DYNAMICS OF THE FERTILIZER VALUE CHAIN IN MOZAMBIQUE

Helder Zavale, Delfim Villisa, G Matchaya, S. Nhlengethwa, Duque Wilson, & C. Nhemachena

Summary

Motivation	Mozambique is characterized by low agricultural productivity, which is associated with low use of yield-enhancing agricultural inputs. Only 3.8% of smallholder farmers used fertilizer, 3.4% used pesticide, 1.8% used manure, 5.2% used maize improved seed and 3.3% used irrigation. Moreover, fertilizer application rate averaged 5.7 Kg/ha in Mozambique during the period 2006 to 2015, which is considerably low by regional targets, yet constraints that affect fertilizer use have not been thoroughly investigated.
Purpose	The purpose of this study is to examine the constraints on fertilizer value chains in Mozambique as a first step towards informing policy on what strategies may be taken by stakeholders to improve fertilizer access by smallholder farmers.
Approach and methods	We use a combination of multivariate analysis and descriptive methods to achieve the study objectives in line with literature.
Findings	Our findings indicate that fertilizer use has both demand-side and supply-side constraints. Key demand-side constraints include liquidity constraints, limited awareness about the benefits of using fertilizer, and low participation in input and output markets. On the other hand, main supply-side constraints include high transaction costs, limited access to finance, and lack of soil testing results and corresponding fertilizer recommendations by soil type and crop soil.
Policy implications	Scaling up the input subsidy program through vouchers with demonstration plots and effective targeting could drive up smallholders' demand for fertilizer and fertilizer supply by strengthening a sustainable network of wholesalers and retailers.

Key words: Fertilizer use, yield-enhancing inputs, value chain, Mozambique

1 Introduction

Agricultural productivity is low in Mozambique. Data from World Development Indicator (WDI) show that cereals yield averaged about 0.8 metric tons (MT) per hectare (ha) in Mozambique

during the period 1996 to 2016, compared with average yields of 1.4 MT/ha in Tanzania, 1.6 MT/ha in Malawi, and 2.0 MT/ha in Zambia. As documented by Johnson et al. (2014), these yields also trail the general Southern African Development Community (SADC) Regional Indicative Strategic Development Plan target of 2 MT/ha. Over the same period, WDI data also show that cereals production in Mozambique jumped from 1.3 million MT in 1996 to 2.9 million MT in 2011, and then it registered a downward trend dropping to 1.7 million in 2016. This increase in cereals production in Mozambique could be associated with expansion in cultivated area under cereals because cereals yield is stagnant. According to data from WDI, average cereals yield in the late 1990s is comparable with that in the late 2000s (0.9 MT/ha during the period 1996 to 2000 versus 0.8 MT/ha during the period 2012 to 2016).

This low agricultural productivity in Mozambique is associated with limited use of yield-enhancing agricultural inputs such as fertilizer, improved seeds, and pesticides, among others. Data from the nationally representative 2015 Integrated Agricultural Survey (IAI) show that only 3.8% of the 4.0 million smallholder farmers used fertilizer in the agricultural season 2014/2015, 3.4% used pesticide, 1.8% used manure and 5.2% used maize improved seed.[1] Data from IAI illustrates that similar levels of yield-enhancing agricultural inputs usage were registered since the agricultural season 2001/2002. Agriculture is predominantly characterized by rain-fed agricultural systems as data from IAI 2015 show that only 3.3% of smallholder farmers used irrigation in the 2014/2015 agricultural season. Furthermore, data from the Statistics Division of the Food and Agriculture Organization of the United Nations (FAOSTAT) demonstrate that fertilizer application rate averaged 5.7 kilograms (Kg) per hectare of arable cropland in Mozambique during the period 2006 to 2015, compared with 6.1 Kg/ha in Tanzania, 31.7 Kg/ha in Malawi, and 38.7 Kg/ha in Zambia. This Mozambique's average rate of fertilizer application also lag far behind regional averages: 19.7 Kg/ha in Sub-Saharan Africa (SSA), 74.5 Kg/ha in Latin American and Caribbean (LAC) and 189.6 Kg/ha in Asia over the same period. On the other hand, the average fertilizer application rate in Mozambique fall short of the target of 50 Kg/ha by 2025 agreed by the African Heads of State in the 2006 Abuja Declaration on fertilizer for an African green

[1] Maize and cassava are the two most important crops in terms of both total number of growers and cultivated area. According to data from IAI 2015, the share of smallholder farmers who grew maize in the 2014/2015 agricultural season stand at 72.5%, and the crop accounted for 33.3% of the total cultivated area in the same agricultural season.

revolution. This commitment has been upheld by the African Head of States in the MALABO Declaration in June 2014.

Recognizing the low agricultural productivity and the paramount importance of improving agricultural productivity given its multiplier effects on food security and poverty, the Government of Mozambique (GoM), through the Strategic Plan for Agricultural Sector Development (commonly known by its Portuguese acronym PEDSA) 2010-2019, aimed at sustaining an average agricultural growth rate of 7% per year over the period 2010-2019 among other program development objectives (PDO). Although this PEDSA target is consistent with both the Comprehensive Africa Agriculture Development Program (CAADP) and the 2014 MALABO Declaration targets of at least 6% agricultural growth rate, it appeared to have been ambitious because registered agricultural growth rates were much lower. According to data from the Mozambique National Institute of Statistics (INE), real agricultural gross domestic product (GDP) grew on average at 2.9% per year over the period 2010-2017, while real GDP grew on average at 6.1% over the same period. Among other targets to induce the 7% growth rate in the agricultural sector, PEDSA target on fertilizer application was set at 25.0 Kg/ha. As shown above, average fertilizer application rate of 5.7 Kg/ha is well below PEDSA target.

Increased fertilizer usage (in terms of both proportion of farmers using fertilizer and fertilizer application rate), complemented especially with improved seed use and better land and crop management, play a paramount role in contributing to rapid and sustainable growth in agricultural productivity in Mozambique. Indeed, findings from Goujard et al. (2011) demonstrated that fertilizer usage (NPK 12:24:12 combined with urea) on average increased maize yield by 76.2% with farmer-saved traditional open pollinated varieties (1.22 MT/ha with no fertilizer versus 2.15 MT/ha with fertilizer) and by 105.2% with hybrid varieties (1.55 MT/ha with no fertilizer versus 3.18 MT/ha with fertilizer) in the agricultural season 2009/2010 in Central Mozambique. Furthermore, smallholder farmers' low fertilizer application rates coupled with small share of fertilizer users in Mozambique suggest that nutrients' outflows from the soils through cropping in general and leaching in high-rainfall areas are greater than nutrients' inflows through natural processes. Again, Folmer, Geurts and Francisco (1998) estimated that annual nutrient depletion rates in cultivated soils in Mozambique stood on average at 32.9 Kg/ha for Nitrogen (N), 6.4 Kg/ha for Phosphorus (P), and 25.0 Kg/ha for Potassium (K); and according to Henao and Baanante (1999), Mozambique is among the African countries with the highest nutrient depletion rates (with

more than 60 Kg/ha/year of NPK). These high nutrient depletion rates could rapidly degrade soils making them unsuitable for agricultural production, but fertilizers when applied in a sustainable way could help increase the stock of nutrients in the soils. Detailed studies that systematically analyze the fertilizer market dynamics in Mozambique are hard to find.

This paper is structured into seven sections including this introductory section. The second section briefly outlines the objective of the study, methodological approaches employed and the data used. The third section describes fertilizer usage in Mozambique, while the fourth section outlines the policy environment. The fifth section describes the structure, key players, challenges and opportunities in the fertilizer value chain; followed by the sixth section that summarizes the main lessons learned from the voucher subsidy program in Mozambique. The final section presents concluding remarks.

2 Objective, methods and data

Given the potential of fertilizer usage complemented with the observed low use of fertilizer, this study aims at describing the dynamics of fertilizer value chain in Mozambique. To achieve this objective, relevant government policy documents, empirical studies and reports were reviewed; complemented with analysis of secondary data gathered from various sources and key informant interviews.

We combined univariate analysis with multivariate analysis to identify factors that drive smallholder farmers' decision to use fertilizer. To do so, we employed data from a nationally representative Integrated Agricultural Survey (commonly referred to as IAI from its Portuguese acronym) administered by MASA. With a sample of 7,130 smallholder farmers covering the 2014/2015 agricultural season, the sample frame for IAI 2015 was derived from the National Population and Housing Census of 2007, employing a stratified clustered sample design (with stratification by province and agro-ecological zone). IAI 2015 covered 147 out of 158 districts and 780 primary sampling units (PSU); households are randomly selected with probability proportion to size. IAI 2015 collected a wide range of information: demographic characteristics, farm and non-farm activities, crop and livestock production, and household productive and non-productive assets. To complement the data from IAI 2015, we gathered agricultural production data, including fertilizer consumption, from the World Development Indicator (WDI) and Statistics Division of the Food and Agriculture Organization of the United Nations (FAOSTAT).

3 Fertilizer Utilization in the Agricultural Sector

Figure 1 displays trends in fertilizer consumption in the agricultural sector in Mozambique. This figure shows that fertilizer consumption trended upward jumping from 3.3 thousand MT in 2003 to 46.3 thousand MT in 2010. It then registered a downward trend, dropping to 21.0 thousand MT in 2016. In absolute terms, average annual growth rate of fertilizer consumption was much greater in the period 2003 to 2010 than in the period 2010 to 2016 (33.6% versus minus 11.5%). Despite the downward trend in fertilizer consumption during the later period, annual average fertilizer consumption is higher in the period 2010 to 2016 than in the period 2003 to 2010 (20.2 thousand MT versus 34.3 thousand MT, with an overall average of 27.2 thousand MT). This suggests that consumption of fertilizer has increased in Mozambique.

Figure 1 also illustrates that nitrogen is undoubtedly the most consumed fertilizer during the period 2003 to 2016; followed by phosphate and potash. Nitrogen accounted for 74.1% of the total fertilizer consumed over the period 2003 to 2016, phosphate for 15.3% and potash for 10.6%. However, there exists considerable variation from year to year. Over the period 2003 to 2016, the share of total fertilizer consumption accounted for by nitrogen ranged between 32.8% in 2004 and 93.6% in 2010; the share accounted for by phosphate ranged between 5.6% in 2010 and 41.1% in 2003; and the share accounted for by potash ranged between 0.8% in 2010 and 33.7% in 2004.

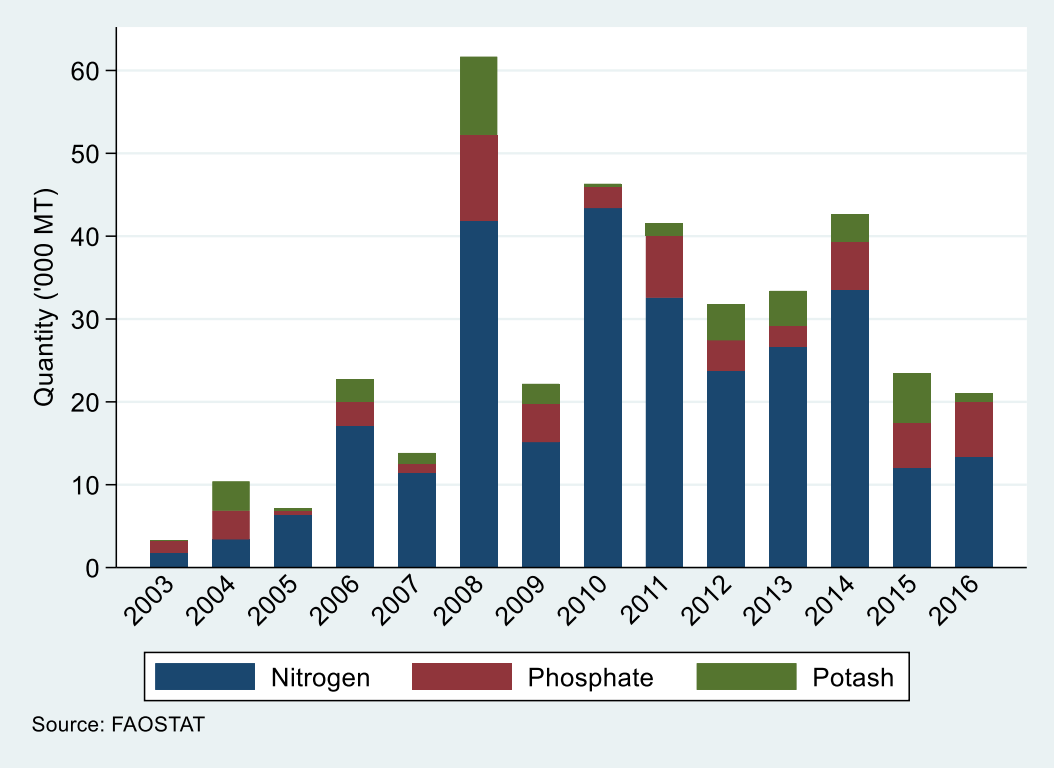

Figure 1 Fertilizer consumption in Mozambique

Fertilizer application rate varies substantially from year to year with no clear trend. Over the period 2003 to 2016, fertilizer application rate averaged 4.7 Kg/ha in Mozambique, ranging between 0.7 K/ha in 2003 and 10.9 Kg/ha in 2008. Like the total amount of fertilizer consumed, during the same period, nitrogen with 3.5 Kg/ha is undoubtedly the fertilizer with the highest application rate; followed by phosphate with 0.7 Kg/ha and potash with 0.5 Kg/ha; with considerable variation from year to year.

4 Structure, Key Actors, Challenges and Opportunities in the Fertilizer Value Chain

4.1 Smallholder farmers

Figure 2 depicts marketing channels through which fertilizer flows. At one end of the spectrum, we have smallholder farmers who use fertilizers. According to data from IAI 2015, about 150 thousand smallholder farmers used inorganic fertilizer in the 2014/2015 agricultural season, representing 3.8% of the total number of smallholder farmers in this agricultural season. This share of fertilizer users is small by any standards. Efforts should be put in place to increase the proportion of smallholder farmers using fertilizer as well as the fertilizer application rates among those who

use fertilizer. The proportion of smallholder farmers who use fertilizer varies from province to province. Tete with 22.8% and Niassa with 10.8% stand out as the provinces with the highest shares of smallholder farmers who used fertilizer; while Nampula with 0.9%, Zambezia with 0.5% and Sofala with 0.3% are the provinces with the lowest shares.

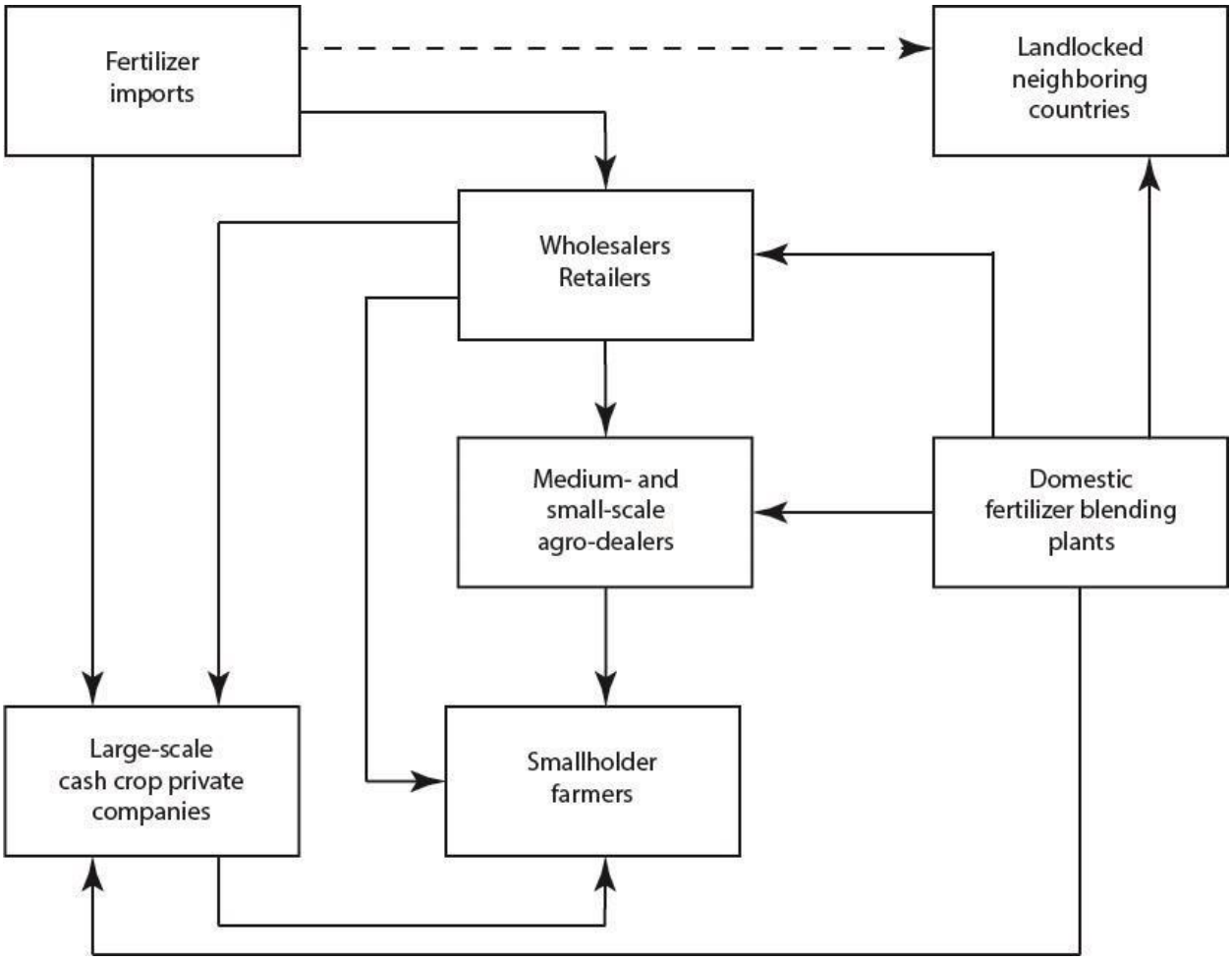

Figure 2 Fertilizer marketing channels

Awareness about the benefits of using fertilizer, skills in using fertilizer and liquidity constraints play a key role in influencing smallholder farmers' decision to use fertilizer. Duflo, Kremer and Robinson (2011) found that the proportion of farmers who used fertilizer in Kenya increased when farmers were given the option to purchase fertilizer immediately after harvest when the farmers had money and maize; hence, farmers faced lower liquidity constraint at the time they made the

decision to purchase fertilizer. In general fertilizer usage appears to be associated with a variety of factors and the importance of these factors is context-specific.

Table 1 illustrates household characteristics by fertilizer usage and shows that shares of smallholder farmers with access to extension services and with access to credit are higher among fertilizer users compared to non-users (3.6% versus 22.0% for extension service and 0.5% versus 5.4% for access to credit). Among fertilizer users, 29.8% of farmers had access to price information; as opposite to 12.9% among non-users. This could suggest that increasing smallholder farmers' awareness of fertilizer benefits combined with information about output prices could increase smallholder farmers' demand for fertilizer if they could afford to purchase fertilizer.

Given that a sizable share of smallholder farmers are resource poor (66.8% are asset poor, see Table 1), access to credit could play a key role in increasing smallholder farmers' demand for fertilizer. Although the share of farmers with access to credit is low (only 0.6% of smallholder farmers had access to credit), fertilizer users (5.4%) have more access to credit than non-users (0.5%). Although increased access to credit can increase fertilizer use by smallholder farmers, interventions that directly reduce fertilizer prices could be more effective in increasing demand for fertilizer given that fertilizer price is among the key determinants of smallholder farmers' demand for fertilizer especially among resource poor smallholder farmers who are the majority. Farmers are going to be reluctant to use fertilizer if it is not profitable.

Furthermore, increasing smallholder farmers' participation in output markets could also trigger increased smallholder farmers' demand for fertilizer given low market participation. Data from IAI 2015 demonstrate that 14.8% of maize growers sold their maize production, but maize market participation is higher among fertilizer users (20.0%) than among non-users (14.6%). Availability of market information could increase smallholder farmers' participation in output markets. Although there are no differences between fertilizer users and nonusers, the proportion of smallholder farmers who owned cellphone in the 2014/2015 agricultural season stands at 57.2%. This large share of smallholder farmers with access to cellphones suggests that cellphones could be used as a venue through which input and output market information – and other crop management information – could be passed on to smallholder farmers, contributing positively to increased smallholder farmers' demand for fertilizers.

Table 1 Characteristics of fertilizer users and non-users

	Fertilizer use			p-value for
	Non-users	Users	Total	difference
Access to extension service (1 = yes)	0.036	0.220	0.043	0.0000
	(0.006)	(0.032)	(0.006)	
Access to price information (1 = yes)	0.129	0.299	0.136	0.0002
	(0.013)	(0.044)	(0.012)	
Access to credit (1 = yes)	0.005	0.054	0.006	0.0046
	(0.001)	(0.017)	(0.001)	
HH is asset poor (1 = yes)	0.677	0.438	0.668	0.0000
	(0.021)	(0.035)	(0.020)	
Total cultivated area (ha)	1.414	2.080	1.444	0.0000
	(0.057)	(0.142)	(0.057)	
HH grew tobacco (1 = yes)	0.006	0.422	0.022	0.0000
	(0.002)	(0.061)	(0.004)	
HH grew cotton (1 = yes)	0.030	0.055	0.031	0.2725
	(0.007)	(0.025)	(0.007)	
Maize production (Kg)	347.54	793.66	371.17	0.0000
	(12.84)	(71.03)	(13.99)	
Area under maize (ha)	0.56	0.75	0.57	0.0025
	(0.02)	(0.06)	(0.02)	
Maize yield (Kg/ha)	929.7	1,766.4	973.8	0.0569
	(74.35)	(434.6)	(72.7)	
Observations	**6,783**	**347**	**7,130**	

Note: Standard errors are in parentheses.
Based on data from the Integrated Agricultural Survey (IAI) 2015

However, availability of market information should be complemented with better road networks (especially those linking areas with high agricultural potential to major consumption hubs). This is because transport costs are among the key impediments to smallholder farmers' input and output market participation. Data from National Road Administration (ANE) illustrate that Mozambique had 30.5 thousand kilometers of classified roads in 2017; of which 74.2% were classified as unpaved and the remaining as paved. Northern Mozambique with 38.1% and Central Mozambique with 36.3% are the regions accounting for the largest share of the total extension of unpaved roads in the country. Data from ANE show that of the 30.7 thousand kilometers of the total classified road in 2013, 48.2% are classified as being in bad conditions. As in the case of unpaved roads, the largest share of the total extension of roads in bad conditions are accounted for by Central Mozambique (39.9%) and Northern Mozambique (35.9%). This not-so-good road network in

Central and Northern Mozambique increase transport cost, creating barriers for smallholder farmers' participation in output markets as well as input markets.

Table 1 suggests that fertilizer users are more resource endowed than non-users. The proportion of households who are asset poor are greater for smallholder farmers who did not use fertilizer than those who used fertilizer (67.7% versus 43.8%). Furthermore, smallholder farmers who used fertilizer cultivated larger land areas and have more animals, compared with those who did not use fertilizers (2.1 ha versus 1.4 ha for cultivated land and 1.8 Tropical Livestock Unit (TLU) versus 0.9 TLU for animal ownership). This suggests that cash liquidity could be a major factor constraining smallholder farmers' decision to use fertilizer in particular and other yield-enhancing agricultural inputs in general. Data from IAI 2015 show that usage of improved maize seed is considerably higher among fertilizer users compared with fertilizer non-users (4.4% versus 23.9%). Proportions of smallholder farmers who use pesticide (1.7% versus 46.5%) and manure (1.1% versus 19.6%) are also considerably higher among farmers who used fertilizer than among farmers who did not use fertilizer. This could be an indication of the complementarity between fertilizer and improved seed and potential negative association between liquidity constraint and adoption of yield-enhancing agricultural inputs.

Fertilizer use appears to be associated with cultivation of traditional cash crops (tobacco, cotton, sugarcane). Table 1 illustrates that the proportion of smallholder farmers who grew tobacco is considerably higher among fertilizer users than fertilizer non-users (42.2% versus 0.6%). This finding could suggest that smallholder farmers apply fertilizer predominantly in traditional cash crops as opposite to food crops. It is also consistent with findings reported in the literature (Benson, Cunguara and Mogues, 2012; Nagarajan et al., 2015) suggesting that fertilizer are predominantly used by smallholder farmers who grow tobacco and sugarcane. Benson, Cunguara and Mogues (2012) document that 90% of fertilizer consumed in Mozambique go to tobacco and sugarcane fields. Furthermore, anecdotal evidence suggests that smallholder farmers who receive yield-enhancing agricultural input – including fertilizer – on credit as part of the contract farming with large-scale cash crop private companies deviate part of the received fertilizer to apply on food crops.

Smallholder farmers who used fertilizer have larger maize production and allocate more land to maize, compared to those who do not use fertilizer (794 Kg versus 347 kg for maize production

and 0.8 ha versus 0.6 ha for cultivated land under maize). Maize productivity is also higher among smallholder farmers who used fertilizer than those who did not use fertilizer (99.9 Kg per adult equivalent versus 207.5 Kg per adult equivalent and 929.7 Kg/ha versus 1,766.4 Kg/ha). It is worth pointing out that fertilizer use should be complemented with other yield-enhancing agricultural input especially improved seed. Figure 3 show that maize yield stood at 1,090 Kg/ha among farmers who used maize improved seed but did not use fertilizer, compared with 1,321 Kg/ha among farmers who used fertilizer but did not use maize improved seed and 3,037 Kg/ha among farmers who used both maize improved seed and fertilizer, suggesting complementarity between fertilizer and improved seed.

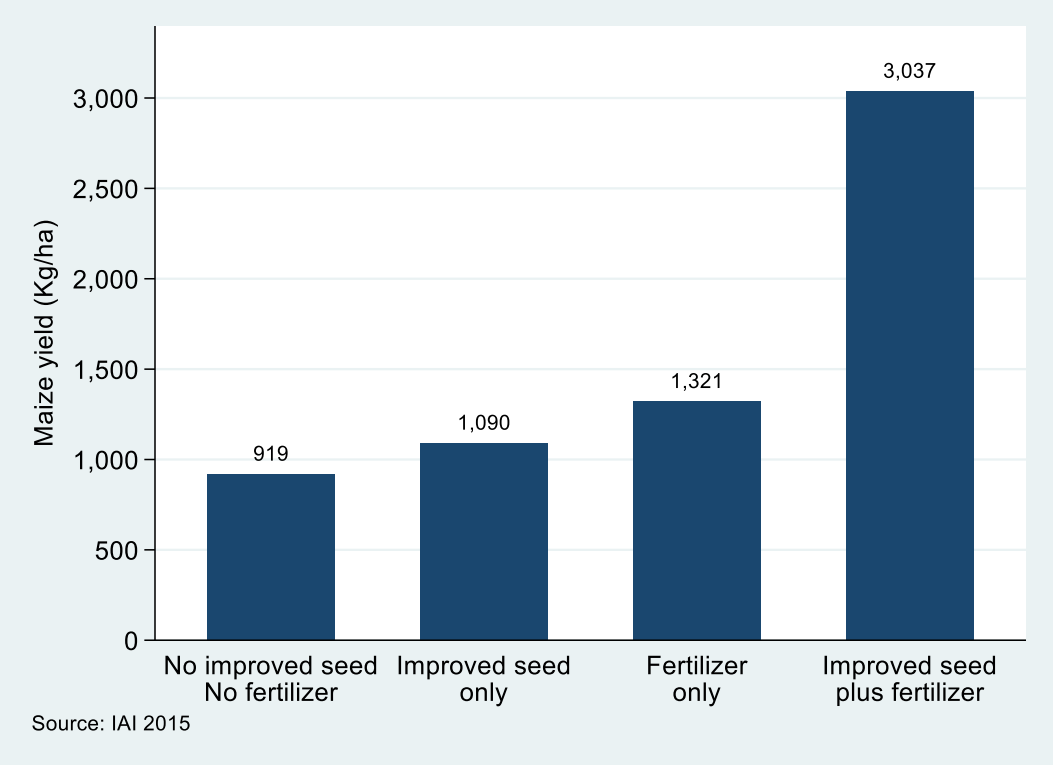

Figure 3 Maize yield by type of input used

To complement our univariate analysis, we employed multivariate analysis by investigating what factors influence the probability of using fertilizer employing Probit model. Table 2 summarizes the marginal effects of explanatory variables included in our Probit model. Findings show that

overall, the estimated model was statistically significant with an estimated chi squared of 1,395 (and corresponding p-value of 0.000). Overall, findings from the multivariate analysis presented in Table 2 are consistent with those from the univariate analysis (Table 1 versus Table 2).

Table 2 Marginal effects on the use of fertilizer

Dependent variable is fertilizer usage	Coefficient	p-value
HH headed by youth (1 = yes; 0 otherwise)	0.00722	0.0970
	(0.00435)	
HH size	0.00018	0.8090
	(0.00075)	
Female-headed HH (1 = yes; 0 otherwise)	0.00210	0.6750
	(0.00502)	
HH head's years of schooling	0.00004	0.9580
	(0.00067)	
Asset poor HH (1 = yes; 0 otherwise)	-0.00879	0.0940
	(0.00524)	
Total cultivated area (hectares)	-0.00004	0.9800
	(0.00145)	
HH had access to extension (1 = yes; 0 otherwise)	0.00534	0.5560
	(0.00907)	
HH received price information (1 = yes; 0 otherwise)	0.02415	0.0130
	(0.00975)	
Association membership (1 = yes; 0 otherwise)	0.01557	0.3070
	(0.01525)	
HH used improved maize seed (1 = yes; 0 otherwise)	0.04443	0.0090
	(0.01704)	
HH used irrigation (1 = yes; 0 otherwise)	0.08954	0.0000
	(0.01840)	
HH sold maize production (1 = yes; 0 otherwise)	0.01319	0.0110
	(0.00518)	
HH grew cotton (1 = yes; 0 otherwise)	0.02395	0.0880
	(0.01403)	
HH grew tobacco (1 = yes; 0 otherwise)	0.13058	0.0000
	(0.02563)	
Observations	**5,858**	

Note: Standard errors in parentheses
Based on data from the Integrated Agricultural Survey (IAI) 2015

Table 2 shows that factors that have significant impact on the probability of using fertilizer include whether the household (HH) is headed by a youth, whether the HH is asset poor, whether the HH received price information, whether the HH used improved maize seed, whether the HH used irrigation, whether the HH sold their maize production, whether the HH grew cotton, and whether the HH grew tobacco. HHs who are asset poor were associated with reduction of 0.8 percentage points in the probability of using fertilizer, compared with those who are not asset poor. This is consistent with findings from the univariate analysis presented earlier and reinforces that financial constraint is an important factor driving household's decision to use fertilizer.

As can be seen in Table 2, usage of improved maize seed and irrigation increased the probability of using fertilizer by 4.4% and 8.9%, respectively. This suggests that yield-enhancing agricultural inputs are complementary, which is consistent with findings from the univariate analysis. Whether the HH received price information and whether the HH sold part of its maize production also increased the probability that a HH used fertilizer by 2.4% and 1.3%, respectively, suggesting that market participation could potentially play a central role in the HH's decision to use fertilizer. Furthermore, Table 2 revealed that cultivation of cash crops was positively associated with usage of fertilizer (cotton with an increase of 2.4 percentage points and tobacco with 13.1 percentage points). All findings summarized in this paragraph are consistent with those from the univariate analysis summarized in Table 1.

Smallholder farmers who use fertilizer acquire their fertilizer predominantly from wholesalers, retailers and medium- and small-scale agro dealers who are usually located in their villages. Data from IAI 2015 show that 66.0% of smallholder farmers who used fertilizer purchased it and that 24.1% received it as credit. Among those smallholder farmers who purchased fertilizer, 39.4% purchased in the villages where they live and 33.0% purchased in the districts where they live. This suggests that considerable share of smallholder farmers purchase fertilizer relatively close to where they live, which is consistent with findings from Nagarajan et al. (2015) showing that the distance travelled by smallholder farmers to acquire fertilizer from agro dealers reduced on average from 179 kilometers in 2006 to 30 kilometers in 2015, equivalent to a 83.2% decline. In addition to purchases of fertilizer from wholesalers, retailers and agro dealers, another channel through which smallholder farmers obtain fertilizer includes contract farming. Some smallholder farmers

under contract farming receive fertilizer from large-scale cash crop private companies, especially tobacco, sugarcane and cotton. Sources of fertilizer acquired by these large-scale cash crop private companies include direct imports of fertilizer, domestic fertilizer wholesalers and domestic fertilizer blending plants; direct imports of fertilizer account for the largest share, followed by fertilizer wholesalers.

4.2 Wholesalers and retailers

Smallholder farmers purchased fertilizers from wholesalers, retailers, and agro dealers as illustrated in Figure 2. Agro dealers acquired fertilizers from wholesalers, retailers and domestic fertilizer blending plants; while wholesalers and retailers obtain fertilizer from fertilizer importers and also from domestic fertilizer blending plants. Fertilizer wholesalers are integrated into retailing distribution concentrated especially in areas where tobacco and sugarcane are produced by large-scale enterprises; hence, fertilizer wholesalers refers to wholesalers and retailers hereinafter. The exact number of wholesalers is not available. In addition to fertilizer, wholesalers have other agricultural inputs (such as improved seeds, herbicides, farming tools, etc.) in their portfolio. These other agricultural inputs account for larger sales share than that of fertilizer. We are not aware of the exact number of the wholesalers, but Chemonics and IFDC (2007); and Benson, Cunguara and Mogues (2012) document that wholesaling market segment is dominated by one firm – AgriFocus – suggesting high concentration of this market segment.

According to Benson, Cunguara and Mogues (2012), considerably large share of fertilizer consumed in Mozambique come from international markets and the main ports through which fertilizer is brought into Mozambique are Beira in Sofala province and Nacala in Nampula province. These ports are also used to deliver fertilizer to the neighboring landlocked countries (Malawi, Zambia and Zimbabwe). Shipments of fertilizer arriving in Mozambique but in transit to these neighboring landlocked countries are not sold in Mozambique. As argued by Chemonics and IFDC (2007), Mozambique should position itself to take advantage of the economies of scale stemming from the large-scale fertilizer shipments going to neighboring landlocked countries by acquiring part of those shipments especially given that fertilizer is shipped in bulk from importing countries. This is because fertilizer importers in Mozambique order low-volume shipments from international markets, especially South Africa, leading to higher ocean transport costs (vessel rental). Ocean freight costs are exacerbated because vessels bringing fertilizer to Mozambique

ports usually return empty to their origins (mainly South Africa) due to low export of other commodities from Mozambique to international markets, especially South Africa. Mozambique is a small market for South African fertilizer. According to DAFF (2018), exports of NPK from South Africa to Mozambique amounted to 22.0 thousand MT over the period 2007 to 2016, representing only 1.8% of the total South Africa exports to Southern Africa countries.

Transport costs are exacerbated because upon arrival in Nacala and Beira ports, fertilizer is transported in poor road networks to be delivered to fertilizer wholesalers, leading ultimately to higher fertilizer prices in retail markets. In addition, handling fees in Nacala and Beira ports are relatively high, contributing to higher fertilizer prices. Chemonics and IFDC (2007) estimated an average fertilizer price (NPK 12:24:12) of USD 546 per MT in Sofala province, of which Free-on-board (FOB) fertilizer price (including cost of fertilizer bagging) accounted for 58.7%, transport costs (ocean freight plus truck cost from port to wholesalers' warehouse) accounted for 23.1%, and margins accounted for 7.3%. Excluding FOB share, Benson, Cunguara and Mogues (2012); and IFDC (2012) estimated that transport cost accounted for about 45% of the fertilizer price in Sofala province. Although this transport share for Mozambique is comparable to that for Tanzania estimated at 43% by Cameron, Derlagen and Pauw (2017), it is considerably high by international standard.

This high transport share of retail fertilizer price suggests that if smallholder farmers' demand for fertilizer are to be driven up, given that price is an important determinant of fertilizer demand especially for asset poor smallholder farmers, efforts should be put in place to reduce transport costs at various stages (both truck and ocean freights) and port handling fees, leading to reduced retail fertilizer prices. High fertilizer prices paid by smallholder farmers could constrain smallholder farmers' returns on fertilizer, making smallholder farmers reluctant to adopt fertilizer because fertilizer application would not be profitable.

4.3 Agro dealers

Agro dealers play a key role in fertilizer marketing in Mozambique, linking on one hand fertilizer wholesalers to smallholder farmers and on the other hand fertilizer blending plants to smallholder farmers given that neither wholesalers nor fertilizer blending plants have distribution networks in rural areas especially in areas with high agricultural potential. According to Nagarajan et al. (2015), four types of agro dealers are found in Nampula and Sofala provinces: very small-scale

agro dealers with gross sales less than USD 1,000 per cropping season; small-scale agro dealers with gross sales ranging from USD 1,000 to USD 5,000; medium-scale agro dealers with sales ranging from USD 5,000 to USD 10,000; and large-scale agro dealers with sales greater than USD 10,000. We believe that this classification of agro dealers can be generalized to the country. The majority of the agro dealers are very small to small in terms of scale of business operation.

Very small- and small-scale agro dealers usually operate seasonally, are located far from main road networks but relatively close to smallholder farmers, sell fertilizer directly to smallholder farmers, and source their fertilizer from wholesalers located in district and provincial headquarters. Medium-scale agro dealers usually are located in district headquarters or close to large towns, acquire their fertilizer from wholesalers and sell fertilizer to very small- and small-scale agro dealers. Finally, large-scale agro dealers are located in district headquarters and large towns, sell fertilizer to all other types of agro dealers and obtain their fertilizer from directly from wholesalers (and fertilizer importers).

Nagarajan et al. (2015) document that depending on the volume intended to purchase, agro dealers source fertilizer from importers, wholesalers, and domestic fertilizer blending plants located in closest large towns (usually as far as 75-90 kilometers). In Central Mozambique, some agro dealers sometimes travel to Zimbabwe and Malawi to acquire agricultural inputs especially fertilizer. Furthermore, these authors reported that the average distance between agro dealers and smallholder farmers dropped from 180 kilometers in 2006 to 150 kilometers in 2014 in four provinces (Nampula, Zambezia, Manica and Sofala). This finding suggests that the distribution of agro-dealer is still thin; having a more concentrated network of agro dealers would make fertilizer more available to farmers, which in turn could lead to increased smallholder farmers if agro dealers put in place demonstration plots and provide credit to smallholder farmers to trigger smallholder farmers' interest in using fertilizer.

Nagarajan et al. (2015) found higher concentration of agro dealers in areas with more intensive growing of vegetables, tobacco and soybeans in Nampula, Zambezia, Manica and Sofala provinces due to higher demand for fertilizer among growers of these crops than among growers of food crops including maize. This is consistent with finding reported earlier showing that the proportion of farmers who use fertilizer is higher among farmers who grow cash crops. As a business diversification strategy due largely to seasonality of smallholder farmers' demand for fertilizer,

agro dealers have other agricultural inputs, in addition to fertilizer, in their business portfolio, and are engaged in the marketing of agricultural outputs, especially grains, grown by smallholder farmers. A considerable share of agro dealers also sell other groceries in their shop premises.

Findings from Benson, Cunguara and Mogues (2012); and Nagarajan et al. (2015) illustrate that in an attempt to drive smallholder farmers' demand for fertilizer, agro dealers provided credit to smallholder farmers and have demonstration plots. This agro dealers' strategy has been somehow effective as agro dealers' sales of especially fertilizer and improved seeds have increased. These findings reinforce the importance of smallholder farmers' awareness of the benefits of yield-enhancing agricultural inputs including fertilizer.

Like smallholder farmers, agro dealers also face finance constraints because considerable share of agro dealers obtain credit from domestic fertilizer blending companies and wholesalers from whom they purchase agricultural inputs including fertilizer. Access to finance through commercial banks is challenging in Mozambique due to four main factors: i) prohibitively high interest rates charged by commercial banks, ii) smallholder farmers' and agro dealers' lack of collateral, iii) commercial banks' aversion to give credit to the agricultural sector due to high riskiness of the sector, and iv) high default rates. Data from the Mozambique Central Bank show that annual interest rate for lending money from commercial banks for one-year maturity in Mozambique averaged 21.8% over the period 2008 to 2017, ranging between 18.8% and 28.3%. Given this high interest rate for lending money, the Ministry of Agriculture and Food Security (MASA) in collaboration with the Mozambique Central Bank and other financial institutions should find mechanisms to provide credit line at discounted interest rate and matching funds to agro dealers who in turn could provide credit lines also at discounted rates to smallholder farmers. This should be complemented with higher amounts of credit going to the agricultural sector. Data from the Mozambique Central Bank illustrates that the share of the total credit accounted for by the agriculture sector dropped from 9.4% in 2008 to 2.9% in 2014. It then increased to 3.5% in 2017.

In additional to Commercial Banks, another channel through which agro dealers access finance includes African Fertilizer Agribusiness Partnership (AFAP), a non-profit organization aimed at building capacity of African small and medium enterprises (SME) which supply yield-enhancing agricultural inputs and increasing smallholder farmers' use of fertilizers, ultimately contributing to agricultural productivity. According to ACB (2015); and Nagarajan et al. (2015) AFAP has

helped: i) reduce the cost of accessing finance by agro dealers through guarantee facility schemes, ii) strengthen linkages between agro dealers, wholesalers, and fertilizer blending companies, and iii) improve the agro dealer network in Mozambique.[2]

4.4 Domestic fertilizer manufacturers

Domestic fertilizer blending plants supply fertilizer to both wholesalers and large-scale cash crop companies. There exist four fertilizer blending plants in Mozambique: Mozambique Fertilizer Company (MOZFERT), Greenbelt, Export Trading Group (ETG), and Omnia. All these fertilizer blending plants are located in Central Mozambique due to two main reasons. First, Central Mozambique is the major producing region in the country in terms of cultivated area, suggesting potentially higher fertilizer demand. Data from IAI 2015 show that Central Mozambique is the region with the highest share of smallholder farmers who used fertilizer in the 2014/2015 agricultural season (6.2% in Central versus 2.5% in Northern versus 2.2% in Southern). These data also indicate that Central Mozambique contributed to 48.8% of the total cultivated area in the 2014/2015 agricultural season; this region also accounted for 56.9% of the total cultivated area under maize and 60.4% of the total maize production in the same agricultural season. According to these data, the share of smallholder farmers who grew maize is higher in Central Mozambique (82.3%) than in Northern Mozambique (79.1%) and Southern Mozambique (53.0%).

Second, Central Mozambique is a strategic location to enable Mozambique fertilizer blending companies to capture relatively higher fertilizer demand requirements from landlocked neighboring countries (Malawi, Zambia and Zimbabwe) for two main related reasons: i) proximity to all those three landlocked neighboring countries and ii) good road network connecting Mozambique (from Beira port in Sofala province) to those three neighboring countries. Indeed, fertilizer blending companies in Mozambique supply fertilizer to Malawi, Zambia, and Zimbabwe. However, Mozambique fertilizer blending companies have to be more efficient in supplying fertilizer to those landlocked neighboring countries because those countries are also key markets sourcing fertilizer from South Africa fertilizer companies. According to DAFF (2018), volumes of NPK exported from South Africa to Zambia and Zimbabwe amounted to 472.6 thousand MT and 425.8 thousand MT, respectively, over the period 2007 to 2016; with annual averages of 47.3 thousand MT for Zambia and 42.6 thousand MT for Zimbabwe over the same period. Zambia with

[2] ACB stands for African Center for Biodiversity.

39.3% and Zimbabwe with 35.4% are the top two main destinations of NPK exported from South Africa to Southern Africa countries over the period 2007 to 2016; followed by Malawi.

Nonetheless, it is worth noting that between 2007 and 2016, exports of NPK from South Africa to Zambia and to Zimbabwe experienced downward trends, dropping from 64.1 thousand MT in 2007 to 18.6 thousand MT in 2016 in the case of Zambia and from 72.0 thousand MT in 2007 to 2.4 thousand MT in 2016 in the case of Zimbabwe. These downward trends of exports from South Africa to both Zambia and Zimbabwe could suggest that Mozambique fertilizer blending companies are taking up part of the market share that used to be taken by South African fertilizer companies by increasing fertilizer exports from Mozambique to Zambia, Zimbabwe, and Malawi. However, further investigation of this issue needs to be conducted to make a well-founded statement.

Consumption of fertilizer is considerably lower in Mozambique than in other neighboring countries. Data from FAOSTAT show that annual consumption of fertilizer averaged 27.2 thousand MT in Mozambique over the period 2002 to 2016; compared with 86.2 thousand MT in Tanzania, 105.4 thousand MT in Tanzania, 108.5 thousand MT in Malawi and 134.7 thousand MT in Zambia. Furthermore, only 3.8% of the 4.0 smallholder farmers used fertilizer in Mozambique. This low consumption of fertilizer in Mozambique represents an unlocked demand potential if smallholder farmers' demand for fertilizer is driven up by mainly increasing smallholder farmers' awareness to the benefits of fertilizer application (both yield gains and profitability) through demonstration plots and releasing finance constraints through credit schemes complemented with strengthened output market information. These are not the only demand drivers but they are demand drivers that can be directly influenced by domestic blending companies; and hence, domestic fertilizer blending companies can take advantage of this potential increased smallholder farmers' demand for fertilizer to ultimately increase fertilizer blending companies' business operations.

Given the high price of fertilizer paid by smallholder farmers, large reserves of natural gas and phosphates in Mozambique constitute another unlocked potential to be exploited by domestic fertilizer blending companies to make fertilizer more accessible and affordable to smallholder farmers. Biggs (2012); and MIREME (2014) documented that Mozambique's reserves of natural gas estimated at 250 trillion cubic feet and coal estimated at 25 billion MT are among the largest

in the World. Natural gas can be used to produce fertilizer (ammonia and urea) at relatively low cost, making nitrogen fertilizer more affordable to smallholder farmers. In an effort to unlock this potential, the Government of Mozambique (GoM) signed an agreement in 2017 with the Norwegian giant fertilizer Yara International – one of the World's largest fertilizer companies – to build a plant, estimated at about two billion USD, in Cabo Delgado to produce nitrogen fertilizer from natural gas.

Furthermore, Van Straaten (2002); Pekkala et al. (2008); and Wanzala and Groot (2013) documented that Mozambique holds high-quality and large deposits of phosphates, especially in Nampula province, estimated at 155 million MT of apatite ore, making it the largest deposit in Central and East Africa. These deposits could also be used to produce phosphate fertilizer at relatively low cost, and the GoM is still looking for potential investors to build a phosphate fertilizer plant in Northern Mozambique. On the other hand, Rocha et al. (2017) reported that direct application of rock phosphate (40.7% of P_2O_5) could be used as a corrective for acid soils with phosphorus deficiency because rock phosphate was more effective than triple super phosphate, a processed phosphate fertilizer, in supplying phosphorus and corresponding yield gains in pigeon pea production in Zambezia province.

Given that one blend of fertilizer cannot fit all soil types and crops, soil analysis would be an effective mechanism through which soil types and crops could be matched with specific blend fertilizers. Hence, soil testing results and corresponding fertilizer recommendations by soil type and crop would be a value-added information for domestic fertilizer blending plants to produce blend fertilizers for specific soils and crops. This would make fertilizer blending companies more relevant for smallholder farmers. However, these fertilizer recommendations for specific soil types and crops for the entire country are not currently available. Institutions that could play a key role in the mapping of fertilizer recommendation for specific soils and crops include the Mozambique Agricultural Research Institute (IIAM) under the Ministry of Agriculture and Food Security (MASA) and higher education institutions – distributed throughout the countries – such as Eduardo Mondlane University's Faculty of Agronomy and Forestry Engineering (FAEF), Gaza and Manica High Polytechnic Institutes (ISPG and ISPM), Lurio University's Faculty of Agricultural Sciences, and Zambeze University's Faculty of Agricultural Sciences.

However, these institutions are in need of investments in capacity building (both human resource and physical infrastructure including laboratories for soil analysis) to effectively contribute to this process. On this front, a good practice includes the triparty agreement among MASA, ISPM and African Fertilizer Agribusiness Partnership (AFAP) under which AFAP upgraded ISPM laboratories located in Manica province to carry out soil analyses to draw fertilizer recommendations for specific soils and crops. This agreement has generated fruitful results as Greenbelt is producing fertilizer blends based on soil-specific fertilizer recommendations, but this experience should be scaled up because so far limited soil mapping to inform blending has been done. Given that countrywide coverage is needed as stated in the National Fertilizer Strategy of 2012; taking advantage of the four IIAM Zonal Centers – namely Southern Zonal Center located in Gaza province, Central Zonal Center in Manica province, Northeastern Zonal Center in Nampula province, and Northwestern Zonal Center in Niassa province – complemented with infrastructure and human capacities from other higher education institutions would be crucial to efficiently generate countrywide soil mapping to inform fertilizer blending.

5 Lessons learned from voucher subsidy programs in Mozambique

Some smallholder farmers receive fertilizer through voucher subsidy programs. Carter, Laajaj and Yang (2013) reported that the Government of Mozambique (GoM) – with assistance from International Fertilizer Development Center (IFDC) and funding from European Union (EU) and Food and Agriculture Organization of the United Nations (FAO) – piloted a voucher subsidy program for maize and rice smallholder farmers in the 2009/2010 agricultural season. This voucher subsidy program targeted 25 thousand farmers (15 thousand maize producers and 10 thousand rice producers) who were required to co-pay 27% of the total market value of the input package in the case of maize and local private agro dealers from whom voucher coupons could be redeemed.

Four main lessons emerged from a randomized trial conducted by Carter, Laajaj and Yang (2013) to assess the impact of paper-based voucher coupons having maize as the targeted crop. First, on one hand, only 50% of farmers who gained access to voucher coupons ended up picking up the coupons from the extension agents who distributed the coupons, suggesting relatively low uptake of coupons among potential beneficiaries. On the other hand, 83% of farmers who picked the voucher coupons redeemed them at participating agro dealers, but only 57% used the fertilizer from the redeemed voucher package for their maize production (the targeted crop for the voucher

coupons). Moreover, among farmers who redeemed their coupons but did not use the redeemed fertilizer on their maize production, 67% allocated the fertilizer to other crops (especially tobacco and horticulture) and 4% sold the fertilizer to other farmers. This suggests that achieving effective targeting could be complex when implementing subsidy voucher programs.

Second, among those who did not picked up the voucher coupons despite being entitled for, 46% reported lacking of the required co-payment (27% of the market value of the voucher coupon) as the reason for not picking up. This emphasizes the importance of liquidity constraints faced by smallholder farmers to increase their access to yield-enhancing agricultural inputs. Third, comparing farmers who gained access to voucher coupons with those who did not gain access, the impact of the voucher coupons was modest but statistically significant. Gaining accessing to voucher coupons increased applications of fertilizer by 14.8 Kg and of improved maize seed by 3.1 Kg. This low impact of voucher coupons on the target farmers is associated with the low uptake of vouchers among those who were entitled for (as discussed above).

Fourth, compared with the impact on the target farmers, the impact of voucher coupons on input usage among farmers who picked up the coupons and used them on the targeted crop is much greater (with statistical significance as well): 68.3 Kg for fertilizer application and 14.4 Kg for improved maize seed application. This suggests that with effective targeting, voucher coupons could bring about sizable increases in uses of fertilizer and improved seed among smallholder farmers, potentially driving up smallholder farmers' demand for fertilizer if fertilizer application proves to be profitable among farmers who benefited from the voucher coupons.

After experiencing with the paper-based voucher coupons for several years, the GoM embarked on electronic voucher (e-voucher) scheme in recent years. According to de Vletter (2018), starting in the 2015/2016 agricultural season, FAO in partnership with the GoM and EU launched the first e-voucher scheme aimed at increasing access to agricultural inputs (seeds, fertilizers, pesticides, and inoculants). Like in the case of paper-based voucher coupons, the e-voucher scheme targeted about 25 thousand farmers who are required to co-pay for the total market value of subsidized input package. These 25 thousand beneficiaries of the e-voucher scheme represent less than 1% of the total number of smallholder farmers; suggesting that the e-voucher scheme is relatively small in scale, especially when compared with neighboring countries – such as Malawi, Zambia and Tanzania – that launched expensive fertilizer subsidy programs at national scale. de Vletter (2018)

documented that e-voucher beneficiaries redeemed 569 MT of fertilizer (301 MT of NPK and 268 MT of urea) in the 2016/2017 agricultural season in Mozambique. By contrast, Jayne et al. (2018) pointed out that the annual volumes of fertilizer distributed under input subsidy programs in 2014 amounted to 208 thousand MT in Malawi, 208 thousand MT in Zambia, and 112 thousand MT in Tanzania.

Based on the assessment made by de Vletter (2018), three main lessons could be learned from the e-voucher program implemented in Manica and Sofala provinces covering about 90% of the total beneficiaries. First, unlike the paper-based vouchers for which 83% of beneficiaries who picked their paper-based vouchers redeemed the vouchers, only 59.5% of farmers who received e-voucher actually redeemed their e-vouchers by making co-payments to obtain the input package. However, it is worth noting that the proportion of farmers who redeemed their e-vouchers are higher among farmers receiving package A with total market value of MZN 3,000 than among those receiving package B with total market value of MZN 7,000 (44.1% versus 74.3%). This could be related to higher liquidity constraints among farmers benefiting from package A (subsistence farmers) than among those benefiting from package B (emerging farmers).

Second, the number of e-vouchers redeemed increased by about 3 fold from 6,099 in the 2015/2016 agricultural season to 16,776 in the 2016/2017 agricultural season. During the same period, it is worth noting that the share of the package B – more expensive and sophisticated – in the total number of redeemed e-vouchers also increased from 45.2% to 51.1%. This rapid increase in the number of farmers who redeemed their e-vouchers coupled with increased share of farmers benefiting from package B could be related to increased aware of the benefits of fertilizer and better knowledge of its use as a considerable share of beneficiaries farmers also participate in farmers' field schools (FFS) with demonstration plots organized by FAO and fertilizer agro dealers;

Third, the number of agro dealers from whom beneficiaries can redeem their e-vouchers increased from nine in the 2015/2016 agricultural season to 15 in the 2016/2017 agricultural season. The average number of beneficiaries farmers served by each agro dealer increased from 678 to 1,118 during the same period. In addition to selling directly to farmers, agro dealers participating in the e-voucher scheme usually have a network of retailers who are regularly supplied with yield-enhancing agricultural inputs on either credit or consignment basis so that beneficiary farmers can

redeem their e-vouchers on those retailers who are located relatively closer to farmers. With the rapid expansion of the e-voucher scheme, some retailers who were previously agents of those agro dealers have become independent agro dealers themselves participating directly in the e-voucher program. This has resulted in increased competition among agro dealers and reduced the distance between fertilizer suppliers and farmers.

6 Conclusion

Fertilizer application rates are low in Mozambique and averaged 5.7 kilograms (Kg) per hectare of arable cropland in Mozambique during the period 2006 to 2015, compared with 6.1 Kg/ha in Tanzania, 31.7 Kg/ha in Malawi, and 38.7 Kg/ha in Zambia. The average fertilizer application rate in Mozambique falls short of the target of 50 Kg/ha by 2025 set during the 2006 Abuja Declaration and of PEDSA target of 25 Kg/ha by 2017. This analysis shows that increased fertilizer adoption (in terms of both proportion of farmers using fertilizer and fertilizer application rate), complemented especially with improved seed adoption and better land and crop management, play a paramount role in contributing to rapid and sustainable growth in agricultural productivity in Mozambique. Our findings indicate that fertilizer use has both demand-side and supply-side constraints. Key demand-side constraints include liquidity constraints, limited awareness about the benefits of using fertilizer (in terms of both yield gains and return to fertilizer use), and low participation in input and output markets. On the other hand, main supply-side constraints include high transaction costs, limited access to finance, and lack of soil testing results and corresponding fertilizer recommendations by soil type and crop soil. Our findings also shed some light suggesting that scaling up the input subsidy program through vouchers (either paper-based voucher or e-voucher) with demonstration plots and effective targeting could drive up smallholders' demand for fertilizer and fertilizer supply by strengthening a sustainable network of wholesalers and retailers.

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