector in Ghana. However, the general consensus among government officials is that used tractors should be neither encouraged nor supported through the private financial sector.

The tractor market is large and diverse in the world, but all tractors in Ghana are imported by GoG, and the country has no domestic manufacturing capacity. With heavy subsidies on larger and more costly tractors, the subsidy policy can distort the development of the tractor supply chain, and only government-selected foreign manufacturers will get access to the Ghanaian market. As a result, many types of lower-cost machines are unlikely to be introduced into the local market. Furthermore, foreign manufacturers are unlikely to accumulate local market knowledge that is essential to developing more suitable and affordable tractors for the country as well as for other West African countries. Without widening the range of choices and opportunities for private providers, they will lack necessary incentives to create more innovative approaches to increase their profits. Improving the utilization rate of tractors may also be achieved through exploiting the potential of tractors for multiple uses. For example, tractor use to power stationary equipment, such as pump for irrigation and tractor sharing for postharvest operations, is practiced by farmers in the country and this should be encouraged. Multiple uses of tractors emerge as a result of farmers' innovation, which can be fostered when tractors are owned by farmers themselves who know how best to use the machines, instead of by nonfarm enterprises. With a policy that focuses on specialized service provision, farmers' innovation in agricultural mechanization is unlikely to occur.

APPENDIX: SUPPLEMENTARY TABLES

Table A.1—General assumptions

Assumptions
Provider has a good knowledge of and experience in farming and business.
There is demand for mechanization service.
Business focus is on plowing service only.
Costs and revenues are assumed to be constant over the years.
Plowing services are provided during both major seasons and the minor season in the south.
Capital invested is generated from the farmer's own fund; there is no lending.
Interest rate on capital is 7 percent per year.

Source: Authors' assumptions based on field data and Ministry of Food and Agriculture reports.

Table A.2—Model assumptions

Number	Components	Assumption Details
1	Three models:	
	1 tractor and 1 plow	Model 1: Normal business model (2010 market prices, no subsidy) Model 2: Subsidized model (33% subsidy on 2010 negotiated price) Model 3: Used hand tractor
		John Deere 55-horsepower tractor and three-disc plow: GH¢ 34,222 John Deere 55-horsepower tractor and three-disc plow: GH¢ 12,969 Tractor and plow: GH¢ 7,300
2	Tractor field capacity	9.88 acres per day (4 hectares)
3	Tractor lifetime (years)	10 years
4	Plough lifetime (years)	10 years
5	Annual tractor depreciation	10% of original investment in tractor
6	Annual plow depreciation	10% of original investment in plow
7	Lubricant costs as a percentage of fuel costs	15%
8	Fuel consumption per acre	1.5 gallons per acre
9	Fuel price per gallon	GH¢ 8
10	Maintenance and repairs costs	7% of commercial tractor and plow prices
11	Shed building costs	GH¢ 1,400
12	Shed useful life (years)	10 years
13	Annual shed depreciation	10% of shed-building costs
14	Office rental per year	GH¢ 100
15	Comprehensive insurance per year	GH¢ 571.02
16	Business registration (one-time payment)	GH¢ 100
17	Business renewal per year	GH¢ 20
18	Tractor registration at Driving License Authority	GH¢ 62.70 (one-time payment)
19	Administrative costs	15% of operating costs
20	Discount rate or saving interest rate	7%

Source: Authors' assumptions based on field data and Ministry of Food and Agriculture reports.

Note: GH¢ denotes Ghanaian Cedi.

Table A.3—Region-specific assumptions

Number	Assumptions	Northern Ghana	Southern Ghana
1	2010 plowing service charge per acre (GH¢)	25	33
2	Effective plowing days	45	60
3	Casual labor wages (one operator and one assistant)	10% of plowing revenue	15% of plowing revenue

Source: Authors' assumptions based on field data and Ministry of Food and Agriculture reports.

Note: GH¢ denotes Ghanaian Cedi.

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