Agricultural Mechanization in Ghana

Is Specialization in Agricultural Mechanization a Viable Business Model?

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ABSTRACT

The Government of Ghana (GoG) since 2007 has been providing subsidized agricultural machines to individual farmers and private enterprises established as specialized Agricultural Mechanization Services Enterprise Centers (AMSECs) to offer tractor-hire services to small-scale farmers across the country. Current demand in the country is primarily focused on land preparation services, especially plowing. This paper assesses whether AMSEC enterprises are a viable business model attractive to private investors. Using firm investment theory and field-based data on costs, revenues, and tractor efficiency, this research examines the profitability of specialized agricultural mechanization service provision with a focus on land preparation.

Findings suggest that the AMSEC model is not a viable business model, even with the current level of subsidy. Low operational scale is the most important constraint to the profitability of investment in specialized agricultural mechanization service provision. With such a low operational scale, it is essential to consider various options for introducing low-cost, small tractors suited to the current farming scale in the country. Also, a used tractor model is one of the options available for policymakers in the country. Tractor-hire services can play an important role in transforming smallholder agriculture, but with heavy subsidies on big and costly tractors, the subsidy policy can distort supply chain development. As a result, many better-suited and lower-cost machines are unlikely to be introduced into local markets.

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I. THE ISSUE

Since 2007, the Government of Ghana (GoG) has embarked on a bid to transform agriculture under its Medium Term Agricultural Investment Plan (METASIP) and Accelerated Agricultural Modernization Policy. This effort has led to the provision of subsidized agricultural machines to individual farmers and to the establishment of private enterprises known as Agricultural Mechanization Services Enterprise Centers (AMSEC). However, the observed demand pattern for the AMSECs in the country is primarily focused on power-intensive operations, especially plowing services. As a result, most of the tractors usually are parked and remain unused after the plowing season in the country. This pattern of demand raises the question as to what should be a practical agricultural mechanization service provision model to promote, and whether the model pursued by the GoG is a viable business model attractive to private investors.

Historically, tractor-based mechanization often has enjoyed popular support among policymakers and the farming population across sub-Saharan Africa 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 FAO 2008; Li 2005; Eziakor 1990; Akinola 1986; Kolawole 1972; Chancellor 1969)¹. These previous attempts to mechanize agriculture in sub-Saharan Africa 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 offering mechanization hire services (FAO 2011). Today, only a few countries support mechanization in sub-Saharan Africa.

This research examines the profitability in Ghana of agricultural mechanization services that focus on land preparation. The results are intended to contribute to the current policy debate on agricultural mechanization in the country. Findings suggest that the AMSEC model of specialized service provision is not a viable business model, even with the current level of subsidy in the country. Furthermore, our results indicate that low operational scale is the most important constraint to the profitability of specialized agricultural mechanization service provision.

This paper is organized as follows. Section 2 describes the current organization of the service provision market. Section 3 presents the theoretical framework applied, whereas section 4 presents the results. Section 5 offers our concluding remarks.

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 the GoG to be the result of a shortage of domestic tractor stock – a belief that has significantly shaped the GoG's agricultural mechanization policy. Mechanization service provision now is dominated by individual tractor owners and AMSECs set up with the support of the 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. 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

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

tractors with basic implements (plows, harrows), plus a trailer. According to the Agricultural Engineering Services Directorate (AESD) of the Ministry of Food and Agriculture (MoFA), 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 ha. Eighty-nine AMSECs have been established to date (Table 1).

Table 1: Package and allocation terms of agricultural machineries to AMSECs, 2008 to 2011

	2008	2009	2010	2011	Total
Number of AMSECs established	12	57	15	5	89
Package – average number of tractors	8.2	5.1	4.3	3.0	472

Source: Compiled from AESD data (2011).

More than 90 percent of Ghana's farming population are small-scale farmers, farming less than 2 ha on quite widely distributed farms (SRID 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 is confirmed by our 2011 survey results, which show that in 2009 and 2010 plowing revenues both for AMSEC and for non-AMSEC providers amount to 88 percent and 90 percent of their total revenues, respectively. 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 – 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- July) and from September to October during the minor rainy season (September - November), allowing for 60 effective days of plowing in total.

While 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 very few AMSECs and individual tractor owners migrated across the two rainfall zones between the North and South. A number of factors constrain the migration of tractor service providers across regions, including providers' lack of knowledge and limited networks outside their own regions and lack of help 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. While it is true that such machines are not affordable to many individual farmers, any subsidy should be designed in a manner so that they do 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 survey data collected in 2011 for the evaluation of AMSECs. For this 2011 survey, 48 AMSEC and 88 non-AMSEC service providers were interviewed. 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 et al. (2010), Mahama et al. (2008), Jayasuriya, (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 as 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 either a plowing service business by investing in a tractor or saving in a bank to earn interest. The firm will only invest in a tractor when the returns to such investment are higher than the interest earned on saving the same amount of capital in a bank.

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 investment profit. In order to simplify the issue, we further assume that the firm will always purchase the same tractor at the same price—that is, we ignore 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 non-arbitrage condition:

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

where δ is the capital depreciation rate. Equation 4 indicates that the non-arbitrage 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 Section 4.

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 $r = 0.07$. Parameters were estimated using field-observed information on costs, prices, and tractor efficiency. With regard to 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 used tractors are comparable with new tractors in terms of field efficiency. 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 support in terms of credits.

Annexes 1 thru 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 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 1: Net profit per tractor investment - model for Southern Ghana (top) and model for Northern Ghana (bottom)

Source: Authors' estimations. 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 non-arbitrage 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 non-arbitrage) 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 in the South is about 600 acres and 450 acres in the single major season in the North. As indicated in Figure 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 which can be plowed in Southern Ghana. In the case of Northern Ghana, more than 600 acres and 710 acres are required to reach the equilibrium point for used and subsidized tractors, respectively, while 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, *GM*, 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 *GM* 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.

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. Table 2 presents the summary statistics across terciles, as well as the model estimates.

Table 2: Relationship (average) between profitability, cost-efficiency, and operational scale among providers by region

Region/tractor price		Terciles of net profit*	Tercile size	Tractor & 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	4,061
		Used tractor	-	-	7,300				-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	8,550
		Used tractor	-	-	7,300				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 AMSEC survey data (2011). *Terciles of increasing net profits from 1 to 3. Tercile ranges in brackets.

Only six firms in the total sample (two in the North, four in the South) made positive net profits. GH¢ denotes Ghanaian Cedi.

Table 2 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. With regard to incomes, plowing revenues and operational profitability 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 2 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 2 a full picture of model outcomes and actual profitability by plotting net profitability in the provider sample against the model curves.

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 non-arbitrage 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 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). The fact 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 non-profitability 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 firm in the North is located in this zone. This result indicates that, while they operate at low scale, the extremely low operational costs observed (lower than the average situation used in the models), making 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, while 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 non-profitability. The average maintenance cost for firms falling into zone C is estimated at 6,200 GH¢, about 40 percent higher than the model assumption of 4,200 GH¢.
- Zone D is the zone with high operational scale and high profit. Unfortunately, none of the firms in either the South or 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.

Figure 2: Net profit of per tractor's investment - actual for Southern Ghana (top) and for Northern Ghana (bottom)

Source: Authors' estimations based on survey data and field-based assumptions. AMSEC denotes Agricultural Mechanization Service Enterprise Center. GH¢ denotes Ghanaian Cedi.

In summary, the low operational scale observed for most providers is the main factor behind the non-profitability of investing in specialized tractor service provider enterprises in the country. 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 (1989) identified the same problems in Nigeria and recently, Paman et al. (2010) reported similar issues in Riau province of Indonesia. While 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. CONCLUSION

This paper assesses whether specialization in agricultural mechanization service provision at the current stage of agricultural development in Ghana can be a viable business model. The results indicate that low operational scale is the most important constraint to the profitability of investment in specialized agricultural mechanization service provision. With such a low operational scale, it is essential to consider various options for introducing lower-cost and smaller tractors into the Ghanaian market. The used tractor model is one of the options available to policymakers. However, little attention has been paid to this option, as the second-hand tractor market is fully operated by the private sector without any promotion by government or

support from the financial sector. Moreover, with heavy subsidies on larger and more costly tractors, the subsidy policy can distort supply chain development, and as a result, many lower-cost machines are unlikely to be introduced into the local market. For example, in Indonesia, Paman et al., (2010) found that the use of low cost and small tractors has enabled owners to realize the full operational capacity of the tractors and to achieve profitability in their use.

The results in this paper also indicate that the current focus on specialized service provision ignores the development stage of agricultural mechanization in Ghana. While the demand for mechanization is increasing in the country, most of this demand concentrates on plowing services. Many other farming operations, including planting, weeding, and harvesting are still performed by manual labor as the only power input. Such a demand pattern is consistent with the current relatively low levels of agricultural intensification and small farm profitability in the country.

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ANNEXES

Annex 1: General assumptions

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

Source: Authors' assumptions based on field data and MoFA reports.

Annex 2: Model assumptions

No.	Components	Assumption details
1	Three models: 1 tractor & 1 plow	Model 1: Normal business model (2010 market prices, no subsidy) John Deere tractor 55hp & 3-disc plow: 34,222 GH¢ Model 2: Subsidized model (33% subsidy on 2010 negotiated price) John Deere tractor 55hp & 3-disc plow: 12,969 GH¢ Model 3: Used hand tractor Tractor & plow: 7,300 GH¢
2	Tractor field capacity	9.88 acres/day (4ha)
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	8 GH¢
10	Maintenance and repairs costs	7% of commercial tractor and plow prices
11	Shed building costs	1,400 GH¢
12	Shed useful life (years)	10 years
13	Annual shed depreciation	10% of shed building costs
14	Office rental per year	100 GH¢
15	Comprehensive insurance per year	571.02 GH¢
16	Business registration (one-time payment)	100 GH¢
17	Business renewal per year	20 GH¢
18	Tractor registration at Driving License Authority	62.70 GH¢ (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 MoFA reports. GH¢ denotes Ghanaian Cedi.

Annex 3: Region-specific assumptions

No.	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 (1operator & 1 assistant)	10% of plowing revenue	15% of plowing revenue

Source: Authors' assumptions based on field data and MoFA reports. GH¢ denotes Ghanaian Cedi.

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