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Fertilizer Subsidy Effects on the Diet Quality of Farm Women in Mali

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Michigan State University (MSU). Established in 1855, MSU is the oldest of the U.S. Land Grant universities and has a long history of agricultural and food policy research in Africa, Asia and Latin America.

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EXECUTIVE SUMMARY

Agricultural policies affect the diets of rural households through various channels, including changes in the structure of farm costs and benefits, returns to family labor within and outside the farm, and product prices that generate incentives to grow one crop vs. another, or purchase one consumption commodity rather than another. Here, we take the example of a policy that has been widely promulgated across nations of Sub-Saharan Africa—the fertilizer (input) subsidy.

Although an impressive body of literature has measured the impacts of fertilizer subsidies in Sub-Saharan Africa since their revival in the form of "smart subsidies," we find less than a handful so far that examine nutritional implications. These include studies conducted in Malawi, where the smart subsidy was initiated in the 1990s, and Tanzania (unpublished, to our knowledge). Further, documenting effects within male-headed households have not been the primary aim of the studies, although many of them report differentials by gender of household head.

It is also the case that relatively few studies have been conducted on the effects of the fertilizer subsidy in Mali. We focus our analysis on measuring the association between the amount of subsidized fertilizer received and the diet quality of women of reproductive age who manage plots within male-headed households in Mali. This analysis thus contributes both to the knowledge base in Mali and to the general literature on the topic of fertilizer subsidies in Sub-Saharan Africa.

We utilize survey data collected by a team of the Institut d'Economie Rurale and Michigan State University during the crop year 2017-8. The dataset includes 2400 households whose plot managers were interviewed about their fertilizer use and other management practices. Within these households, 5900 women of reproductive age were interviewed regarding their consumption in the preceding 24 hours. We constructed two currently recommended indicators of the diet quality of women: 1) the minimum adequate dietary diversity score, and 2) the women's dietary diversity score. These are shown to be correlated with anthropometric measures and associated with the diet quality of the respondent's children.

We find a disturbingly low proportion of women (43%) who meet the minimum adequate score of consuming foods from 5 or more of 10 key food groups in the day preceding the survey. This proportion was considerably lower among households in the agroecological zone of the Koutiala Plateau than in that of the Niger Delta. Sample statistics suggest that women managing plots planted to crops targeted by the subsidy were more likely to consume sources of food rich in iron, but also to consume snacks or meals outside the home and sources of sugar than other female plot managers. However, overall consumption of sugary foods appears to remain low—by far the largest source of sugar was sugar added to tea or coffee and on average, even this was not consumed on a daily basis. Finally, we found that the overall effect of the fertilizer subsidy on the diet quality of women who manage plots of targeted crops was likely to be very small in magnitude, although the association between kgs per ha and the count of food groups is statistically significant. Further work will examine hypotheses and findings in greater detail.

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1. INTRODUCTION

Agricultural policies influence the diet of rural households through changing the cost structure, returns to farm labor, and product prices that generate incentives to grow particular crops or purchase one consumption commodity instead of another. Historically, one of the most consistently practiced agricultural policies in Sub-Saharan Africa has been subsidization of fertilizers, undertaken operationally in various forms over the decades since national independence (Morris et al. 2007; Druilhe and Barreiro-Hurlé 2012; Jayne and Rashid 2013). The main objectives of fertilizer subsidy policy are generally to boost agricultural productivity through improved access to fertilizer, contributing to food and nutrition security via higher income and lower consumer prices. The current generation of subsidies are referred to optimistically as "smarter," but reviews generally find them to be regressive (Gautam 2015), with no evidence to date of long-term impacts (Jayne et al. 2018).

A substantial body of literature has emerged to analyze the impacts of these subsidies on the supply of commercial fertilizer, uptake and benefits of fertilizer use on household farms, particularly in Eastern and Southern Africa, but also to a lesser extent in West Africa. Informative reviews of the evidence concerning the outcomes or impacts of the most recent generation of subsidies have been conducted by Druilhe and Barriero-Hurlé (2012), Jayne and Rashid (2013), Wanzala-Mlobela, Fuentes, and Mkumbwa (2013); Kato and Greeley (2016) and Jayne et al. (2018). At the household level of analysis, researchers have focused on measuring direct impacts of fertilizer subsidies on farm yields, income, and poverty status, including effects on use of commercial fertilizer.

In a comparative review of these studies (Smale and Theriault 2019), we identified only two that have addressed the potential impacts of fertilizer impacts on nutrition (Snapp and Fisher 2015; Gine et al. 2015). The report by Gine et al. (2015) tested the effects of the fertilizer subsidy in Tanzania on dietary diversity among but not within households. The authors did not find a significant positive impact of the fertilizer subsidy on household food security or dietary diversity. Snapp and Fisher (2015) identified two pathways through which the Malawi's input subsidy program positively affected household dietary diversity: crop diversification and income generation from greater commercialization of maize. They did not address the intrahousehold effects of the input subsidy program. While a number of studies have examined the success of programs designed to target women-headed households, we found only two that explore gender differentials in adoption and productivity (Karamba and Winters 2015; Fisher and Kandiwa 2014) and only two that analyze intrahousehold effects of the subsidy (a working paper by Chirwa et al. in 2011 and a thesis by Haider in 2018).

Walls et al. (2018) draw similar conclusions from a systematic review of the literature about the impact of agricultural input subsidies (including, but not limited to fertilizer subsidies) on food and nutrition security. The authors find that where studies have considered nutritional outcomes, typically they have addressed only changes in the consumption of the targeted staple food, ignoring wider aspects such as dietary diversity. While their initial search resulted in 1527 publications, after detailed screening by multiple authors, Walls et al. (2018) found only four studies that met the criteria for inclusion in their article. Three were analyses of the fertilizer subsidy program in Malawi, of which one was an unpublished thesis by Karamba (above). The fourth was a 1988 paper on rice technology in the Gambia, and thus unrelated to fertilizer subsidies.

This paper takes the agricultural policy example of the fertilizer subsidy program in Mali and tests the association of the subsidy with the diet quality of farm women. As in other nations, the aim of a fertilizer subsidy is to boost farm productivity by enabling farmers with financial or knowledge barriers to apply this key input, leading potentially to higher shares of the harvest sold and rising farm incomes. The dietary intake of farm households and their members can be influenced either by changes in crops grown and farm production or by changes in food purchases. We adapt a framework initially developed by Mason and Smale (2013) in order to analyze the per-kg impacts of hybrid maize seed on farmer welfare. Here, instead, we test the per-kg impacts of fertilizer received at a subsidized price on the diet quality of women of reproductive age who manage plots of crops targeted by the subsidy (sorghum, rice, maize, millet or cotton) within farm households of the Niger Delta and Koutiala Plateau agroecological zones. We contribute to the extensive general literature on fertilizer subsidies in Sub-Saharan Africa by investigating the intrahousehold effects of the fertilizer subsidy on the diet quality of farm women. We also contribute to a limited literature on the impacts of the fertilizer subsidy in Mali (see review by Smale and Theriault 2019).

The econometric approach is presented next, followed by a description of the data source and variables. We then present some descriptive statistics and the econometric findings. We draw conclusions and suggest future research in the closing section.

2. ECONOMETRIC APPROACH

The precepts of the non-separable model of the agricultural household provide the conceptual basis of the econometric approach (Singh, Squire and Strauss 1986). Utility is maximized rather than profits, and input demands include both observed prices and household characteristics that affect endogenous prices through household-specific transactions costs. Fertilizer subsidies affect nutrition outcomes through the primary impact pathway of income, although changes in the composition of income among sources (own production, purchased foods) and household members (collective, individual fields) may also influence outcomes.

We adapt an empirical strategy used by Mason and Smale (2013) to measure the per-kg effects of hybrid seed use on indicators of household well-being. Here, we measure the effects of subsidized fertilizer received (s) on fertilizer applied (h) by individuals to the plots they manage (h), and estimate the effect per kg of fertilizer on the diet quality of female plot managers. The general approach involves the application of the chain rule and estimation in two parts. Because the subsidy effect is heterogeneous among and within[1] households and because we seek to measure the effects on the outcome, we prefer to use kgs of subsidized fertilizer applied instead of a binary variable indicating

[1] We hypothesize that subsidized fertilizer use is heterogeneous across plots managed by different members of the same household.

whether or not a subsidy was received. Each outcome (*y*) is a function of the quantity of fertilizer (kgs) applied and other factors, *x*.

$$y=y[h(s, \mathbf{z}), x] \tag{6}$$

The quantity of fertilizer applied is a function of the amount of subsidized fertilizer received, *s,* as well as other factors, ***z***. We apply the chain rule to obtain the partial effects of interest:

$$\frac{\partial y}{\partial s} = \frac{\partial y}{\partial h(s,z)} \cdot \frac{\partial h(s,z)}{\partial s} \tag{7}$$

The first term represents the partial effect on the outcome variable of fertilizer (kgs) applied, considering other factors. The second term on the right-hand side expresses the effect of subsidized fertilizer (kgs) on fertilizer use (kgs), conditional on other covariates. Each partial effect is estimated econometrically. To derive the per kg effects of the subsidy on outcome variable, as a third step, we take the product of the two partial effects.

In the first step, the fertilizer use variable represents a corner solution with values concentrated at zero, suggesting a Tobit model. We employ the Control Function Approach (CFA) to test for the potential endogeneity of *subsidized fertilizer* in the amount of fertilizer applied, while controlling for plot, plot manager, household and market characteristics. Following that approach, we first explain kgs of subsidized fertilizer applied and then enter the predicted values along with the residual in a second regression explaining total fertilizer use.

Instrumental variables in past research have include the presence of family members of politicians in the village, the length of time since the household was established in the village, the median village- or commune-level fertilizer price, and the proportion of households belonging to a cotton cooperative at the village or commune level. In our study of the fertilizer subsidy in Mali, we use three instrumental variables. Two of these are "design" variables that represent the form of the subsidy received—paper vouchers or a combination of paper and electronic vouchers. Electronic vouchers are currently in a pilot stage in Mali, and the farmers we interviewed combined these with paper vouchers. The third instrument in our analysis is the fee that must be paid to obtain the subsidy. These variables affect overall fertilizer use only through the subsidy program.

In the CFA, the t-test on the residual in the equation explaining overall fertilizer use is the test of endogeneity of subsidized fertilizer. If, by rejecting the null hypothesis that the coefficient on the residual is equal to zero, we reject exogeneity, we then control for endogeneity by including the predicted values of the residual from the first stage along with the observed subsidized fertilizer in the final regression explaining total fertilizer use. In the case of endogeneity, standard errors are bootstrapped to deal with the inclusion of the predicted regressor (control function-fitted residual from the first stage) in the second stage regression. Bootstrapping also takes into account that fertilizer applied on plots belonging to the same household may be correlated. We support tests of potential endogeneity with instrumental variables regression (IVREG2 in Stata), which assumes no concentration of values at zero.

The estimation procedure in the second step depends on the form of the outcome variable that we use to measure *diet quality*. For example, a Poisson model may be most appropriate for modeling diversity scores, depending on the range of the score. The minimum adequate dietary diversity score for women of reproductive age is a binary variable. Once again, the variable of interest, *fertilizer use*, is potentially endogenous in outcome variables and we may apply the CFA or an IV approach. Instruments used in previous studies include the adoption rate at the commune or district level, which expresses the confluence of supply and demand at a large geographical scale of analysis. Secondary data on quantities of fertilizer marketed by retailers have also been employed. The proportion of farmers who are members of registered cooperatives is another possibility, since this measures the strength of the associations that supplies fertilizer outside of commercial markets. Other researchers have utilized variables such as whether or not a politician or his/her relative resides in the village, and the duration of residence of the family benefiting from the subsidy. There are numerous studies on the topic that have applied instrumental variables approaches with cross-sectional or panel data (see references reported in Jayne et al. 2018). Here, we use three variables that are related to fertilizer use but not directly to dietary diversity: whether the plot is rainfed, whether or not the plot was beset by water problems, and whether or not a drought was experienced in the three years preceding the survey.

In both the first and second steps of econometric estimation, we cluster errors by household. In the third step, we apply the chain rule to compute the overall average partial effect of a 1-kg increase in subsidized fertilizer on the outcome variable, multiplying the partial effect from the first step by the partial effect from the second step.

In this third step, we also take into consideration the organization of the farm household. In rainfed farming systems of West Africa, many farming households are organized under the supervision of a senior male head, who is responsible for allocating individual plots among household members and managing the collective plots in the interests of extended family. Intrahousehold decision-making processes mediate input use, including, potentially, subsidized fertilizer. For example, recent research in Burkina Faso suggests that providing senior male heads with subsidized fertilizer on behalf of the household as a whole may increase total farm output less than targeting women and young men (Haider 2018). In Mali, Smale et al. (2019) found little evidence that intrahousehold allocation of fertilizer was inefficient but concluded that persistent gender gaps in yield may be explained in part by differences in land quality. Here, we estimate equations using plot-level data, and in the final step, we consider only the diet quality of women managing plots of crops targeted by the fertilizer subsidy.

3. DATA AND VARIABLES

3.1 Data

We employ a detailed survey conducted by the Institut d'Economie Rurale and Michigan State University (IER/MSU) in repeated visits from October of 2017 through July of 2018. The sample was stratified by agroecological zone, including the zones of the Delta du Niger (heavily based on irrigated rice production with surrounding areas of dryland farming based on millet production) and the Plateau de Koutiala (based on sorghum and a cotton-maize rotation in a rainfed system). A sample of 60 standard enumeration areas was selected in each of the zones, with 20 household farms (*Exploitations Agricoles Familiales*, or EAF) per SE (a total of 2400 households). Detailed information on the fertilizer subsidy and input use was collected on plots of target crops (rice, maize, millet, sorghum, cotton).

IER/MSU team chose to implement an independent survey after careful consideration of the data collected under the Living Standards Measurement Survey-Integrated Survey of Agriculture (LSMS-ISA) for the first time in Mali during 2014-15. While this public dataset is nationally representative, representation of particular crops and farming systems was sparse, data on plot management did not include adequate detail for our purposes with respect to the fertilizer subsidy. In addition, the diet diversity module measured household rather than individual diet diversity.

Combined, collective and individual plots of target crops numbered 9194. All women of reproductive age (15-60) were interviewed within households surveyed, totaling 5930 women. The Malian team chose to expand the age group to 60 from 50. A test of differences in means of diet diversity scores between the 15-50 age group and 15-60 age group revealed no statistical significance, so we include all observations in our summary statistics. Of the complete sample of women of reproductive age in households surveyed, only 439 were managers of individual plots planted to crops targeted by the subsidy. Forty-four percent of their plots were planted to rice, 25 percent were sorghum plots, 23 percent were millet plots, and only seven and one percent were maize and cotton plots, respectively. Although these crops are not usually managed by women, the few cases were found were wives, daughters or daughters-in-law of heads. These plots are included in our econometric model.

3.2 Dietary impact indicators

Dietary intake is one of two major immediate determinants of maternal and child nutritional status, alongside disease (UNICEF 2015). While there is no universal index of diet quality, there is some agreement on what a healthy or non-healthy diet would include: a diversity of foods with energy levels appropriate for age, sex, and disease status and physical activity; essential micronutrients; and limited intake of free sugars and salt, sugary snacks and beverages, or processed meat (GLOPAN 2016). Inadequate dietary intake, as a cause of malnutrition, refers to imbalances, both in terms of excess and insufficiency, in energy as well as macro and micronutrients. A balanced diet (or diet quality) is defined as "a diet that provides energy and all essential nutrients for growth and a healthy and active life" (Committee on World Food Security 2012:9).

Dietary diversity refers to the number of different food items or food groups that a household or an individual has consumed over a specified period (i.e., over the preceding 24 hours or week). More diverse diets are positively correlated with greater energy and macro and micronutrient intakes, and more favorable anthropometric measures in adults and children (Arimond et al., 2010; Steyn et al., 2006). Diets consisting of a limited number of food items, especially starchy staples, can lack the macro and micronutrient adequacy despite meeting calorie requirements. According to Ruel et al. (2013, p. 259): "Studies done in different contexts and in populations with vastly different dietary patterns show a strong and robust, positive association between dietary diversity indicators and diet quality in both children and women… Several recent studies also confirm the positive association between dietary diversity and anthropometry in both children and women, even when controlling for a variety of individual and household socio-demographic and economic factors."

The Household Dietary Diversity Score (HDDS) is a measure of energy availability (Leroy et al. 2015) or a snapshot of the economic ability of a household to access a variety of foods (Kennedy, Ballard and Diop 2013). The Individual Dietary Diversity Score (IDDS) distinguishes among members and is a measure of individual access to diet quality. For households structured like those in our survey area, women's diet quality is also a good indicator of the diet quality of their children. Both the HDDS and IDDS have been widely applied across disciplines. Within our region of study, for example, Kennedy et al. (2009) tested them in research conducted in Bamako, and Spigelski (2004) applied them in thesis research in Senegal. Considerable work has been conducted with these indices in urban and rural Burkina Faso (e.g., Becquey and Prével 2010; Savy et al. 2006. Our study provides a needed update, particularly for rural women in Mali.

Instead of either the HDDS or the IDDS, we apply the more recently developed Women's Dietary Diversity Score (WDDS) and Minimum Dietary Diversity for Women (MDD-W). Each is assessed by 24-hour recall and represents micronutrient adequacy for women of reproductive age; the MDD-W is a binary variable (0-1) measuring whether or not the respondent's consumption exceeded 5 out of 10 food groups, while the WDDS measures the number of food groups out of a total of 9 (FAO and FHI 360 2016; Martin-Prével et al. 2015). The 10 food groups of the MDD-W are: 1) grains, white roots and tubers, plantains; 2) pulses (beans, peas and lentils); 3) nuts and seeds; 4) eggs; 5) dark green leafy vegetables; 6) other vitamin A-rich fruits and vegetables; 7) other vegetables; 8) other fruits; 9) dairy; or 10) meat, poultry and fish. We designed the survey instrument so that several indicators can be constructed by aggregating or counting over categories in different ways. The 9 food groups of the WDDS include, as in the WDDS 1) starchy staples; 2) dark green leafy vegetables; 3) other vitamin A-rich fruits and vegetables (and red palm oil if applicable); 4) meat, poultry, and fish; 5) other fruits and vegetables, 6) dairy and 7) eggs. Organ meat represents a unique category in this indicator (group 8), and pulses are combined with nuts and seeds (group 9). We also derive indices for micronutrient adequacy (e.g., vitamin A, iron) from the same survey instrument and test these indicators (Kennedy, Ballard and Diop 2013).

Outcomes such as shares of certain categories of food purchased (sweets and sodas) or consumed outside the home, serve as indicators of potentially unhealthy effects (Smith and Subandoro 2007). Neither the WDDS nor the MDD-W include these categories. Recent work in Mali (Theriault et al. 2018) shows that sugars and vegetable fats are key ingredients in one-third and one-fifth of processed grain and dairy products. In our analysis, we consider binary variables for sugars (sugary foods, sugary sodas or juice, tea or coffee with sugar) consumed the day before the survey, a variable indicating whether or not the respondent had consumed a snack or meal outside the home the previous day, and the amount spent.

In sum, the dietary intake indicators used here, which represent some of the latest indices developed in the nutrition literature to rapidly assess dietary intake and quality, are measurable with farm survey data that include a dietary diversity module. The indicators can be tabulated in summary form, as in Table 1, or serve as outcome variables in a model of intrahousehold model decision-making.

The overall mean MDD_W shows that only 43 percent of all women interviewed consumed at least 5 of the 10 food groups that are considered to be sources of an adequate diet. Similarly, the average WDDS count is 4 out of 9. Cash spent on food items or snacks purchased outside the home range from 0 to 4000 FCFA, with a mean of only 36 FCFA[2]. Only 7 percent of women had consumed a sugary drink within the preceding 24 hours, but 79% percent had consumed either sugary foods (jam, honey), sugary drinks (soda or juice), or sugar added to tea or coffee. Most of this consumption was sugar added to coffee or tea. Thus, sugar consumption appears to be quite limited among women in our survey zones.

Only 35% if all women of reproductive age had consumed foods rich in iron during the preceding 24 hours. An even lower share (16%) had consumed foods rich in vitamin A.

3.3 Explanatory variables

Explanatory variables, including potentially endogenous variables, instruments, and exogenous variables, are shown in Table 2, along with descriptive statistics. We test for the potentially endogeneity of total fertilizer (kgs) obtained at a subsidized price (step 1) in both the total fertilizer (kgs) applied and fertilizer (kgs) applied per ha. We then test for the potentially endogeneity of total

[2] $1 is roughly equivalent to 530 FCFA.

fertilizer (kgs) and fertilizer per ha in diet quality of female plot mangers (step 2). In all three of these variables, we trimmed outliers at 1% and use the median value to replace them.

Instrumental variables used for identification differ between the steps of the analysis. In the first step, as explained above, these include the design of the subsidy program available to the farmer (paper, paper and electronic voucher), and the subsidy fees paid in the village as reported by key informants. Key informants included village elders and where relevant representatives of the main organizations and institutions, such as the Office du Niger, which administers the gravity irrigation system along the Niger River or the parastatal ginning company, CMDT. These are all variables that are exogenously determined and outside the influence of individual farmers. In step 2, we employ three instruments that are related to environmental conditions on the plot (rainfed, water problem, drought in last 3 years) and would influence fertilizer use but not the diet quality of plot managers except through fertilizer use effects on productivity.

Other exogenous variables include binary variables to control for agroecological zone, institutional affiliation (part of the Office du Niger or CMDT), target crop grown on the plot, and interactions with Office du Niger and/or CMDT agents. Given that a negligible percentage of women managed a cotton or maize plot, these regressions include millet—although millet is the omitted category in the step 1 regressions. Distances related to market access include the distance to the nearest input shop, asphalt road, and Bamako. In the fertilizer regressions, the distance to the nearest fertilizer market is also included. These affect transactions costs for fertilizer, and effective prices faced by farmers. The number of microfinance organizations per village is included in all regressions. Fundamental plot and plot manager characteristics (plot area, presence of intercropping, education of the manager) and household characteristics (labor, transfers, off-farm earnings) are found in all regressions, but others are differentiated by regression. For example, in the fertilizer regressions (step 1), we control for the age of the plot and manure application, which we hypothesize may affect farmer demand for fertilizer. Family labor supply is a complementary input. There is evidence that whether the plot is collectively- or individually managed is likely to influence intrahousehold allocation of fertilize (Haider et al. 2018). By comparison, we hypothesize that the number of children in the household and the size of the farm may influence the diet quality of female plot managers. We also control for their age, since this may also play a role in the composition of their diets.

4. RESULTS

4.1 **Diet quality of farm women**

Average dietary diversity scores of women in the Delta du Niger and Plateau de Koutiala, which are the breadbasket of Mali, are shown in Tables 3 and 4. These are weighted by the probability of selection in order to better represent averages for the population under study (means shown in Tables 1, 2 and 5 are sample means). Overall, weighted by probability of selection, 53% of 5,930 women between the ages of 15 and 60 consumed less than 5 of the 10 food groups included in the minimum adequate dietary diversity score during the 24-hour period preceding the interview. The percentage of women falling below minimum adequacy was considerable larger among households on the Plateau than among households in the Delta (65% vs. 42%, respectively. This score is a proxy for the probability of micronutrient adequacy, which is a "critical dimension of diet quality" (FAO and FHI 360 2016: 5).

Mean Women's Dietary Diversity Scores were 4.6 in the Delta compared to 3.9 on the Plateau. The difference appears to be of meaningful magnitude (a bit more than half an additional food group). Unweighted sample statistics show significant differences in means at 1% with a t-test assuming either equal or unequal variance. Differences in the underlying distribution (the score ranges from 0 to 9) are also significant at 1% with a Kruskal-Wallis test and chi-squared statistic. Overall, however, the distribution appears normal in shape (Figure 1). The WDDS is also correlated with micronutrient adequacy (ibid.).

Table 5 shows some observed differences by receipt of the fertilizer subsidy only for women managers of plots planted to crops targeted by the subsidy program. Sugar in some form (foods, soda or juice, tea or coffee with sugar) is more likely to have been consumed by women plot managers who benefited from the subsidy, other factors held constant. They are more likely to have consumed foods rich in iron as well, and to have purchased food outside the home. No differences are observable in the likelihood of consuming foods rich in vitamin A, and these are not reported. At the mean, it is also of interest that MDD_W and WDDS scores did not differ significantly by receipt of subsidized fertilizer (and thus are not reported).

4.2 Regression results

Tests of the major hypotheses in step 1 are shown in Table 6, including the effects of subsidized fertilizer (kgs) on total fertilizer (kgs) and fertilizer per hectare while controlling for other factors. The combined Wald (chi-squared) tests of the equations show strong statistical significance (less than 1%). The p-values on instrumental variables in the first-stage regression have statistical significant of under 1%, with expected signs. Subsidy fees reduce the amount of subsidized fertilizer obtained by the plot manager, while the paper voucher and combination of paper and electronic voucher raise it relative to the electronic voucher only (4 cases) or neither (1519 cases). In both of the second-stage regressions, the residuals from the first stage are highly significant, leading us to reject the null hypothesis of exogeneity of the subsidy in fertilizer use. As additional evidence, in the instrumental variables regression, the Anderson canonical correlation LM statistic and Cragg-Donald Wald F statistic lead to rejection of under- and weak identification, while the Sargan test casts no doubt on validity. The Wu-Hausman test also leads to rejection of the hypothesis of exogeneity of the subsidy. Each kg of subsidized fertilizer increases total kgs applied per plot by 0.96 kgs, raising kgs/ha by 0.28.

Estimated effects of some of the other factors shown in Table 6 are of interest. Market distances have a negative effect even on amounts of subsidized fertilizer purchased, although the farther away from Bamako, the better—suggesting good reach in more remote areas. The greater the plot area, the more the subsidized fertilizer applied and the more the total fertilizer applied, but the lower the fertilizer rate per ha. Plot age is positively associated with fertilizer use (subsidized and total), and intercropping is negatively related. The more adult labor available within the household, the lower the total subsidized fertilizer amounts applied to plots, but the higher the total fertilizer rates per ha. The first result reflects that less is available per individual plot manager; the second, that fertilizer requires labor to apply and the inputs are complementary. Education of the plot manager is positively associated with use of subsidized fertilizer, since it enables access to information and understanding of the conditions of the subsidy program. Plot management by individuals raises the application rate per ha, consistent with findings reported for other areas of the Sudan Savanna by Smale et al. (2019). Individually-managed plots are smaller than the extensive, "grand champs" managed collectively on behalf of the household—contributing to more intensified production.

Tests of the major hypotheses in step are shown in Tables 7-9. The first three columns of Table 7 provide the results for the first-stage, reduced form equation predicting fertilizer use by female plot managers. Again, each of the three instrumental variables is statistically significant. In the second three columns of the same table, we see that the residual is not statistically significant. Thus, we fail to reject exogeneity of fertilizer use in the probit model explaining minimum adequate dietary diversity for women (MDD_W). This is not surprising given that many other factors influence dietary diversity scores. The third and fourth sets of three columns treat fertilizer use as exogenous, and we do not observe a significant effect of fertilizer kgs applied in either case. Joint tests of regressors on these equations support statistical significance at less than 1%.

Nor do we observe significance of total kgs of fertilizer used in the WDDS (Table 8), although the rate of fertilizer applied on the plot (kgs/ha) does appear to be significant. Table 8 shows the same models estimated with OLS and Poisson regression. In terms of statistical significance, results are similar between OLS and Poisson forms. Depending on the measurement of the variable (total kgs vs. kgs/ha), fertilizer use appears to affect FCFA spend on foods consumed outside the home, sugars and soda or juice in the preceding 24 hours (Table 9). These are estimated with either Tobit or probit regressions. No significance was found for effects of fertilizer kgs applied on sources of vitamin A or iron. All of the joint tests of regressors in Tables 8 and 0 indicate statistical significance under 1% and 2%, respectively.

Turning to some of the other factors that influence dietary diversity of women plot managers in Mali, we see again that location on the Plateau de Koutiala is associated with a decrease in the MDD_W (columns 10-12, Table 7) and a reduction by one food group in the WDDS (OLS models, Table 8). Managing a rice or millet plot has a counteracting effect on the WDDS. As expected, women are more likely to manage rice plots on the Plateau than in the Delta, and to manage millet plots in the Delta than the Plateau. Rice plots on the Plateau are not irrigated, and millet plots in the Delta are generally outside the irrigated areas. The size of the area cultivated by the EAF as a whole tends to be positively associated with WDDS—suggesting wealth but also household capacity to growing a wider range of crops. Off-farm earnings also have a positive effect on WDDS. Similar variables (area cultivated by the EAF, but also plot size; off-farm earnings, but also transfers received) are significant in the regressions predicting effects on expenditures on snacks or meals outside the home or consumption of sugars.

The final step of the approach is to compute the marginal effect of the fertilizer subsidy as the product of the partial effects. Using the WDDS and fertilizer kgs/ha (Table 8 OLS), which we believe to be the strongest effect, the estimated effect of 1 kg of subsidized fertilizer on dietary diversity is only 0.0002563. Assuming the recommended rate of 100 kgs/ha, this would be equivalent to 0.02563, or only 2.5% of an increase in the number of food groups consumed. Thus, while it may be statistically significant, the effect appears to be of negligible magnitude. On the other hand, it must be remembered that the diet quality instruments are themselves blunt indicators to use in a marginal analysis since they are counts over relatively few groups. We cannot necessarily expect an effect of large magnitude. These indicators are perhaps of greatest policy import, as recognized by those who developed them (references cited above), when used to summarize information about populations (FAO and FHI 360 2016).

5. CONCLUSIONS AND IMPLICATIONS FOR FURTHER RESEARCH

In this paper, we tested empirically the effects of fertilizer subsidies on diets of female plot managers in farming households of Mali. Summary statistics indicate a disturbingly low overall likelihood (43%) that women in our sample attained minimum adequate dietary diversity scores, and a worse situation on the Plateau de Koutiala compared with the Delta du Niger. We saw that, other factors held constant, women managing plots planted to crops targeted by the subsidy were more likely to consume sources of food rich in iron, but also to consume snacks or meals purchased outside the home and sources of sugar than other women of reproductive age in households surveyed. We found that the overall effect of the fertilizer subsidy on Women's Dietary Diversity through fertilizer applied to plots they managed was likely to be quite very small in magnitude, although statistically significant—a kg/ha was associated with a change in score that is 2.5% of a point (food group). Given the bluntness of this count indicator as a measure of magnitude, combined with the statistical significance of the coefficient, we consider the finding to be worthy of further investigation.

Women were interviewed during the "hungry season," when farm families are also working in their fields. Over half of them reported consuming wild fruits or plants during the preceding 24 hours, and 40 % had consumed these seven days during the previous week. These are often considered to be "famine foods," although baobab leaves and other foods gathered in common areas around the farm also play a role in the usual diet of many rural households in Mali. To test for seasonal differences, the team intends to conduct the interviews with a subset of the overall sample in early 2019. Expectations are that seasonal differences will be significant, although this does not diminish the gravity of the findings with respect to July 2018. Slightly over a third (36%) had consumed foods rich in iron during the 24 hours before the survey, but only 16% had consumed foods rich in vitamin A.

On the other hand, we have no evidence so far of significant consumption of sugary foods. Only 7% of women had consumed a soda or sugary juice in the preceding 24 hours, and while 79% reported consuming these, sugary foods such as jam, honey, or candy and sugar with coffee or tea in that same time period, but far the largest category was sugar with coffee or tea.

With respect to the econometric modeling, various estimation techniques might be employed to control for potential selection bias and endogeneity issues as well as to check the robustness of results in future work. Selection bias can arise if some individuals/households were targeted by or self-selected into the fertilizer subsidy. Matching, regression adjustment, and endogenous switching approaches might be considered. A treatment model framework might be feasible, depending on the underlying data-generation process (e.g., Gine et al. 2015).

In addition to further analysis of diet quality among farm women in Mali with this data set, and additional analysis of the impacts of the fertilizer subsidy, we intend to examine the dietary transformation in Mali with larger-scale data sets.

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Table 1. Diet quality variables: definitions and descriptive statistics

Variable	Definition	Mean	Std. Dev.	Min	Max
MDD_W	Minimum dietary diversity score (see text)	0.4323777	0.4954479	0	1
WDDS	Women's dietary diversity score (see text)	4.217201	1.564827	0	9
Outside costs	FCFA spend on snacks or meals purchased outside the home in the preceding 24 hours	35.9199	155.254	0	4000
Soda or juice	Consumed sugary drink in preceding 24 hours	0.0730185	0.2601889	0	1
Sugars	Consumed jam, candy, soda or juice, or sugar in coffee or tea in preceding 24 hours	0.7935919	0.4047609	0	1
Iron	Consumed foods rich in iron (meats)	0.3512648	0.4774058	0	1
Vitamin A	Consumed foods rich in vitamin A (orange fleshed sweet potato, orange or red vegetables or fruit, red palm oil)	0.1642496	0.3705331	0	1

Source: Authors, from data collected by IER/MSU in 2017-18. Sample statistics.
Number of women of reproductive age= 5930.

Table 2. Explanatory variables: definitions and descriptive statistics

	Definition	mean	sdev	min	max
Endogenous variables					
Subsidized fertilizer	fertilizer (kgs) purchased at a subsidized price	249	371	0	2200
Fertilizer	fertilizer (kgs) applied to crop	155	163	0	959
Fertilizer per ha	fertilzier kg/ha applied to crop	272	376	0	2250
Instruments					
Paper voucher	Received paper voucher (1=yes, 0=no)	0.798	0.402	0	1
Paper and electronic voucher	Received electronic voucher and paper voucher (1=yes, 0=no)	0.0367	0.188	0	1
Subsidy fees	FCFA paid to benefit from subsidy	498	2685	0	25000
Rainfed plot	rain is source of water on plot=1, 0 else	0.774	0.418	0	1
Water problem	access to water on plot is a problem=1, 0 else	0.0820	0.274	0	1
Drought	plot experienced drought in past 3 years	0.660	0.474	0	1
Other exogenous variables					
Koutiala	agroecological zone Koutiala plateau=1, Delta du Niger=0	0.619	0.486	0	1
Sorghum plot	sorghum plot=1, else 0	0.172	0.377	0	1
Rice plot	rice plot=1, else 0	0.296	0.457	0	1
Cotton-maize plot	cotton-maize rotation plot=1, else 0	0.152	0.359	0	1
Millet plot	millet plot=1, else 0	0.215	0.411	0	1
Office du Niger	"encadre" by the Office du Niger	0.220	0.414	0	1
Interaction rice plot-ON	interaction of rice plot with Office du Niger	0.184	0.387	0	1
CMDT	"encadre" by the CMDT	0.412	0.492	0	1
Interaction cotton-CMDT	interaction of cotton plot with Office du Niger	0.109	0.312	0	1
Market distance	mean distance to fertilizer markets (km)	5.13	12.1	0	500
Shop distance	distance to nearest input shop (km)	2.88	15.2	0	142
Asphalt road	distance to asphalt road (km)	17.45	18.7	0	95
Bamako	distance to Bamako (km)	396	88.4	183	826
Microfinance	number of microfinance organizations in village	0.161	0.622	0	6
Plot area	GPS measured (ha) in survey season	2.04	1.95	0	13.23
Plot intercropped	intercropped=1, 0 else	1.12	0.320	1	2
Plot age	plot age (years)	18.3	13.8	0	99
Organic fertilizer	manure applied (kgs)	77.6	877	0	30000
Education	instruction level (of 16) of plot manager	1.52	3.03	0	16
Age	age of plot manager	43.7	13.3	15	94
Plot management	collective plot=1, else 0	0.903	0.296	0	1
Labor	number of adult family members/ha (EAF)	1.25	2.24	0.072	93.3
Transfers	total transfers received from family members living outside the home in previous year	35965	114464	0	2050000
Off-farm earnings	total off-farm earnings of family members living in the home in previous year	88822	393838	0	1.03E+07
Farm size	total area cultivated by EAF (ha)	13.0	12.3	0.12	188
Children	number of children in EAF	8.13	5.47	0	32

Source:Authors, from data collected by IER/MSU in 2017-18. Number of total plots=9194, households=2400. Sample statistics (unweighted). Note: EAF = Exploitaion familiale agricole (Farm family household)

Table 3. Minimum Adequate Dietary Diversity for Women Scores, by agroecology

Agro-ecological zone	MDD_W		
	0	1	Total
Delta du Niger	1044	1442	2486
	42	58	100
Plateau de Koutiala	2239	1205	3444
	65	35	100
Total	3143	2787	5930
	57	43	100

Weighted proportions. No statistical tests feasible.
With sample proportions, Pearson chi2(1) = 751.7102 Pr = 0.000
Source: Authors, from data collected by IER/MSU in 2017-18.

Table 4. Women's Dietary Diversity Scores, by agroecology

Agro-ecological zone	WDDS	
	mean	n
Delta du Niger	4.55	2486
Plateau de Koutiala	3.97	3444
Total	4.28	5930

Weighted means. No statistical tests feasible.
Difference of means test with sample means shows statistical significance less than 1% assuming either equal or unequal variances. Kruskal-Wallis chi-squared test shows statistically different underlying distributions.
Source: Authors, from data collected by IER/MSU in 2017-18.

Table 5. Consumption of certain foods in 24 hours preceding survey, by receipt of subsidized fertilizer

	Sugary drinks and foods			Iron-rich food sources			Food purchased outside the home		
Received subsidized fertilizer	No	Yes	All female plot managers	No	Yes	All female plot managers	No	Yes	All female plot managers
No	84	244	328	232	96	328	294	34	328
	25.61	74.39	100	70.73	29.27	100	89.63	10.37	100
Yes	18	93	111	59	52	111	87	24	111
	16.22	83.78	100	53.15	46.85	100	78.38	21.62	100
Total	102	337	439	291	148	439	381	58	439
	23.23	76.77	100	66.29	33.71	100	86.79	13.21	100
Pearson chi2(1) = 4.1029 Pr = 0.043				Pearson chi2(1) = 11.4676 Pr = 0.001			Pearson chi2(1) = 9.1634 Pr = 0.002		

Note: includes only subsample of female plot managers growing crops targeted by the fertilizer subsidy. Sample statistics.
Source: Authors, from data collected by IER/MSU in 2017-18.

Table 6. Effects of subsidized fertilizer on fertilizer use by plot managers

Explanatory variables	First-stage, reduced form Tobit model: Average partial effects	sig	p-value	Second-stage, structural Tobit model explaining total fertilizer use (kgs): Average partial effects	sig	p-value	Second-stage, structural Tobit model explaining fertilizer use (kgs per ha): Average partial effects	Sig	p-value
Potentially endogenous variable									
Subsidized fertilizer				0.962	***	0.000	0.275	***	0.000
Residual stage 1				0.0319	**	0.014	-0.085	***	0.000
Instruments									
Paper voucher	623	***	0.000						
Paper and electronic voucher	690	***	0.000						
Subsidy fees	-0.0051068	***	0.008						
Other exogenous variables									
Koutiala	48.6	**	0.041	28.3	***	0.000	15.4	*	0.085
Sorghum plot	-323	***	0.000	-78.8	***	0.000	-89.0	***	0.000
Rice plot	125	***	0.000	50.5	***	0.000	69.6	***	0.000
Cotton-maize plot	370	***	0.000	44.9	***	0.000	28.2	***	0.002
Office du Niger	-880	***	0.000	-228	***	0.000	-114	***	0.000
Interaction rice-ON	1122	***	0.000	269	***	0.000	144	***	0.000
CMDT	69.1	***	0.000	10.73	**	0.047	14.8	**	0.017
Interaction cotton-CMDT	-41.8	*	0.085	-15.9	*	0.082	-18.9	**	0.035
Market	-2.65	***	0.001	-0.123		0.582	0.136		0.686
Shop distance	-2.54	***	0.000	-0.015		0.905	-0.181		0.250
Asphalt road	0.412		0.280	-0.221		0.130	-0.444	***	0.000
Bamako	0.341	***	0.000	0.039		0.175	-0.039		0.244
Microfinance	8.30		0.522	18.7	***	0.000	8.2	**	0.029
Plot area	88.9	***	0.000	14.60	***	0.000	-49.1	***	0.000
Plot intercropped	-121	***	0.000	-20.7	***	0.008	-2.2		0.777
Plot age	1.82	***	0.000	0.293	*	0.069	-0.156		0.274
Organic fertilizer	0.00185		0.867	0.00252		0.317	0.00204		0.236
Labor	-4.71	***	0.004	0.36		0.599	3.74	***	0.004
Education	5.44	***	0.001	0.56		0.336	0.27		0.671
Plot management	-14.1		0.519	10.6		0.113	23.1	***	0.005
Transfers	-0.0000412		0.365	-0.0000283	**	0.023	-0.0000223	*	0.082
Off-farm earnings	0.0000037		0.784	0.0000075		0.210	0.0000056		0.328
Constant	-769	***	0.000	-68.49	***	0.000	119	***	0.000
Observations	8,731						8,728		

All errors clustered by household. Joint test of regressors shows statistical significance < 1% in all cases. Source: Authors, from data collected by IER/MSU in 2017-18.

Table 7. Effects of fertilizer use on diet quality (Minimum Dietary Diversity Score) of female plot managers

	First-stage, reduced form Tobit model			Second-stage, structural probit model			MDD_W Probit model total fertilizer (kgs)			MDD-W Probit model fertilizer (kgs/ha)		
Explanatory variables	Average partial effects	sig	p-value	Marginal effects	sig	p-value	Marginal effects	Sig	p-value	Marginal effects	Sig	p-value
Endogenous variable												
Fertilizer (kgs)				0.0006825		0.245	0.0007027		0.222			
Fertilizer (kgs/ha)										0.0002164		0.269
Residual stage 1				-0.0000996		0.873						
Instruments												
Rainfed plot	-586.67	***	0.000									
Water problem	-35.58	*	0.070									
Drought	-33.12	***	0.003									
Other exogenous variables												
Koutiala	252.11	***	0	29.62	***	0.000	16.32	*	0.077	-0.38	***	0.000
Rice plot	-364.36	***	0.000	49.57	***	0.000	78.76	***	0.000	0.20	**	0.036
Sorghum plot	-610.36	***	0.000	-77.31	***	0.000	-92.50	***	0.000	0.10		0.325
Millet plot	-547.28	***	0.000	-277.87	***	0.000	-55.09	*	0.083	0.22	**	0.024
Shop distance	-1.08	**	0.022	-0.032		0.803	-0.141		0.386	-0.012	**	0.050
Asphalt road	0.546	*	0.075	-0.227	*	0.064	-0.492	***	0.000	-0.003	**	0.037
Bamako	0.255	***	0.000	0.043		0.133	-0.055		0.109	0.000		0.998
Microfinance	-1.433		0.834	19.50	***	0.000	8.46	*	0.051	0.11		0.123
Plot area	48.68	***	0.000	11.00	***	0.000	-30.09	***	0.000	0.02		0.487
Plot intercropped	-93.51	***	0.000	-23.66	***	0.001	0.330		0.968	0.007		0.919
Education	3.2250557	**	0.045	0.55		0.350	0.29		0.657	0.01		0.631
Age	0.93	**	0.012	11.35	*	0.088	15.88	*	0.065	0.00		0.762
Children	2.91	**	0.013	0.325	**	0.049	-0.349	**	0.022	-0.002		0.729
Farm size	1.35	*	0.099	0.012	*	0.08	0.0124816	*	0.081	0.00	*	0.093
Household transfers received	-0.0000292		0.603	-0.00003	**	0.015	-0.0000269	*	0.082	0.000000237		0.509
Household off-farm earnings	0.0000151		0.442	0.000008		0.178	0.0000039		0.492	0.00000123	***	0.011
Constant	620.31921	***	0.000	-65.140457	***	0.000	106.51981	***	0.000	0.00000123		0.940
Observations	439			439			439			439		

All errors clustered by household. Joint test of regressors shows statistical significance < 1%. Source: Authors, from data collected by IER/MSU in 2017-18.

Table 8. Effects of fertilizer use on diet quality (Women's Dietary Diversity Score) of female plot managers

	OLS model			Poisson			OLS model			Poisson		
Explanatory variables	Coeff.	sig	p-value	Average partial effects	sig	p-value	Coeff.	sig	p-value	Average partial effects	sig	p-value
Fertilizer (kgs)	0.000731		0.211	0.0001618		0.22						
Fertilizer (kgs/ha)							0.001105	**	0.045	0.0002643	**	0.042
Koutiala	-1.23	***	0.000	-0.29	***	0.000	-1.26	***	0.00	-0.30	***	0.00
Rice plot	1.039	***	0.004	0.267	***	0.007	0.948	***	0.01	0.242	**	0.01
Sorghum plot	0.448		0.118	0.116		0.132	0.429		0.12	0.109		0.14
Millet plot	0.637	**	0.015	0.163	**	0.017	0.623	**	0.01	0.158	**	0.01
Shop distance	0.00758		0.688	0.00119		0.802	0.00453		0.813	0.00035		0.941
Asphalt road	-0.00607		0.107	-0.00167	*	0.098	-0.00577		0.123	-0.00159		0.113
Bamako	-0.00081		0.557	-0.00021		0.576	-0.00083		0.548	-0.00022		0.566
Microfinance	0.199		0.401	0.056		0.321	0.207		0.38	0.059		0.29
Plot area	0.002		0.983	0.002		0.900	0.074		0.36	0.018		0.33
Plot intercropped	0.187		0.322	0.043		0.343	0.163		0.382	0.038		0.389
Education	-0.03535		0.649	-0.00990		0.651	-0.04044		0.60	-0.01147		0.60
Age	-0.00038		0.957	-0.00015		0.925	-0.00093		0.89	-0.00031		0.85
Children	-0.00354		0.814	-0.00062		0.855	-0.00356		0.810	-0.00064		0.849
Farm size	0.01834	**	0.013	0.00422	***	0.007	0.01689	**	0.01	0.00384	***	0.01
Transfers	0.0000004		0.800	0.0000001		0.819	0.0000005		0.742	0.0000001		0.768
Off-farm earnings	0.0000052	***	0.000	0.0000011	***	0.000	0.0000051	***	0	0.0000011	***	0
Constant	4.01	***	0.000	1.38	***	0.000	4.04	***	0	1.39	***	0
Observations	439			439			439			439		

All errors clustered by household. Joint test of regressors in OLS models shows statistical significance < 1%. Source: Authors, from data collected by IER/MSU in 2017-18.

Table 9a. Effects of fertilizer use on other diet quality of female plot managers

	FCFA spent on snack or meal eaten outside home (Tobit)			FCFA spent on snack or meal eaten outside home (Tobit)			Probit model (Soda or Juice)			Probit model (Soda or Juice)		
Explanatory variables	Marginal effects	sig	p-value	Marginal effects	sig	p-value	Marginal effects	sig	p-value	Marginal effects	sig	p-value
Fertilizer (kgs)	0.0658		0.707				0.0014	***	0.006			
Fertilizer (kgs/ha)				0.1	***	0.005				-0.000660		0.619
Koutiala	22.0		0.821	-7.60		0.646	-0.668	*	0.065	-0.708	*	0.052
Rice plot	154.8		0.166	16.8		0.924	0.434		0.197	0.227		0.507
Sorghum plot	39.4		0.734	7.59	*	0.098	0.133		0.837	-0.320		0.618
Millet plot	31.9		0.808	1.77		0.339	0.735		0.160	0.254		0.603
Shop distance	4.09		0.555	0.53		0.341	-0.0170		0.567	-0.031		0.345
Asphalt road	-2.70	*	0.073	-0.105		0.583	-0.0346	***	0.002	-0.0312	***	0.003
Bamako	0.436		0.371	0.052	*	0.101	-0.000199		0.947	-0.0005		0.861
Microfinance	42.7		0.609	-1.0		0.319	0.139		0.690	0.132838		0.711
Plot area	35.4	*	0.059	3.933		0.504	-0.001903		0.983	0.195	**	0.025
Plot intercropped	104.4		0.158	4.074		0.503	-0.249		0.523	-0.376996		0.336
Education	2.11		0.872	-0.79		0.949	0.0206		0.786	0.005487		0.949
Age	1.36		0.621	0.099		0.908	-0.001846		0.825	0.0013		0.879
Farm size	-0.934		0.706	-0.314	***	0.004	0.005087		0.515	0.002063		0.805
Children	-0.369		0.943	-0.032		0.154	0.008955		0.687	0.008		0.721
Transfers	0.0006731	*	0.064	0.0001749		0.743	0.000003	*	0.073	0.000003	*	0.050
Off-farm earnings	0.0007484	***	0.007	0.0001329	*	0.061	0.0000017		0.131	0.0000017		0.144
Constant	-843.1	***	0.006	-20.117279		0.007	-1.331		0.369	-0.8020138		0.577
Observations	439			439			439			439		

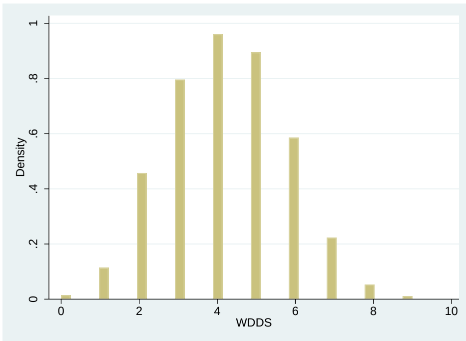
Errors clustered by household. Effects not significant for iron or vitamin A with either total fertilizer or fertilizer per ha.

Table 9b. Effects of fertilizer use on other diet quality of female plot managers

	Probit model (Sugars)			Probit model (Sugars)		
Explanatory variables	Marginal effects	sig	p-value	Marginal effects	sig	p-value
Fertilizer (kgs)	0.0015	*	0.073			
Fertilizer (kgs/ha)				0.000967		0.176
Koutiala	-0.160		0.584	-0.182		0.528
Rice plot	0.522	*	0.091	0.408		0.174
Sorghum plot	0.023		0.934	-0.049		0.855
Millet plot	0.237		0.4	0.159		0.566
Shop distance	-0.0118		0.634	-0.015		0.53
Asphalt road	0.0107	**	0.019	0.0110	**	0.017
Bamako	-0.001874		0.218	-0.0018		0.232
Microfinance	-0.177		0.493	-0.177957		0.498
Plot area	-0.044998		0.629	0.032		0.669
Plot intercropped	-0.304		0.187	-0.344956		0.13
Education	-0.0058		0.92	-0.005537		0.923
Age	-0.000367		0.963	-0.0001		0.992
Farm size	0.010232	*	0.053	0.009427	*	0.078
Children	0.017109		0.297	0.016		0.34
Transfers	0.000003	***	0.008	0.000003	***	0.004
Off-farm earnings	0.0000024	*	0.066	0.0000023	*	0.068
Constant	0.983		0.223	1.0567359		0.185
Observations	439			439		

Errors clustered by household. Sugars category includes foods with added sugar (e.g., jam), tea or coffee with sugar, soda or juice with added sugar.

Figure 1. Distribution of Women's Dietary Diversity Score



Variable values range from 0-9. n=5930
Source: Authors, from data collected by IER/MSU in 2017-18.