

EVOLUTION OF AGRICULTURAL MECHANIZATION IN NIGERIA

Hiroyuki Takeshima and Akeem Lawal

Abstract: Demand for mechanization in Nigeria is growing in a fairly consistent way, as predicted by economic theories. The farming system has intensified and the use of animal traction has grown at a substantial rate. Demand-side factors considerably explain the low adoption of tractors in Nigeria. Where demand is sufficient for tractors, the private sector has emerged over time as a more efficient provider of hiring services (particularly farmer-to-farmer services) than the public sector. Conditions are consistent with the hypothesis that, because of generally low support for the agricultural sector in Nigeria in the past few decades, agricultural mechanization (tractor use in particular) has remained low despite the declining share of the workforce engaged in the agricultural sector. Agricultural transformation in the form of a declining agricultural labor force has happened partly through the growth in the oil industry since the 1970s. Instead of inducing further exit from farming, tractor adoption in Nigeria might have helped those who have remained in farming to start expanding their production scale. A knowledge gap, however, remains regarding the dominance of large tractors and the potential effects of tractor adoption on smallholders who have yet to adopt them.

Demand-Side Analysis

Nigeria has a diverse production environment, including in its land-to-labor ratios and farm power use (Table 13.1).¹ The North Central region (NC)

This chapter is a shortened version of Takeshima and Lawal (2018), which also discusses in more detail the historical evolution of mechanization in Nigeria.

- 1 The remaining sections of this chapter rely primarily on the first and second rounds of the Living Standards Measurement Study–Integrated Surveys on Agriculture (LSMS-ISA) for Nigeria, jointly collected by the National Bureau of Statistics of Nigeria and the World Bank, as well as on various spatial variables. The first and second rounds of the LSMS-ISA covered the main production seasons in 2010 and 2012, respectively. These two rounds of the LSMS surveys contain 10,000 observations in total, among which approximately 6,000 observations are farm households.

TABLE 13.1 Farmland endowments, farm sizes, labor, and animal use by region, Nigeria, 2010 and 2012

Region	Agricultural area per capita (ha per capita) ^a		Farm size (ha)		Average manual farm power use (days per farm household per year)	
	Area divided by all households	Area divided by farm households	Average	Median	Labor (family + hired)	Animal traction
NW	0.41	0.46	0.8	0.5	227	6
NE excluding Taraba	0.68	0.74	2.0	1.2	302	9
NC + Taraba	0.73	0.86	1.5	0.8	493	1
South	0.14	0.21	1.0	0.2	380	0

Source: Authors' calculations based on data from Living Standards Measurement Study–Integrated Surveys on Agriculture, Nigeria, 2010 and 2012; Ramankutty et al. (2008); and Nigeria, NPC (2010).

Note: NC = North Central; NE = North East; NW = North West. a. Agricultural area per capita is calculated using the sum of cropped area and pasture area (data from Ramankutty et al. 2008), with population data obtained from the Nigeria 2006 Population Census (Nigeria, NPC 2010).

plus Taraba state is the most endowed with agricultural area per capita (both cropped area and pasture area). The intensity of animal traction is higher in the North East (NE) excluding Taraba and North West (NW) regions than in other zones, although the land-to-labor ratio is lower in NW. The south zones are generally less endowed with farmland per capita, and the use of animal traction is almost nonexistent. As is shown below, these patterns are correlated with the adoption of tractors. However, the use of farm power, particularly animal traction, may be still relatively lower than in Asia. For example, in Japan, animal power use was often 150 hours/year/ha (30 days per farm household if it was used 5 hours/day) in the 1950s, immediately before the widespread substitution of power tillers for animal power (Takeshima and Lawal 2018).

Machinery Use or Ownership by Farm Size

In the 2010 and 2012 rainy seasons, 4 percent and 24 percent of farm households in Nigeria used tractors and animal traction, respectively (Table 13.2), covering 7 percent and 25 percent of the cultivated area (Table 13.3). For tractors, these shares were higher in the NC and NE regions, and moderate in the South West (SW) region. Animal traction was used by more than 50 percent of farm households in the NW and NE regions, but it was almost never used in the south of the country. The use of draft animals is limited in southern Nigeria largely due to trypanosomiasis carried by the tsetse flies that are prevalent (Alsan 2015). Southern Nigeria is also characterized by root crops and tree crops cultivated on relatively heavy soils and hilly upland, compared with

TABLE 13.2 Percentage of farmers using tractors or animal traction in 2010 and 2012 rainy seasons in Nigeria

Region	Share (%) of farm households using tractors or animal traction				
	Tractors	Animal traction			No tractor or animal traction
		Total	Owned animal	Rented animal only	
Total	4	24	14	10	72
North West	2	55	30	25	44
North East excluding Taraba	6	63	42	21	32
North Central + Taraba	10	7	4	3	84
South East	1	0	0	0	99
South South	0	0	0	0	100
South West	5	0	0	0	95

Source: Authors' calculations based on Living Standards Measurement Study—Integrated Surveys on Agriculture, 2010 and 2012.

Note: Because of rounding, figures may not always add up to 100.

TABLE 13.3 Percentage of area using tractors or animal traction in 2010 and 2012 rainy seasons in Nigeria

Region	Share (%) of cultivated area using tractors or animal traction				
	Tractors	Animal traction			No tractor or animal traction
		Total	Owned animal	Rented animal only	
Total	7	25	18	8	68
North West	1	68	46	23	31
North East excluding Taraba	5	61	44	17	36
North Central + Taraba	19	9	6	3	72
South East	1	0	0	0	99
South South	0	0	0	0	100
South West	4	0	0	0	96

Source: Authors' calculations based on Living Standards Measurement Study—Integrated Surveys on Agriculture, 2010 and 2012.

Note: Because of rounding, figures may not always add up to 100.

northern Nigeria, where more cereal crops are cultivated on relatively lighter soils and more flat land. This may partly explain the greater use of animal traction in northern Nigeria than in southern Nigeria.

Nigeria is largely dominated by smallholder farmers, with a median farm size of 0.5 ha and less than 10 percent of farm households cultivating 3 ha or more (Table 13.4). The adoption rates of tractors and animal traction

TABLE 13.4 Farm size distribution in Nigeria and corresponding mechanization levels, 2010–2012

Farm size (ha)	% of farm households	% of farm households using tractors	% of farm households using animal traction
0–0.09	16	1	8
0.1–0.49	34	2	22
0.5–0.99	21	4	39
1.0–1.49	11	4	41
1.5–2.99	11	9	43
3.0 and more	8	10	47

Source: Authors, based on data from Living Standards Measurement Study–Integrated Surveys on Agriculture 2010 and 2012.

Note: Because of rounding, figures may not always add up to 100.

are positively correlated with farm size, although the tractor adoption rates remain relatively low even among those cultivating 3 ha or more.

The information is limited regarding the farm size dynamics in Nigeria and whether farm expansion is an important motivation for mechanization. Although the share of population considered agricultural has declined over time, the absolute agricultural population has remained high (partly due to high population growth) and the average farm size has remained small in Nigeria. Therefore, a substantial farm expansion or shift in farm size distribution has not been observed in Nigeria.

There is no information, to the authors' knowledge, on all the types of tractors used in Nigeria. However, various sources of information suggest that most tractors used in the country are four-wheel tractors, with the horsepower ranging between 50 and 75, and the use of two-wheel tractors, or lower-horsepower four-wheel tractors, is still limited (Takeshima et al. 2015; World Bank 2014).²

Agroecological Conditions, Cropping Systems, and Farm Household Typologies

Tractor use is particularly correlated with rice, whereas tractor use on other crops is limited (Table 13.5). Tractors are used in as much as 30 percent of rice area in Nigeria, although the margins of error are large because of small samples. Importantly, most crops that are widely grown in Nigeria (maize,

2 There may be close to 500–1,000 functional power tillers in the country (Takeshima et al. 2014), considerably lower than the number of four-wheel tractors, which is around 30,000 (FAO 2016).

TABLE 13.5 Estimated area and area shares of tractor use in Nigeria, 2010–2012

Crop	Tractor-cultivated area (1,000 ha)	Share (%) of cropped area with tractor use
Rice	410–790	31 [21, 41]
Maize	140–240	6 [4, 8]
Sorghum	70–190	5 [3, 7]
Millet	20–50	2 [1, 3]
Cowpeas	50–90	4 [3, 5]
Groundnuts	10–60	3 [1, 5]
Cassava	50–120	3 [2, 4]
Yams	10–70	2 [1, 3]
Vegetables	0–10	1 [0, 2]

Source: Authors' calculations as the averages from Living Standards Measurement Study–Integrated Surveys on Agriculture (LSMS-ISA) 2010 and 2012.

Note: Due to the small sample size, we combine two waves of LSMS-ISA surveys and take the average from the two years. Lower- and upper-bounds of 95% confidence intervals are in square brackets.

sorghum, millet, and root crops) are “plow-negative,” meaning that plow use on them is difficult (Alesina, Giuliano, and Nunn 2013). Rice is the only “plow-positive” crop—one for which the plow is beneficial—widely grown in Nigeria, because the production of the other major plow-positive crop, wheat, is minimal due to high temperatures.

ASSOCIATIONS WITH FARM HOUSEHOLD TYPOLOGY

Mechanization is closely related to distinct farming systems in both northern Nigeria and southern Nigeria (Takeshima, Nin Pratt, and Diao 2013a; Takeshima 2016) (Table 13.6). In the south of the country, a higher share of tractor use is found among medium-scale, input-intensive rice growers who are highly mechanized, have higher incomes and more assets, and operate in remote areas facing higher real wages for land preparation. In the north, a higher share of tractor use is found among mechanized cereal growers who have higher incomes and more assets, operate in remote areas facing higher real wages for land preparation, and use inputs more intensively.

Patterns of mechanization still differ somewhat between the north and the south in Nigeria. In the north, mechanization, including tractor use, seems to lead to intensive production without much effect on area expansion. Some tractor renters are located remotely from the market and grow staple crops, such as maize, sorghum, millet, and legumes, mostly for subsistence. Input intensity is driven rather by the use of irrigation for more commercial crops such as rice and vegetables. Correlation between tractor use and either crop

TABLE 13.6 Major characteristics of each type of farm household in Nigeria, 2010

Variable	South						North					
	<i>c</i>	<i>mcy</i>	<i>c</i>	<i>syc</i>	<i>a</i>	<i>r</i>	<i>ms</i>	<i>msg</i>	<i>sgl</i>	<i>m</i>	<i>sgl</i>	<i>rv</i>
Main crop ^a												
Real wage	9	10	10	11	11	17	11	17	10	10	8	8
Population density	366	473	315	105	335	44	92	91	114	129	155	173
% literate	3	81	82	31	73	59	8	75	10	94	85	72
Household assets	91	292	283	260	333	763	184	437	174	478	257	343
Expenditures	46	85	69	42	118	112	35	53	32	53	36	57
% with nonfarm income	33	58	52	25	84	90	51	52	44	66	71	90
% owning some plots	10	12	14	8	37	48	36	41	20	25	23	3
% using irrigation	0	1	1	2	10	41	9	0	3	5	3	86
Total area	0.2	0.1	0.3	1.5	1.3	2.6	0.8	1.1	0.9	0.7	0.7	0.5
Fertilizer cost	0	0	0	0	0	93	26	5	0	60	27	67
Seed, chemical cost	0	4	0	33	34	87	14	26	4	27	11	39
% hiring harvesting labor	23	15	16	34	57	79	50	14	48	79	68	93
% with crop sales	70	80	56	95	100	90	62	75	59	68	56	62
% using animal traction	0	0	0	0	0	0	58	4	56	69	74	48
% using tractors	1	3	0	5	2	93	4	4	4	14	5	17
Number of observations	274	275	233	61	63	29	157	79	362	148	347	29

Source: Takeshima, Nin Pratt, and Diao (2013b).

Note: ^a Main crops are those grown by more than 50% of households in each type: *a* = cocoa; *c* = cassava; *g* = legumes; *l* = millet; *m* = maize; *r* = rice; *s* = sorghum; *v* = vegetables; *y* = yams.

sales or the intensity of inputs used is somewhat weaker in the north compared with the south. In northern Nigeria, it seems tractors are used mostly to replace labor rather than for intensification, and animal traction may be playing the role of an intermediate substitute for tractors.

In the south, due to the absence of animal traction, tractor use is more defining of the level of mechanization. In addition, farm size is generally smaller than in the north, and the farm size of tractor users appears relatively larger than that of nonusers. The intensity of input use among tractor-using farms also is more pronounced than in the north. Use of tractors is highly concentrated among the (irrigated) rice growers. In the south, the use of mechanization seems limited to area expansion for input-intensive production of certain crops, such as rice.

AGRICULTURAL WAGES

Reliable information on the trend of representative wages in Nigeria is scarce. Continued growth of the nonfarm sector and urbanization have been

TABLE 13.7 Real male wages per day in Nigeria for land clearing and land preparation (in kilograms of local rice grain at local purchase price), 2010–2012

Geopolitical zone	Sector	
	Urban	Rural
NW	4.0	3.5
NE excluding Taraba	4.5	4.0
NC + Taraba	6.5	3.5
SE	10.5	7.0
SS	9.0	7.0
SW	6.0	5.0

Source: Authors' calculations as median values from Living Standards Measurement Study–Integrated Surveys on Agriculture, 2010 and 2012.

Note: NC = North Central; NE = North East; NW = North West; SE = South East; SS = South South; SW = South West.

considered factors that provide upward pressures on rural farm wages. The rural population growth rate has been relatively modest at 1 percent/year, considerably lower than the urban population growth rate of 4.4 percent/year (World Bank 2016). Nominal farm wages, which often stand at around \$4–\$6³ per day (Takeshima, Nin Pratt, and Diao 2013a) are higher than the nominal wages in Asia, where the daily agricultural wages were often \$1–\$2 per day (in 2010 dollars) before the 2000s (Barker, Herdt, and Rose 1985; Nepal chapter of this book), when tractor adoption started growing.

However, real rural wages in Nigeria, when measured based on the local purchase price of a kilogram of cereals, are equivalent to around 4 kg (of local rice grain at the local purchase price) in northern Nigeria, and 6 kg in southern Nigeria (Table 13.7). The figures in northern Nigeria, where most tractor use is found, are still lower than they were in Asia when the mechanization level started rising—6 kg of rice in rural Bangladesh in 2001 (Zhang et al. 2014) and 8 kg in 1995 in Nepal (Takeshima 2017a). This is because of the generally high food price in Nigeria—for example, the farmgate price of rice in Nigeria is almost double that of Thailand (Gyimah-Brempong, Johnson, and Takeshima 2016). The current real farm wages in Nigeria, on average, may still be somewhat too low to induce wider-scale adoption of tractors.

3 Dollar figures are US dollars throughout the chapter.

TABLE 13.8 Determinants of the area cultivated by tractors (pseudo-panel double hurdle model; marginal effects evaluated at the mean of observations), Nigeria, 2010–2012

Dependent variable	Double hurdle model	
	Probability of using tractor	Area cultivated by tractors (ha)
Model	Probit	Truncated regression
$\ln(\text{cultivable land per capita})$.007***	-.011
Average area (ha) of owned or distributed land per plot	-.000	.153***
Number of owned or distributed plots	.002	.012
Household size	.001	.024
No. of working-age household members (no education, M)	-.004*	-.078
Primary education, M	.002	.018
Secondary education or above, M	-.001	.021
Koranic education, M	-.003	-.162
Any other education, M	-.019	.398*
No. of working-age household members (no education, F)	-.002	-.041
Primary education, F	.001	-.088
Secondary education or above, F	.003**	-.099**
Koranic education, F	.002	.009
Any other education, F	-.006	-.350
$\ln(\text{real district average farm wage})$.014	-.129
$\ln(\text{real asset value})$.003***	.023
Own draft animals (yes = 1, no = 0)	.002	-.246

Determinants of Tractor Use

Table 13.8 summarizes the key determinants of the area cultivated by tractors in Nigeria (technical details are provided in Appendix 13A). The figures shown are marginal effects on the probability of using tractors, and the area cultivated by tractors, measured at the mean values of each variable.

Results are generally intuitive. Doubling of agricultural land per capita raises the likelihood of tractor adoption by 0.7 percentage points. A greater land endowment relative to labor induces the use of tractors. A greater number of noneducated male working-age household members reduces the likelihood of tractor service adoption. Conversely, a greater number of working-age female members with at least a secondary education raises the adoption of tractor services. These results are consistent with the hypothesis that human capital formation induces the substitution of machinery for land-preparation

Dependent variable	Double hurdle model	
	Probability of using tractor	Area cultivated by tractors (ha)
Model	Probit	Truncated regression
<i>ln(real values of draft animals)</i>	-.000	.072*
Real price of 1 kg of fertilizer (average of urea and NPK)	.0007	-.007**
Soil with high workability (1 = workable, 0 = otherwise)	.014***	.770**
Bulk density of the soil (tons per m ³ of soil)	.041	-1.115
Clay contents of the soil (% of clay < 2 micrometers)	-.001**	-.022*
Distance to the nearest town with population of 20,000 (hours)	.001	-.094*
Euclidean distance to the nearest dam (geographical minutes)	-.006*	-.333**
Euclidean distance to the nearest river (geographical minutes)	-.183	-3.832
<i>ln(sample maximum owned and distributed land within district)</i> (ha)	.003**	n.a.
Time dummy (year 2012 = 1)	Included	Included
Sector dummy (rural = 1, urban = 0)	Included	Included
Correlated random effects components	Included	Included
Zonal dummies	Included	Included
Constant	Included	Included
σ	n.a.	4.292***
Number of observations	5,241	223

Source: Takeshima (2015a).

Note: Significance: *** 1 percent, ** 5 percent, * 10 percent. F = female; M = male; NPK = nitrogen, phosphate, and potassium. n.a. = not applicable.

labor. Once we control for human capital, farm labor wages in the area do not seem to affect tractor adoption, possibly indicating that it is the labor costs of household members that may induce substitution with tractors.

Doubling real asset values raises the adoption possibility by 0.2 percentage points, possibly because of the reduced risk aversion toward tractor services. Tractor service adoption is higher on more workable soil and soil with less clay content, possibly because of lower plowing costs. Adoption is also higher in areas closer to the nearest dam, possibly because of better access to formal irrigation facilities where intensive production, including mechanized plowing, can have high returns.

Upon the adoption of tractor services, the area cultivated by tractors depends largely on the average plot sizes and soil workability. A positive effect of the higher bulk density of soil may reflect the use of higher-horsepower

tractors (as indicated in Takeshima et al. 2014) that are more appropriate for cultivating a larger area. A greater number of highly educated female working-age household members has negative effects on tractor use intensity, though it has positive effects on tractor adoption. This reflects the general orientation of such households to be engaged in farming to a lesser extent. However, an increased number of male working-age household members with any type of education has a positive effect, indicating somewhat complicated effects of human capital.

Greater draft animal assets positively affect tractor use intensity. A greater endowment of draft animal assets indicates possibly greater demand for such animals, for which tractors can substitute. An increase in real fertilizer price reduces the extent of tractor adoption, potentially indicating that tractor and fertilizer may be gross complements (possibly because of the synergy between deeper tillage and soil nutrient absorption). Soil workability, lower clay content, and proximity to a dam also induce greater tractor use intensity.

Importantly, doubling the size of the largest owned and distributed land within the local government area (LGA) in the sample raises the possibility of tractor service adoption by 0.2 percentage points. This indicates that the supply of tractor service is somewhat constrained by the scarcity of large farm households that are likely to have an incentive to invest in tractors and serve nearby farmers.

Demand for Wider-Scale Adoption of Tractors in Nigeria

Because tractor use growth in Nigeria has been stagnating for a few decades, it is generally difficult to identify its primary drivers. However, certain factors are associated with greater smallholder mechanization demand.

The demand for mechanization in land preparation has grown to a sufficient level in various pockets within Nigeria, potentially warranting the development of a hiring market with smallholders as customers. The demand for tractor adoption is higher in NC, NE, and SW than in other zones, higher in rice areas than in areas with other crops, and higher in areas where land is relatively more abundant than labor.

In northern Nigeria, relatively widespread use of animal traction suggests that a farming system that involves fairly intensive plowing has evolved. In such an environment, greater farm endowment relative to labor seems an important determinant of tractor adoption.

The use of animal traction may be another indicator of the use of farm power that is substitutable with tractors. This is also consistent with the

correlation between more widespread animal traction use and tractor adoption in the north, particularly the NE region. However, the overall animal traction use intensity may still be lower compared with the use intensity in Asia. The average real wages are also still somewhat low. These factors may partly limit wider-scale adoption of tractors.

The prevalence of plow-negative crops (maize, millet, root crops) and the near absence of plow-positive crops such as wheat may limit the overall demand for tractor tillage in Nigeria. Although in the long run these crops are also likely to be mechanized, the cropping system may still limit the wider diffusion of tractor use in the short to medium term.

The demand for mechanized harvesting may be still generally low partly due to low overall yields and harvests, as well as low production intensity, with limited use of dry-season irrigation. The patterns in Nigeria, in which tractor tillage is observed to some extent (albeit in low intensity) and mechanized harvesting is still largely absent, are consistent with past sequential patterns, in which mechanization of land preparation has preceded the mechanization of harvesting.

Supply-Side Analysis

Machinery Purchase, Import, and Financing Policies

The Nigerian government has long intervened into domestic tractor markets, including subsidized tractor distribution. Until recently, subsidized tractor distribution had been similar to the nation's fertilizer subsidy program, in that both federal and state governments procured tractors and distributed them with subsidies. Subsidy rates have varied over time. Subsidies of 50–75 percent were common up to the early 1980s (Scherr 1989; World Bank 1985, 37). Sometimes the subsidies were provided to cooperatives or group farms. For example, a machinery ownership scheme launched in 1980 by the federal government provided half of the purchase cost of farm machinery to be owned and used by farming cooperatives or group farms (Manyong et al. 2005, 41). In the 2000s, the subsidy rates were slightly lower. For example, under the Obasanjo administration, the subsidy was typically 25 percent (Ladeinde et al. 2009). States often added subsidies, which vary from year to year. For example, the rate in Kaduna state was a 40 percent subsidy (25 percent by the federal government and 15 percent by the state government) in 2010 (Ajibola and Zalla 2011, 3), but it rose to 50 percent (with the state government

contribution increasing to 35 percent) in 2013.⁴ Takeshima and others (2014) also provided detailed descriptions of current state-level tractor distribution systems in Kaduna state in Nigeria, which seemed to continue in various states even as the federal government discontinued the subsidized distribution of tractors in 2012.⁵

Government loans have also been made available, providing indirect subsidies in the form of interest rate subsidies. Details of government loan arrangements were not revealed to the authors and are expected to vary across states and over time. Informal interactions with the beneficiaries of subsidized tractors indicate that a recent common arrangement is an interest-free loan with a three-year payback period. Costs are, however, also often incurred due to delays in loan approval or through various transaction costs paid either by beneficiaries for subsidy applications or by the government for monitoring repayment (Takeshima et al. 2014).

The quantities distributed with subsidies were also determined ad hoc, often depending on the budget availability, and varied from year to year. The number of subsidized tractors distributed in the country was likely the highest from the late 1970s to the early 1980s. From 1975 to 1983, 22,000 (mostly imported) tractors were sold at subsidized prices to parastatal agencies, such as the River Basin Development Agencies, and to large-scale private companies (Jabbar 1995), as well as cooperative societies, group farmers, and retired tractor operators to run tractor hiring units, or THUs (Akinbamowo 2011). The federal government's expenditure on the tractorization program increased from 11 million Nigerian naira, or NGN (about \$16 million at the time, or \$85 million in 2010 dollars), during the first five-year plan (1970–1974) to NGN 54 million in 1975–1979 (about \$86 million then, or \$319 million in 2010 dollars), and NGN 240 million during the third plan, 1980–1985 (about \$341 million then, or \$775 million in 2010 dollars) (Jabbar 1995, 101). In the 2000s, the number of tractors distributed by the federal government was often around 1,000 per year, but tractors were not distributed every year (Bello 2005).

Trade, Import Policies (Tariffs, Direct Restrictions, and Other Interventions), and Parts

In the early 1970s, import policies regarding tractors and agricultural equipment were generally liberalized (Manyong et al. 2005). During the 1970s, the

⁴ Personal communication with the Kaduna State Ministry of Agriculture (June 15, 2019).

⁵ Personal communication with Federal Ministry of Agriculture and Rural Development officials (June 16, 2019).

import duty on raw materials used to manufacture pipes, electronics, metal fabrications, and kitchen utensils was abolished (Egwaikhide 1999). Although trade policies became generally more restrictive in the early 1980s, the majority of importation of agricultural tractors was largely government-led between the late 1970s and the early 1980s, and was less dependent on trade policies.

After the Structural Adjustment Program (SAP) that started in the mid-1980s, private-sector tractor importation was unregulated, except for the imposition of tariffs. However, tractor importation was still mostly led by the government, and the private sector's importations of four-wheel or two-wheel tractors remained small. This continued to be the case into the 2010s, when the government was importing approximately 900 tractors a year and the private sector brought in around 100 (World Bank 2014).

Import tariffs have been generally imposed on tractors and spare parts in Nigeria. Import duties (customs duties) have accounted for the bulk of import tariffs on agricultural tractors. Even after the introduction of value-added tax (VAT) in 1994, agricultural equipment, including tractors and spare parts, has often been exempt from VAT. Only recently, VAT has become imposed on certain types of agricultural tractors: 5 percent for fully built tractors imported, but still 0 percent for completely-knocked-down (CKD) and semi-knocked-down (SKD) tractors imported, as of October 2016 (Takeshima & Lawal 2018).

Import duties on component parts of commercial vehicles and tractors were reduced from 25 to 5 percent by 1989 (Busari and Udeaja 2007). Import duties for spare parts remained largely at 5 percent into the 2010s (World Bank 2014). Import duties for tractors have fluctuated but often remained less than 25 percent. Before 2005, import duties were often 0 percent for agricultural machinery (Manyong et al. 2005). More recently, some import duties have been imposed, which often differ between CKD, SKD, and fully built tractors (World Bank 2014). At times, including the latest tariff structure as of October 2016 (Takeshima & Lawal 2018), all types of agricultural tractors have been exempted from import duties.

CONCESSIONAL LOANS

Whereas concessional loans are often used as part of South–South cooperation in several countries in Africa south of the Sahara, including Nigeria, the use of concessional loans for tractor imports seems to have been less common in Nigeria. This may be partly because in Nigeria, the 37 state governments often import tractors, and imports by the federal government have generally accounted for a small share of total imports. It is, however, not surprising if

there are ongoing discussions between the state governments in Nigeria and foreign governments, which may later lead to the development of bilateral agreements.

Small tractors are generally less common in Nigeria, and importation of smaller Chinese tractors seems to have been minimal. This may be partly because China's concessional loans are not applied to tractor importations into Nigeria. In contrast, the shares of Indian four-wheel tractors seem to have been growing in Nigeria, including Mahindra and Sonalika brands, India's two major manufacturers. AGCO's Massey-Ferguson tractors are another new brand of tractor that is relatively commonly marketed. Both Mahindra and Sonalika set up tractor assembly lines in Nigeria in the late 2000s, to expand sales in both the Nigerian market and the rest of the West African region. Such growth seems to have been driven by the general growth of various private Indian companies' entries into Nigeria since its transition into a democratic regime in 1999 (Osondu-Oti 2015), rather than simply due to the Indian government's general interests in strengthening ties with Nigeria. Because Nigeria is the largest source of oil imported into India to meet its growing energy demand, this demand often motivates the use of concessional loans.

Industrial Policy on Machinery Manufacturing

Although Nigeria has attempted in the past to manufacture tractors domestically, it has largely failed. In the 1970s, two tractor assembly plants and the National Center for Agricultural Mechanization (NCAM) were established, with the aim of releasing 5,000 tractors per year (Jabbar 1995). Specifically, Nigeria Truck Manufacturers (NTM), assemblers of Fiat tractors as well as Fiat trucks, and Steyr Nigeria Ltd., assemblers of Steyr tractors and Steyr trucks, were both established in the 1970s. Similarly, Peugeot Automobile Nigeria Limited (PAN) and Volkswagen of Nigeria Limited (VWON) were established in Kaduna and Lagos, respectively, to assemble passenger cars from imported CKD parts and components, through joint ventures between the Nigerian government and the respective companies (Adubifa 1993, 43). However, both NTM and Steyr Nigeria Ltd. folded up within 10 years of their establishment, and PAN and VWON also closed within a short period of operations. Even while in operation, many of these companies complemented their sales with imported implements and equipment. Besides, government policy that production incorporate a minimum of 30 percent local content was never adhered to, because of the often low quality of locally produced raw materials such as steel (Adubifa 1993; Oni 2011).

Attempts to raise the local manufacturing capacity have also been made. Mechanization units have been set up within the Agricultural Development Projects as well as the state and federal governments. These institutions and NCAM have been assigned a mandate to coordinate the local research and development (R&D) conducted by 140 institutions, including universities, polytechnic institutes, research institutes, industrial development centers, incubation centers, and colleges of agriculture, and provide training for machine operators, mechanics, blacksmiths, and artisans at sites such as the Rural Artisan Training Support Unit in Ilorin (Ajibola and Zalla 2007). However, the extent of such activities, as well as the impact, is relatively unknown.

Machine Ownership and Market Institutions for Mechanization Service Provision

Currently, tractors in Nigeria are sold by both the large importers mentioned above and small and medium-size retailers. Several importers in Nigeria tend to meet the demand by institutional clients, such as state governments (for their tractor distribution programs), sugarcane estates, international groups, and Zimbabwean farmers in Kwara state (Ajibola and Zalla 2007; authors' fieldwork in 2014). These importers import either the finished product or equipment in CKD format, the latter of which is sold to distributors who assemble the machines. Some importers have specific clients and send technicians to provide services under contract (Ajibola and Zalla 2007). In addition, a number of tractor retailers, ranging from medium-scale retailers selling about 100 tractors per year to small-scale retailers selling 10–30 tractors per year (new, refurbished, or a combination of both), also operate in Nigeria. Small-scale retailers focus more on repair and maintenance; sales of tractors are often supplementary for them. These small retailers transact mostly with individual farmers. In Zaria, the second-largest city in Kaduna state, there are several small-scale retailers of this type. Small-scale retailers are likely to be the major source of secondhand tractors for individual buyers. Whereas some state governments still directly supply new tractors, these private-sector agents currently largely serve the tractor hiring service (THS) providers in Nigeria.

In Nigeria, there have been both THS providers run by the public sector and those run by the private sector. However, the public-sector THS has gradually been overtaken by that of the private sector. The Living Standards Measurement Study–Integrated Surveys on Agriculture (LSMS-ISA) survey indicates that a majority of THSs are provided by the private sector, as well as friends, neighbors, or relatives (Table 13.9).

TABLE 13.9 Sources of tractor services in 2010 rainy season (percentages), Nigeria

Source	Share (%)
Private markets	42
Government	28
Friends/neighbors	14
Relatives	10
Others	7

Source: Authors' calculations based on Living Standards Measurement Study–Integrated Surveys on Agriculture, 2010.

Note: The percentages are calculated using sample weights. Because of rounding, shares may not add up to 100.

PUBLIC-SECTOR TRACTOR HIRING SERVICES

In Nigeria, some of the first public-sector THUs were established in 1958 in the former Western region, which is now Oyo, Ondo, Ogun, and Bendel states (Makanjuola et al. 1990). The first National Development Plan (1962–1968) expanded THUs (Asoegwu and Asoegwu 2007). In the early 1970s, state governments were mostly in charge of the operation of government THUs (Manyong et al. 2005). Land clearing was also subsidized. Earlier THUs did not always provide services for farms. For example, at the Akure tractor station in southwestern Nigeria, 86 percent of the total work done in 1970 consisted of mowing school and police compounds (Kolawole 1972). Mechanics who could repair tractors were often few (Kolawole 1972). Public-sector THUs were expanded gradually after the 1970s. In 1983, more than 3,000 four-wheel and 300 single-axle tractors were in operation in more than 250 THUs distributed all over the country (Akinola 1987). In most cases, the government THUs were subsidized by 25–50 percent (Manyong et al. 2005), apart from the government's purchase of tractors and paying of wages and salaries (Akinbamowo 2011, 2).

By the mid-1980s, the government THUs were largely considered inefficient (Akinbamowo 2011); delays were frequent, forcing many farmers to travel distances of about 60 km or more about 10 to 15 times to visit the hire stations before being served (Akinola 1987, 66). By the mid-1980s, it was recommended that all government THUs be phased out within two years to be replaced by privately owned THUs (Akinbamowo 2011). For example, in Ondo state, THUs were commercialized by transferring 102 tractors and assorted equipment to the Ondo State Investment Holding Company (1989–1992) and later the Agricultural Inputs Supply Company (1992–1999)

(Akinbamowo 2011). Other government THUs were also gradually transferred to the private sector.

Recently, the federal government of Nigeria shifted its focus from the direct distribution of subsidized tractors to the promotion of private-sector THSs. Currently, the Nigerian government is pursuing a mechanization implementation program (MIP), which focuses on establishing private sector–managed tractor hiring enterprises called Agricultural Equipment Hiring Enterprises (AEHEs). The MIP also provides subsidies for small-scale farmers (those cultivating between 0.5 ha and 4.0 ha) who use tractor services. As of 2016, about 80 AEHEs had been set up within key industrial clusters, each with five tractors plus implements, five two-wheel tractors, and a few other harvesters or threshers, operated by the private sector, including farmers, cooperatives, or investors.⁶

PRIVATE-SECTOR TRACTOR HIRING SERVICES: FARMER-TO-FARMER SERVICE PROVISION

By the mid-1980s, private-sector THUs were growing (Akinola 1987). Whereas various types of tractor ownership and service provision have been promoted, including cooperative, joint, or enterprise ownership, as briefly mentioned above, the most common type is the individual ownership of tractors by farmers, who provide farmer-to-farmer THSs.

Although nationally representative figures are, to the authors' knowledge, unavailable, a case study of 111 tractor owners in two Nigerian states, Kaduna and Nasarawa (Takeshima et al. 2014), provides useful insights into key characteristics of the tractor owners. The case study compared two types of tractor owners: (1) government-sourced (GS) tractor owners, who selected and obtained tractors from the government, and (2) market-sourced (MS) tractor owners, who obtained tractors from the market.

BRANDS, SOURCES OF TRACTORS, AND FINANCING

Tractors owned by sampled tractor owners varied in terms of brand, including Fiat, Ford, Massey Ferguson, Mahindra, New Holland, Steyr, and Tak tractors. Common brands and financing of tractors differed considerably between the MS owners and GS owners. Typically, MS owners had obtained second-hand tractors, which were mainly Steyr, Fiat, and Ford brands, whereas GS owners had obtained new tractors (New Holland, Massey Ferguson), although Massey Ferguson and Mahindra were owned extensively by both MS and GS owners. Relatively few tractors were registered, despite the requirements to do

⁶ Personal communications with Federal Ministry of Agriculture and Rural Development staff, February 28, 2018.

so. This was particularly so among MS owners. For MS owners, 80 percent of tractor acquisition costs were financed by personal savings and informal loans. For GS owners, about 34 percent of the costs were financed by government loans, although 40 percent of the costs were still financed by private savings and informal loans.

KEY CHARACTERISTICS OF SERVICE PROVISION

Significant shares of tractor use are dedicated for the owners' own farms. [Table 13.10](#) summarizes the typical area cultivated by each tractor per year, through hiring out and own-farm use. Typically, own-farm use accounts for 25–30 percent of the total area served by tractors. Tractor owners often value tractors for own-farm use more than for hiring out; in terms of perceived value, own-farm use accounts for 33–50 percent of total value extracted from tractor use (Takeshima et al. 2014). Such higher perceived value of own-farm use may reflect higher marginal returns than the competitive market prices owners can charge for hiring out. MS owners in the sample cultivated greater area per tractor per year ([Table 13.10](#)). On average, MS owners operated 169 ha at the mean and 133 ha at the median. These are statistically significantly higher than the mean and median among GS owners—103 and 70 ha, respectively ([Table 13.10](#)).

Tractors are used for a few activities. [Table 13.11](#) summarizes how many hectares of different farming activities and how many hours of different non-farm activities tractors are used for. Typically, harrowing, plowing/tilling, and ridge making account for a majority of farming use. For each of these, own-farm use accounts for about a quarter of the total farming use of tractors. For nonfarm activities, transporting farm products or nonfarm goods accounts for the majority of tractor use. Own-farm use accounts for about 40 percent of total tractor use for nonfarm activities.

The extent of service provision is fairly seasonal, but MS owners are more active than GS owners throughout the year ([Figure 13.1](#), left-hand panel). The asterisks in the figure indicate statistically significant differences between the two groups (at 10 percent statistical significance). In June, MS tractor owners operated close to 150 hours per tractor on average, whereas they operated for only 44 hours in September. The off-season hours operated by MS owners were still often greater than those operated by GS owners.

[Figure 13.1](#), right hand-panel, illustrates the extent of travel by the service providers from home districts, measured in Euclidean distance, in each month. For example, on average, tractor owners stayed 6 km away from their home districts in January. This could mean either they spent the whole month

TABLE 13.10 Area cultivated annually per tractor (hectares per year), Nigeria, 2013

Category	Government-sourced tractor owners		Market-sourced tractor owners	
	Mean	Median	Mean	Median
Total farming	103	70	169*	133*
Hired-out farming	74	30	128	88
Own farming ^a	29	16	41	23

Source: Takeshima et al. (2014).

Note: * = 10 percent statistical significance. a. Counted multiple times if multiple operations (plowing, harrowing, ridge making) are applied to the same plots.

TABLE 13.11 Average annual tractor use by farming activity (all tractors combined), Nigeria, 2013

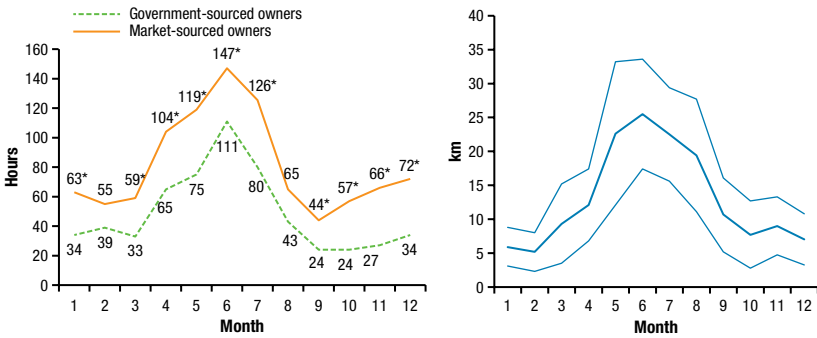
Type of activity	Hiring		Own farm		Total	
	Mean	Median	Mean	Median	Mean	Median
Farming (ha)						
Land clearing	1	0	0	0	1	0
Harrowing	74	33	21	11	94	60
Plowing, tilling	49	11	16	8	64	45
Ridge making	30	0	12	0	42	0
Rotovating	2	0	1	0	3	0
Planting, weeding	2	0	1	0	3	0
Harvesting	1	0	0	0	1	0
Total farming^a	156	74	51	25	208	124
Nonfarm activities (hours)						
Milling, threshing, processing	2	0	7	0	9	0
Transporting farm products	103	0	75	18	178	98
Transporting nonfarm goods	44	0	22	0	67	0
Local transportation	6	0	1	0	7	0
Fetching water	8	0	3	0	10	0
Firewood transport	13	0	5	0	17	0
Total nonfarm^a	177	10	112	30	290	179

Source: Takeshima et al. (2015).

Note: ^a Figures may not add up to total due to rounding.

in a district that is 6 km from their home district, or they spent half the month in their home district (0 km away) and the rest of the month in a district that is 12 km away (so that the within-month average is 6 km), regardless of the direction of travel. This is a crude, yet useful, indicator of how the extent of their travels varies across seasons. The extent of travel is generally

FIGURE 13.1 Seasonality of tractor use, hours per month, by tractor owners (left panel); average distance between home district and where hiring services are provided (right panel); Nigeria, 2014



Source: Takeshima et al. (2014), based on 111 samples of tractor owners in Nasarawa and Kaduna states combined.

Note: * Indicates the statistically significant difference from the figures for the government-sourced owners. In the right panel, the narrower lines indicate a 90% confidence interval around the average in each month.

low. On average, tractor owners stay only 10–15 km away from their home districts throughout the year. Distribution is also highly skewed, however, and the average is driven by a fraction of owners who spent time far away from their home districts. The operations are therefore generally confined to interviewees' home districts and to neighboring or adjacent districts, except for a few service providers who travel relatively long distances. Even during the peak season, service providers other than these long-distance travelers typically operate within a 25–30 km radius of their home districts. Typically, 75 percent of hiring services are provided within the LGA, and half of all hiring services are provided within the village. Moreover, a substantial share of operations is conducted on the tractor owners' own farms. Therefore, tractor owners typically conduct more than 80 percent of their operations within their own LGAs. MS owners are relatively more efficient than GS owners because, when they do travel, they tend to travel to areas with soils that are suitable for the horsepower of the tractors they own (Takeshima et al. 2015).

PROFITABILITY

Table 13.12 summarizes the revenues and costs of tractor use, by both GS owners and MS owners. MS owners earn annual revenues of \$13,000 at the mean and \$11,000 at the median (including the self-evaluated value of own-farm use), which are statistically significantly higher than those of GS owners (\$5,000 at the median and \$8,000 at the mean). For both types of owners,

TABLE 13.12 Profitability differences between types of tractor owner-operators (in US\$1,000s), Nigeria, 2013

Category	Government-sourced tractor owners		Market-sourced tractor owners	
	Mean	Median	Mean	Median
Total gross benefits per year	8	5	13*	11*
Monetary value of own-farm use	2	1	4	3
Farming activities	2	1	3	1
Nonfarm activities	0	0	1	0
Gross earnings from hiring out	6	4	9	6
Farming activities	5	3	7	5
Nonfarm activities	1	0	2	1
Payment for operators and fuel	3	1	5	3
Operators	1	0	2	1
Fuel	2	1	3	2
Maintenance and repair	1	1	1	1

Source: Takeshima et al. (2014).

Note: * = 10 percent statistical significance.

earnings from farming-related use account for 80–90 percent of total earnings. Earnings from hiring services account for 70 percent of total earnings. MS owners therefore use tractors to a greater extent than do GS owners for both own use and hiring, as well as for both farm and nonfarm activities. Differences of fuel and operator payments are small and statistically insignificant between MS owners and GS owners, as compared with the differences in the gross benefits. MS owners pay statistically significantly less for fuels, and sometimes for operators per unit for farming and nonfarm operations, than GS owners do (Takeshima et al. 2014). The maintenance and repair costs are not statistically significantly different between MS and GS owners.

In addition, in Nasarawa state, a significant share (23 percent) of sampled MS owners travel in a group. These group travelers earn more from hiring services than those who travel alone (Takeshima et al. 2014), indicating that forming a group is motivated by potentially greater returns.

Overall, there are private-sector THS providers in Nigeria who remain largely in the informal sector but have invested in tractors through personal savings and informal loans, and who provide more extensive services than those who are supported by the government. They do so despite the considerable seasonality in demand and generally limited mobility of tractors.

The Role of Mechanization in Agricultural Transformation

This section provides empirical evidence of various effects of the adoption of tractors on agricultural productivity, intensification, and farm household welfare, using the LSMS-ISA 2010 and 2012, and narratives based on past studies. These effects are estimated using the propensity score matching (PSM) method (detailed technical issues are discussed in Appendix 13B). The estimates should be interpreted as the effects experienced by actual tractor adopters and cannot be generalized to include the effects for nonadopters.⁷ Because most adopters operate relatively larger farms (although many are still smallholders), the findings cannot be generalized as potential effects for smaller farms that have yet to adopt tractors. Due to the low level of tractor use growth, it is generally difficult to assess the role of mechanization in agricultural transformation. This is particularly so for mechanized harvesting. There are, however, some observed effects of mechanization on key economic behaviors and outcomes, which offer insights into how mechanization is related to the agricultural transformation that is unique in Nigeria.

Substitution for Animal Traction

The clearest effect of tractor adoption is found in its substitution for animal traction (Table 13.13). Generally, on average, adopting tractors leads to a 2-day reduction in the use of animal traction (using owned and rented animals combined) and a 1.4-day reduction in the use of animal traction by the farmer's own draft animals. In addition, adopting tractors reduces the probability of using animal traction by 20 percentage points. This effect is statistically significant at 5 percent and also robust against the violation of the unconfoundedness assumption in the PSM. These effects hold both at the national level and within the North West and North East zones, where the use of animal traction is particularly high.

Significant Effects on Chemical Fertilizer Use and Area Cultivated

Tractor adoption is also found to significantly increase both the area cultivated, by 0.4 ha on average, and the likelihood of the use of chemical fertilizer, by 13.7 percentage points (Table 13.14). Tractor use therefore seems to induce greater use of land and chemical fertilizer. Although not shown, the effects on

7 This is because we rely on average treatment effects “on the treated” (adopters), whose consistency requires fewer assumptions than average treatment effects for the entire population.

TABLE 13.13 Effects of tractor adoption on animal traction use, Nigeria, 2010, 2012

Sample	Use of animal traction (days)	Use of own animal traction (days)	Use of rented animal traction (days)	Whether using animal traction (yes = 1)	Whether using own animal traction (yes = 1)
Whole sample	-1.91** (.86) [2.73]	-1.36** (.67) [2.98]	-.55 (.45)	-.20*** (.05) [2.11]	-.11** (.04) [1.50]
NW and NE	-2.20** (1.08) [1.76]	-1.28† (.87)	-.93† (.62)	-.22*** (.07) [1.87]	-.11* (.06) [1.27]

Source: Living Standards Measurement Study–Integrated Surveys on Agriculture, 2010, 2012.

Note: Statistical significance: *** 1%, ** 5%, * 10%, †15%. NE = North East; NW = North West. Numbers in parentheses indicate the standard errors. Numbers in brackets indicate the Rosenbaum bounds of the robustness of results.

TABLE 13.14 Effects of tractor adoption on chemical fertilizer use, crop revenues, and household income, Nigeria, 2010, 2012

Area cultivated	Use chemical fertilizer (yes = 1)	Real household income (PP period)	Real household income (PH period)	Real household income (PP and PH combined)
.410*** (.144) [1.23]	.137** (.060) [1.37]	.148† (.097) [1.30]	.136 (.098) [1.15]	.128† (.080) [1.22]

Source: Living Standards Measurement Study–Integrated Surveys on Agriculture, 2010, 2012.

Note: Statistical significance: *** 1%, ** 5%, * 10%, † 15%. PH = postharvesting; PP = postplanting. Numbers in parentheses indicate the standard errors. Numbers in brackets indicate the Rosenbaum bounds of the robustness of results.

cropping systems are found to be generally insignificant, indicating that such intensifications of land and chemical fertilizer use generally occur while preserving the current cropping systems.

Tractor use is also found to have slightly significant effects on household income (with less statistical significance). Specifically, it raises real household income during the postplanting period by 14.8 percent and in the postharvesting period to a lesser extent. Overall, tractor adoption seems to increase real household income by 13 percent. Although these effects are relatively less precise than those in [Table 13.13](#), due to the small sample size, they still indicate the general directions of tractor adoption's impacts.

Relatively Insignificant Effects on Labor Use

In contrast to the substitution for animal traction use and the effects on land and chemical fertilizer use and real household income, the effects of tractor adoption on labor use are generally insignificant ([Table 13.15](#)). In addition, the effects are also insignificant on hired labor for harvesting. The effects on labor are insignificant for both the postplanting season and the postharvesting season, as well as for male, female, and child workers. The impacts on off-farm

TABLE 13.15 Effects of tractor adoption on household labor use and off-farm income, Nigeria, 2010, 2012

Farm labor use from postplanting survey (person-days, 12-month equivalent)			Farm labor use from postharvesting survey (person-days, 12-month equivalent)			Hired labor use for harvesting (person-days)	
Adult males	Adult females	Children	Adult males	Adult females	Children	Males	Females
10.037 (12.123)	4.457 (12.134)	17.844 (22.019)	23.417 (22.549)	-18.035 (28.922)	-1.844 (30.792)	3.655 (4.029)	-367 (2.227)
Off-farm labor use from postplanting survey (person-days, 12-month equivalent)			Off-farm labor use from postharvesting survey (person-days, 12-month equivalent)			Nonfarm salary (equivalent to kg of cereals)	Probability of having nonfarm income (%)
Adult males	Adult females	Children	Adult males	Adult females	Children		
-3.474 (13.967)	-3.813 (17.485)	-18.845 (13.579)	12.151 (24.987)	2.480 (30.923)	4.298 (25.879)	-795.100 (1009.661)	7.2 (5.8)

Source: Living Standards Measurement Study–Integrated Surveys on Agriculture, 2010, 2012.

Note: Numbers in parentheses indicate the standard errors.

labor use, nonfarm salary, and the likelihood of having nonfarm income are also insignificant. Tractor adoption therefore may not be inducing significant transitions from farming to off-farm activities.

Overall, currently, the effect of mechanization on agricultural transformation in Nigeria is somewhat unique. Tractor adoption seems to be helping smallholders survive and become more productive, rather than inducing their exit from farming. This is partly consistent with the economic structures in Nigeria. The share of the labor force in the agricultural sector in Nigeria is already somewhat low given the level of mechanization; about 50 percent of the workforce has left farming even though the tractor adoption rate is only 8 percent (Takeshima 2015a). Those who are still in farming may be those who are less induced to exit farming due to various characteristics and household-specific constraints. Tractor adoption is used, rather, to help them become more productive.

In Nigeria, exit from farming has occurred without mechanization, possibly because of low agricultural support (such as R&D) and labor absorption in the nonfarm sector (oil sector, financial industry, and so on). Tractors seem to be primarily substituting for animal traction, rather than for labor. Mechanization itself does not induce a further significant exit from farming or shift of labor into the nonfarm sector. However, tractor use helps those who

have remained in farming to narrow their income gap with nonfarm households, partly by increasing area cultivated and the use of inputs such as chemical fertilizer.

Tractor Use and Soil Compaction

The effects of mechanization on soil compaction are known to be some of the key environmental consequences of applying greater weight on the plot. Whether these effects are particularly greater in Nigeria or not is still under investigation in the literature.

The heavy tractor weights are still one of the primary causes of soil compaction. In Nigeria, as was mentioned above, a majority of tractors imported are greater than 60 hp, with weights of more than 3.5 metric tons, which exceeds the limit set for soils resistant to compaction (Ahaneku and Asonibare 2014). Such a high average weight of tractors in Nigeria may be potentially damaging to the soils. Some soils are easily compacted; they include those that predominate in the fine sand and silt fractions in the Sahel, commonly found in northern Nigeria (Lal 1985). Similarly, for sandy loam soils in northern Nigeria, the dry bulk density of soils that changes due to tractor traffic before sowing does not get recovered during the production season (Mamman and Ohu 1997; Dauda and Samari 2002).

However, high-horsepower tractors do not necessarily cause more soil compaction than small tractors. This is because often soil compaction is aggravated by the greater number of passes, so that reducing the number of passes by using units that carry out several operations also generally reduces the soil degradation (Hamza and Anderson 2005). Sometimes stronger tractors are also needed to break up the compacted soils (Lal 1995). Sometimes yields respond to traction intensity in an inverted U-shaped curve—that is, they respond positively to the initial few tractor passes, and negatively afterward (Lal 1995). Similarly, animal traction can have a possibly significant effect on soil compaction (Soane and van Ouwerkerk 1994). Depending on its severity, switching from animal traction to tractors may not substantially aggravate soil compaction. Whereas the effects of soil compaction on Alfisols (Lixisols, Luvisols, and Nitisols) have been relatively commonly studied (Lal 1995), the effect on Fluvisols is generally understudied, even though Fluvisols are one of the major soil types in Nigeria on which tractors are used (Table 13.16). In addition, many earlier studies focused on crops other than rice (Lal 1995), although tractors are mostly used on rice in Nigeria.

TABLE 13.16 Soil types and tractor use in Nigeria, 2010, 2012

Soil type	Share of tractor-using households, by soil type (%)	Share of area cultivated by tractors, by soil type (%)
Fluvisols	26	34
Lixisols	5	29
Luvvisols	19	14
Nitisols	2	9
Arenosols	4	6
Leptosols	7	5
Plinthosols	5	2
Others	32	1

Source: Authors' calculations based on data from Living Standards Measurement Study–Integrated Surveys on Agriculture (2010 and 2012 combined) and FAO et al. (2012).

Conclusions

The adoption patterns suggest that demand for mechanization in Nigeria is growing in a fairly consistent way, as predicted by economic theory. Substantial growth in the adoption of animal traction indicates that the demand for increased farm power is rising in Nigeria, consistent with the increase in overall population density. At the intensive margin, however, adoption of animal traction may still be low. Real farm wages may still be low in northern Nigeria. These factors are consistent with the low overall demand for tractor use in Nigeria. Where tractors are adopted, adoption seems induced by greater overall farmland endowment per population in the area, a larger size of tractor owners' farms, and cropping systems centered around plow-positive crops such as rice. When there is sufficient demand for tractors, the private sector has emerged over time as the source of more efficient service providers (particularly farmer-to-farmer service providers) than the public sector as far as meeting greater demand and overcoming the seasonality of demand and limited mobility. These patterns are consistent with the experiences described in the Asian chapters. These conditions suggest that demand factors considerably explain the low adoption of tractors in Nigeria. Conditions are consistent with the hypotheses that (1) because of generally low support for the agricultural sector in the past few decades in Nigeria, the growth in the nonagricultural sector increased the country's reliance on food importation, rather than domestic production intensity, and (2) agricultural mechanization (tractor use in particular) has remained low despite the declining share of the workforce engaged in the agricultural sector. This is in contrast to experiences

in some Asian countries, such as Viet Nam (among others), where significant agricultural-sector investments in complementary technologies and agricultural infrastructure in the 1980s and 1990s partly led to the growth of mechanization in the 1990s and afterward.

Where tractors have been adopted, such adoption has generally helped smallholders to remain in farming, rather than inducing their exit from farming. This pattern is similar to experiences in some Asian countries, such as Nepal (as described in its chapter). Tractor adoption has not directly induced agricultural transformation in Nigeria. Agricultural transformation in the form of a declining agricultural labor force has happened partly through the growth of the oil industry since the 1970s. Tractor adoption might have, rather, helped those who remained in farming due to remoteness (and relative farmland abundance) to start expanding their scale of farming.

Last, there are still knowledge gaps, which need to be addressed in future studies. There are still signs of market imperfections (Takeshima 2015a). Accessibility of a custom hiring service may remain a constraint, possibly due to the dominance of expensive, high-horsepower tractors in Nigeria. It is unclear why small tractors are so few, relative to large tractors. Experiences in Asia suggest that technical support by the government through mechanization R&D on more diverse types of machines—rather than just large, high-horsepower tractors—may be needed to stimulate the private sector’s importation and adaptation of smaller tractors. Furthermore, agricultural productivity growth and tractor use growth have been stagnant in Nigeria. Because of this, the linkages between agricultural productivity growth and tractor use growth remain largely unknown, even though several of the Asian chapters point toward significant productivity effects of mechanization for smallholders. Future studies will have to continue investigating how the increase in labor costs affects smallholder farmers, how tractor use growth may help smaller farmers who are yet to adopt tractors, and how wider-scale mechanization growth continues to affect the economic transformation in Nigeria.

References

- Adubifa, A. 1993. “Technology Policy in National Development: A Comparative Study of the Automobile Industry in Nigeria and Brazil.” *Journal of Asian and African Studies* 28 (1–2): 42–53.
- Ahaneku, I. E., and O. F. Asonibare. 2014. “Compaction Characteristics of Some Agricultural Soils in Niger State of Nigeria.” *Agricultural Engineering* 4: 11–20.

- Ajibola, F., and T. Zalla. 2007. *Value Chain Study of Small-Scale Agricultural Mechanization*. DFID PrOpCom Monograph Series 9. London: United Kingdom Department for International Development.
- Akinbamowo, R. 2011. "Trends and Challenges to Government Tractor Hiring Units in Ondo State, Nigeria." *Journal of Agricultural Engineering and Technology* 19 (2): 1–8.
- Akinola, A. 1987. "Government Tractor Hire Service Scheme as a Tractorization Policy in Africa: The Nigerian Experience." *Agricultural Administration & Extension* 25 (2): 63–71.
- Alesina, A., P. Giuliano, and N. Nunn. 2013. "On the Origins of Gender Roles: Women and the Plough." *Quarterly Journal of Economics* 128 (2): 469–530.
- Alsan, M. 2015. "The Effect of the Tsetse Fly on African Development." *American Economic Review* 105 (1): 382–410.
- Asoegwu, S., and A. Asoegwu. 2007. "An Overview of Agricultural Mechanization and Its Environmental Management in Nigeria." *Agricultural Engineering International: The CIGR eJournal* 6 (9): 1–22.
- Barker, R., R. W. Herdt, and B. Rose. 1985. *The Rice Economy of Asia*. Washington, DC: Resources for the Future.
- Bello, A. 2005. Keynote address at commissioning of AFCOTT Mahindra Tractor Assembly Plant, Eleyele, Ibadan, Nigeria, September 15.
- Busari, D., and E. Udejaja. 2007. "Tariff and Factor Allocation in a Small Open Economy: Nigeria." *Economic and Financial Review* 45 (2): 73–98.
- Chamberlain, G. 1984. "Panel Data." In *Handbook of Econometrics*. Vol. 2, edited by Z. Grilliches and M. D. Intriligator, 1247–1318. Amsterdam: North-Holland.
- Cochran, W., and D. Rubin. 1973. "Controlling Bias in Observational Studies: A Review." *Sankhyā: The Indian Journal of Statistics, Series A* 35 (4): 417–446.
- Cragg, J. G. 1971. "Some Statistical Models for Limited Dependent Variables with Application to the Demand for Durable Goods." *Econometrica* 39 (5): 829–844.
- Dauda, A., and A. Samari. 2002. "Cowpea Yield Response to Soil Compaction under Tractor Traffic on a Sandy Loam Soil in the Semi-Arid Region of Northern Nigeria." *Soil Tillage Research* 68: 17–22.
- Egwaikhide, F. 1999. *Determinants of Imports in Nigeria: A Dynamic Specification*. African Economic Research Consortium Research Paper 91. Nairobi.
- FAO (Food and Agriculture Organization of the United Nations). 2016. FAOSTAT database. Accessed August 31, 2016. <http://faostat.fao.org>.

- FAO, IIASA (International Institute for Applied Systems Analysis), ISRIC (International Soil Reference and Information Center), ISSCAS (Institute of Soil Science—Chinese Academy of Sciences), and JRC (Joint Research Center of the European Commission). 2012. Harmonized World Soil Database, vers. 1.2. Accessed August 1, 2012. www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/.
- Gyimah-Brempong, K., M. Johnson, and H. Takeshima. 2016. *The Nigerian Rice Economy: Policy Options for Transforming Production, Marketing, and Trade*. Philadelphia: University of Pennsylvania Press.
- Hamza, M., and W. Anderson. 2005. "Soil Compaction in Cropping Systems: A Review of the Nature, Causes and Possible Solutions." *Soil and Tillage Research* 82 (2): 121–145.
- Jabbar, M. 1995. "Energy and the Evolution of Farming Systems: The Potential for Mixed Farming in the Moist Savannas." In *Moist Savannas of Africa: Potentials and Constraints for Crop Production: Proceedings of an IITA/FAO Workshop Held from 19–23 September 1994, Cotonou, Republic of Benin*, edited by B. T. Kang, I. O. Akobundu, V. M. Manyong, R. J. Carsky, N. Sanginga, and E. A. Kueneman, 87–104. Ibadan, Nigeria: International Institute of Tropical Agriculture.
- Kolawole, M. 1972. "Economic Aspects of Tractor Contracting Operations in Western Nigeria." *Journal of Agricultural Engineering Research* 17 (4): 289–294.
- Ladeinde, M., E. Atanda, A. Ageh, S. Idowu, and S. Olayemi. 2009. "Agricultural Machinery Operators and Mechanics Training in Nigeria: An Overview of Contributions." *Journal of Agricultural Engineering and Technology* 17 (2): 11–18.
- Lal, R. 1985. "A Soil Suitability Guide for Different Tillage Systems in the Tropics." *Soil and Tillage Research* 5 (2): 179–196.
- . 1995. *Tillage Systems in the Tropics: Management Options and Sustainability Implications*. FAO Soils Bulletin 71. Rome: Food and Agriculture Organization of the United Nations.
- Makanjuola, G. A. 1990. *Agricultural Mechanization Policies and Strategies of Africa: A Case Study of Nigeria*. Workshop on Agricultural Mechanization in Commonwealth Africa. Ahmadu Bello University, August 13–17.
- Mamman, E., and J. Olu. 1997. "Miller Yield as Affected by Tractor Traffic in a Sandy Loam Soil in Borno State, Nigeria." *Soil Tillage Research* 42: 133–140.
- Manyong, V., A. Ikpi, J. Olayemi, S. Yusuf, B. Omonona, V. Okoruwa, and F. Idachaba. 2005. *Agriculture in Nigeria: Identifying Opportunities for Increased Commercialization and Investment*. Ibadan, Nigeria: International Institute of Tropical Agriculture.
- Nigeria, NPC (National Population Commission). 2010. *2006 Population and Housing Census: Priority Tables, Volume III, Population Distribution by Sex, State, LGA & Senatorial District*. Abuja, Nigeria.

- Oni, K. C. 2011. *Man, Machine and Food Insecurity*. Inaugural Lecture Series 94. Ilorin, Nigeria: University of Ilorin.
- Osondu-Oti, A. 2015. "An Appraisal of India-Nigeria Historical and Contemporary Relations." *Alternation* 15: 102–126.
- Ramankutty, N., A. Evan, C. Monfreda, and J. Foley. 2008. "Farming the Planet: 1. Geographic Distribution of Global Agricultural Lands in the Year 2000." *Global Biogeochemical Cycles* 22 (1): 1–19.
- Rubin, D. 2001. "Using Propensity Scores to Help Design Observational Studies: Application to the Tobacco Litigation." *Health Services and Outcomes Research Methodology* 2 (3–4): 169–188.
- Scherr, S. 1989. "Agriculture in an Export Boom Economy: A Comparative Analysis of Policy and Performance in Indonesia, Mexico and Nigeria." *World Development* 17 (4): 543–560.
- Soane, B., and C. van Ouwerkerk. 1994. "Soil Compaction Problems in World Agriculture." In *Soil Compaction in Crop Production*. Vol. 11, edited by B. Soane and C. van Ouwerkerk, 1–26. Amsterdam: Elsevier.
- Takeshima, H. 2015. *Market Imperfections for Tractor Service Provision in Nigeria: International Perspectives and Empirical Evidence*. IFPRI Discussion Paper 01424. Washington, DC: International Food Policy Research Institute.
- Takeshima, H. 2016. "Understanding Irrigation System Diversity in Nigeria: A Modified Cluster-Analysis Approach." *Irrigation and Drainage* 65 (5): 601–612.
- Takeshima, H. 2017. *Overview of the Evolution of Agricultural Mechanization in Nepal, with a Particular Focus on Tractors and Combine Harvesters*. IFPRI Discussion Paper 01662. Washington, DC: International Food Policy Research Institute.
- Takeshima, H., H. Edeh, A. Lawal, and M. Isiaka. 2014. *Tractor Owner Operators in Nigeria: Insights from a Small Survey in Kaduna and Nasarawa States*. IFPRI Discussion Paper 01355. Washington, DC: International Food Policy Research Institute.
- . 2015. "Characteristics of Private-Sector Tractor Service Provisions: Insights from Nigeria." *Developing Economies* 53 (3): 188–217.
- Takeshima, H., and A. Lawal. 2018. *Overview of the Evolution of Agricultural Mechanization in Nigeria*. IFPRI Discussion Paper 01750. Washington, DC: International Food Policy Research Institute.
- Takeshima, H., A. Nin Pratt, and X. Diao. 2013a. *Agricultural Mechanization Patterns in Nigeria: Insights from Farm Household Typology and Agricultural Household Model Simulation*. IFPRI Discussion Paper 01291. Washington, DC: International Food Policy Research Institute.

- . 2013b. “Mechanization and Agricultural Technology Evolution, Agricultural Intensification in Sub-Saharan Africa: Typology of Agricultural Mechanization in Nigeria.” *American Journal of Agricultural Economics* 95 (5): 1230–1236.
- Takeshima, H., and E. Nkonya. 2014. “Government Fertilizer Subsidy and Commercial Sector Fertilizer Demands: Evidence from the Federal Market Stabilization Program (FMSP) in Nigeria.” *Food Policy* 47: 1–12.
- World Bank. 1985. *Nigeria: Agricultural Sector Memorandum*. Report No. 4723-UNI. Vols. I and II. Washington, DC: World Bank.
- . 2014. *Agribusiness Indicators: Nigeria*. Washington, DC: World Bank.
- . 2016. *World Development Indicators*. Washington, DC: World Bank.
- Zhang, X., S. Rashid, K. Ahmad, and A. Ahmed. 2014. “Escalation of Real Wages in Bangladesh: Is It the Beginning of Structural Transformation?” *World Development* 64: 273–285.

Appendix 13A: Specifications for the Pseudo-Panel Double Hurdle Model (Table 13.8)

Results for [Table 13.8](#) were obtained through the following regressions. The adoption of tractors and its intensity (area cultivated) are in one way characterized as the variant of the hurdle model, in which there is a hurdle in accessing the tractor hiring market (which represents the majority of modes of tractor use among farmers in Nigeria). Following the transaction costs literature, this process is framed as follows:

$$d = f(X, Z),$$

$$T = g(X) \text{ if } d = 1,$$

where $d^1 = 1$ if the farm household hires in tractor service (= 0 otherwise), and T is the hiring intensity. Z represents the specific factors that affect only the decision to hire tractors, X represents the factors that affect both the decision to hire tractors and how much area on which to use tractors (such as agroecological conditions, households' farm sizes, farm wages, and access to general output and input markets other than a tractor hiring service), and Y represents factors that affect both processes. The first equation can typically be estimated by a probit model in which the dependent variable d is regressed on X and Z . The second equation can be estimated using a truncated regression. Estimation of these two equations lead to Cragg's (1971) double-hurdle model.

The specification also applies the idea of a correlated random-effects model as in Chamberlain (1984) and its pseudo-panel extension (Takeshima and Nkonya 2014) to control for some of the potentially unobserved cohort-specific effects. Specifically, we use LGAs as such cohorts. We assume that LGA sample averages of certain time-variant variables across two rounds of LSMS surveys are correlated with the unobserved LGA-specific effects.⁸ Inclusion of these cohort variables reduces the potential bias in the pooled cross-section method.

Marginal Effects

Marginal effects of the variable k on the probability of using a tractor, evaluated at the mean of observations, are as follows:

$$\frac{\partial \text{Prob}(d=1)}{\partial X_k} \Big|_{X=\bar{X}} = \phi(\bar{X}\tilde{\beta})\tilde{\beta}_k,$$

where $\phi(\cdot)$ is the standard normal density function and $\bar{X}\tilde{\beta}$ is the linear prediction calculated with \bar{X} , a vector of sample mean values of each variable (among 5,241 observations), and $\tilde{\beta}$, a vector of estimated coefficients from the probit regression. $\tilde{\beta}_k$ is the estimated coefficient for variable k .

Marginal effects of variable k on the area cultivated by tractors, conditional on using tractors, evaluated at the mean of observations, are:

$$\frac{\partial \text{E}(T|T>0,X)}{\partial X_k} \Big|_{X=\bar{X}} = \hat{\gamma}_k \left[1 - \lambda\left(\frac{\hat{X}\hat{\gamma}}{\hat{\sigma}}\right) \left\{ \frac{\hat{X}\hat{\gamma}}{\hat{\sigma}} + \lambda\left(\frac{\hat{X}\hat{\gamma}}{\hat{\sigma}}\right) \right\} \right],$$

where

$$\lambda(\cdot) = \frac{\phi(\cdot)}{\Phi(\cdot)},$$

in which $\Phi(\cdot)$ is the standard normal distribution function. T is the dependent variable (area cultivated by tractors), and $\hat{X}\hat{\gamma}$ is the linear prediction calculated with \hat{X} , a vector of sample mean values of each variable (among 223 observations that actually use tractors), and $\hat{\gamma}$, a vector of estimated coefficients from the truncated normal regression. $\hat{\sigma}$ is the estimated standard deviation of the underlying truncated normal distribution. $\hat{\gamma}_k$ is the estimated coefficient for variable k .

8 We focused on LGA-level unobserved fixed effects (and thus pseudo-panel fixed effects), rather than household-level fixed effects, because the household characteristics exhibited considerable deviations between two rounds of LSMS and it was unclear whether households were actually panel households. However, their reported LGAs were likely to be correct in both rounds.

Appendix 13B: Balancing Properties of the Propensity Score Matching Analysis

As was seen in the main text, the extent and depth of the adoption of tractors vary considerably across geopolitical zones within Nigeria. Comparing adopters and nonadopters of tractors in very different environments often biases the estimates of tractor adoption. We therefore focus on specific regions with relatively favorable environments for intensifying tractor adoption. Specifically, we focus on farm households in LGAs that have at least one tractor adopter and one nonadopter, and are included in the samples in LSMS-ISA 2010 and 2012. Furthermore, we exclude farm households cultivating more than 5 ha of land, which account for approximately 5 percent of samples, to improve the matching quality. The application of PSM shows that selected samples and estimated propensity scores satisfy requirements for sufficient balancing properties (Table 13B.1). Table 13B.2 shows the set of variables used and their effects on propensity scores. Note that, because we focus on specific subsamples for our analyses in PSM, the set of variables is somewhat different from those in Table 13.8.

TABLE 13B.1 Balancing properties of propensity score matching

Variable	Values
Rubin's B	0.35
Rubin's R	0.88
% of variables with statistically significant differences (at 10%) in means	0
Sample	
Control	537
Treated	168
Treated—on support	147
Total	705

Source: Living Standards Measurement Study—Integrated Surveys on Agriculture, 2010, 2012.

Note: In a well-balanced sample, Rubin's B should be less than 0.4, Rubin's R should be between 0.5 and 2.0 (Cochran and Rubin 1973; Rubin 2001), and few variables should have statistically significant differences in means between adopter and nonadopter samples.

TABLE 13B.2 First-stage regression of propensity score matching method

Variable	Coefficient
EA share (%) of vegetable producers	-.002
EA share (%) of sorghum producers	-.001
EA share (%) of maize producers	-.0002
EA share (%) of rice producers	.003***
EA share (%) of cassava producers	.0004
Annual precipitation (mm)	-.0004*
Terrain roughness	.004
Soil workability	-.142
Drought index (0 = severe, 100 = no drought)	-.0003
Household size	.003
Gender of household head (female = 1)	.229**
Age of household head	-.002
Share of noneducated working-age household members	-.092**
Own farmland	.087*
Area of own farmland (ha)	-.011
Real value of household assets (natural log)	.041***
Own draft animals	-.019
Distance to the nearest town with population 20,000	.040**
Real price of chemical fertilizer	.057
Number of farm plots	.020
Agricultural land per capita	.026
Euclidean distance to the nearest state governor–origin LGA	.115**
Real agricultural wages	-.044**
Soil bulk density	-.130
Soil clay contents	-.016***
Size of the largest farm area within EA (natural log)	-.020
Geopolitical zones dummy	Included
Year dummy	Included
Urban/rural sector dummy	Included
Sample size	705
Pseudo- R^2	.224

Source: Living Standards Measurement Study–Integrated Surveys on Agriculture, 2010, 2012.

Note: Asterisks indicate the statistical significance: *** 1%, ** 5%, * 10%. EA = enumeration area; LGA = local government area.