Input subsidy impacts on smallholder cowpea farmers in Mali

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Abstract

The unexpected consequences of farm input subsidies on legume crops have not been widely documented since the Green Revolution in Asia. In Mali, cowpea is an economically minor legume crop with nutritional and agronomic characteristics that are important for sustainable food systems. We test the effects of the fertilizer subsidy on several facets of cowpea production and consumption by smallholders. Applying a control function approach to a dataset collected from 2400 farming households, we find that the fertilizer subsidy reduces crop richness, the number of plots intercropped with cowpea and their areas, and farm area shares not targeted by the subsidy. Contrary to our expectations, women manage cowpea plots infrequently. Yet, the subsidy is negatively associated with the revenues' women earned from cowpea sales, and positively associated with men's revenues. We find no overall linkage between the subsidy and minimum dietary intake of women household members of reproductive age. The subsidy appears to affect positively the consumption of the legume group—which included cowpea, Bambara groundnut, and soja. Findings raise questions regarding the design of the subsidy program and highlight the need for further empirical research.

Introduction

As in many Sub-Saharan African countries, Mali has established a new generation of agricultural input subsidies with the goal of expanding use of fertilizer and improved seed, raising productivity, and ultimately, reducing food insecurity. Reducing food insecurity is undeniably a critical policy goal; in 2018, the prevalence of undernourishment in Mali reached a three-year average of 25% of the population (FAO et al. 2019). Undernourishment refers to habitual food consumption that is insufficient to provide the dietary energy required to maintain a normal, active, healthy life.

Input subsidies are clearly a blunt instrument for achieving goals related to hunger because they affect only the "supply-side" of the equation. Since early work by A.K. Sen (1981), policymakers have understood that entitlements to food are the proximate cause of nutritional status rather than availability—although lack of food may be one of the causes of loss of access to food. A large share of Mali's population remains rural and depends largely on their own farm production for food, if not to generate income for food purchases. It seems logical, then, that raising productivity of starchy staples such as rice, maize, millet, and sorghum should enhance the intake of calories, supporting nutrition. Yet, there is more to nutrition than calories. Legumes such

The archetypal story about input studies and legumes such as cowpeas is told against the backdrop of Green Revolution in South Asia during the 1960s. The rice–wheat cropping system of the Indo-Gangetic Plains was an epicenter of the technological changes (Dwivedi et al. 2017:

845) “which, on the one hand, enhanced food and nutritional security, and displaced legumes from the system on the other.” Since then, the system has exhibited not only declining productivity and “a great resurgence of malnutrition…. among South Asian populations depending entirely on rice and wheat, with micronutrient deficiency being the major cause” (ibid.). Joshi (1998) observed the decline in area under legumes in the rice-wheat system from the 1960s. He concluded that even if the existing subsidies on fertilizers and electricity for irrigation had been withdrawn, the rice-wheat cropping sequence would have remained the most profitable. Substitution of legumes for rice or wheat would have meant a loss in earnings (Joshi et al. 2000). During the decades of the 1980s and 1990s, annual compound growth rates in area, production and yield of major commodity groups in South Asia show that among food grains, cereals performed better than pulses as measured by annual compound growth rates in areas, production and yield (Joshi et al. 2003). Specialization in favor of rice and wheat resulted from the availability of high-yielding rice and wheat varieties to address an overriding concern for food self-sufficiency in terms of starchy staples. Pingali (2015) calls this the “staple grain fundamentalism” of the Green Revolution. Dwivedi et al. (2017) underscore the nutritional benefits of diverse food production systems.

Mali’s subsidy program is described as “universal” because, unlike some longstanding programs in Malawi and Zambia, for example, it does not explicitly target a specific group of farming beneficiaries. However, Mali’s program does “target” specific crops and farming systems. An agricultural policy such an input subsidy that favors one crop over another can distort farmers’ choice of crops, crop areas, production, and market sales—with long-term implications for the sustainability of the farming and food systems.

Cotton and starchy staples (maize and irrigated rice) are the crops predominantly targeted by fertilizer subsidies in Mali. If eligible under the policy, Malian growers of target crops can gain access to subsidized fertilizer at a quantity that is proportional to the number of hectares devoted to those target crops. For sorghum and millet, the rate of subsidization is one-third the rate for rice and cotton.

Most of the empirical evidence concerning the impacts of the most recent generation of input subsidies in Sub-Saharan Africa (Druilhe and Barriero-Hurlé 2012, Wanzala-Mlobela 2013, Kato and Greeley 2016, Jayne et al. 2018;) has examined effects of fertilizer use on crop yields of starchy staples, crop or farm income, and poverty status. Among the studies reviewed, we found only two articles that address effects on crop diversity (both in Malawi: Snapp and Fisher 2015; Chibwana, Fisher and Shively 2012). We are not aware of studies of the effects on minor crops such as cowpea.

Similarly, we found only a few published studies have examined implications of fertilizer subsidies for dietary intake, including Snapp and Fisher (2015) and Harou (2018) in Malawi. None of these studies addressed the effects of the input subsidy program within households. Smale et al. (2020) tested the effects of the fertilizer subsidy on female plot managers in Mali. The amount of subsidized fertilizer received appears to affect crop production and sales positively whether men or women manage the plot. Subsidized fertilizer also contributes to the chances that female plot managers will meet the minimum number of food groups needed for an adequate diet, but positive effects are offset by the negative effects of all subsidized fertilizer received by other plot managers—which may reflect greater farm orientation toward targeted cereals and cotton.

Here we further explore the effects of the fertilizer subsidy in Mali on cowpea, production and consumption *within* farm households. Are cowpeas a "women's crop" in Mali? According to CNFA (2016), within farm households, both men and women grow cowpea, but harvest and processing of cowpea are activities mostly done by women. Dembélé's (2015) study documents the successful introduction and commercialization of forage cowpea by a women's cooperative in Kati, but does not discuss the socio-economic roles of women participants—perhaps because these are assumed to be already understood. Cissé (2012) remarks that in several countries of this sub-region of West Africa, preparation and sales of lightly processed cowpea and cowpea products is the domain of women, who have the potential to generate substantial revenues. He reports that in Mali, certain vendors inherit the enterprise from their mothers. He notes that one of the main constraints to development of their industry is that they have access only to the individual fields allocated to them by the household head on marriage into the family. These are typically small. They also bargain for access to any equipment or other inputs needed for production, which are destined to the larger collective fields managed by the head on behalf of the entirely family. Our working hypothesis is that cowpea is not a "women's crop" per se in Mali but a "women's enterprise."

The analyses presented here, which are based on data collected in Mali, contribute in several ways to the literature. First, we add to a relatively sparse literature on the impacts of fertilizer subsides in the Sahelian region of West Africa. We provide new information on the potential distortionary effects of fertilizer subsidies on production of minor crops, using cowpea as an example. We also contribute new findings on the intrahousehold effects of the subsidy on production, sales, and consumption (dietary intake) of an economically minor, but nutritionally and agronomically important crop (cowpea). This third contribution adds to our knowledge about gender roles in cowpea production.

Methods

The precepts of a non-separable model of the agricultural household (Singh, Squire and Strauss 1986) are the conceptual basis of the behavioral model underlying our empirical model. Utility is maximized rather than profits, and decisions are affected by both observed prices and household characteristics that affect endogenous prices through household-specific transactions costs. Farm households both produce and consume a portion of the crops they grow, although they also participate actively in markets as both sellers of crops and purchasers of inputs and food products. They are neither fully commercial nor fully oriented toward subsistence.

Fertilizer subsidies can affect land allocation patterns among crops by influencing the incentives to grow one crop over another, favoring crops targeted by the subsidy by lowering input costs and offering the potential of attaining higher yields for those crops. The number of crops grown, and the share of total farm area they occupy, can shift when land is re-allocated. Minor crops such as cowpea may be planted to fewer plots or less area than without the subsidy. Greater volumes of targeted crops produced can lead either to a change in the amount consumed on farm or to a change in the basket of goods purchased for food as a result of a change in sales, or both.

Our households are not unitary, but collective decision-makers. The theory that underlies our thinking also follows the intrahousehold decision-making models of Udry (1996), Kazianga and Wahhaj (2013), Guirkinger and Platteau (2014), and Haider et al. (2018). The fundamental precepts of these models are similar and reflect observed behavior of farming families in the dryland farming systems of Burkina Faso and Mali. The models depict an extended family that organizes farm production in a patrilineal tenure system under the headship of a senior male. Farm family members work together to produce a public good (starchy food staple) on a collective plot managed by the head and some also work individually to produce private goods on plots allocated to them for their personal use. Members contribute labor to the collective plot and receive a share of the harvest; if allocated use rights to an individual plot, they alone control the proceeds. Input use decisions are the result of bargaining and negotiation among family members. These may or may not be efficient.

Evidence from Mali demonstrates that the use of subsidized fertilizer is likely to be heterogeneous both among households and among different members of the same household. (Thériault et al. 2018; Smale et al. 2020). Effects of the fertilizer subsidy may be differentiated by gender or status. Cowpeas grown on fields allocated to women by the head are a source of cash that they may use to meet personal needs and supplement their children's diets. Similarly, income earned on individual plots allocated to sons and younger brothers alongside the collective fields managed by the head is the responsibility of the plot manager.

In a regression framework, we test the working hypotheses that the fertilizer subsidy: 1) reduces overall diversity (richness, evenness) of crops grown on farms; 2) reduces the number of cowpea plots and the share of farm area allocated to cowpeas; 3) has gender- and status-differentiated effects on cowpea revenues earned by household members; 4) affects the overall diet quality of farm women and reduces the consumption of cowpeas.

We use the total kgs of subsidized fertilizer (s_i) applied by household i to crops targeted by the subsidy (cotton, maize, rice, sorghum and millet) during the cropping season as the impact variable. Each outcome variable (y_i) is a function of the quantity of subsidized fertilizer (s_i)

applied s and other factors ($\boldsymbol{z}_{ima}$): $y_i = f(s_i, \boldsymbol{z}_{ima})$. The vector $\boldsymbol{z}$ includes characteristics that co-vary with outcomes at the household (i), market (m) and agroecology (a) levels.

Econometric approach

Subsidized fertilizer s may be endogenous in variables that measure household outcomes because the subsidy is not randomly allocated among households. Unobserved factors that affect the outcome variables may also affect the application of subsidized fertilizer by the household. These include factors such as transactions costs of market or subsidy access that reflect household endowments. Other unobserved factors that may affect gender-differentiated outcomes are intrinsic characteristics such as the status and relative empowerment of plot managers. These affect their capacity to negotiate for farm inputs and other resources within the household.

The Tobit model is appropriate when the application of subsidized fertilizer represents a corner solution with values concentrated at zero. In the presence of this non-linearity, rather than a two-stage least squares model, we employ the Control Function Approach (CFA) to test for the potential endogeneity of subsidized fertilizer in the equation for each outcome (Smith and Blundell 1986; Vella 1993; Wooldridge 2015). Our outcome variables also have various forms, including values concentrated at zero, values concentrated at one, continuous and count variables. In our second stage regression, we apply econometric models that fit the form of the outcome variable, including Tobit, OLS, poisson and negative binomial models.

To apply the CFA approach, we begin by estimating a first stage Tobit model of the subsidized fertilizer applied by the household on the vector $\boldsymbol{z}$ (as defined above) and instrumental variables (IVs). To be valid, the IVs should be strongly individually and jointly correlated with subsidized fertilizer in the first stage regression, but uncorrelated with the error term in the outcome equation. A t-test of the individual coefficients on the generalized residuals (or a joint test of the significance of the set of residuals[1]) tests the null hypothesis of exogeneity of subsidized fertilizer to outcome *y* against the alternative hypothesis of endogeneity. This is a statistical test of the relevance of the IV to the potentially endogenous variable.

The exclusion restriction has no formal statistical test and is met primarily by logical argument. We tested three candidate IVs. The first is a "design" variable: location of the plot manager (household farm) in the pilot zone for electronic vouchers (0,1). This variable is determined outside the decision-making scope of the plot manager. The second is an institutional variable: whether a plot manager in the household had received training in the past from the CMDT (also 0,1). The third is the maximum number of years (excluding the current year) that any plot manager in the household has benefited from a subsidy on either seed or fertilizer in the past. This variable is predetermined. While each of these instruments is related causally to the amount of subsidized fertilizer applied on the plot, we see no apparent link to our cowpea outcome variables other than through subsidy incentives. Nor do we see causal links to consumption outcomes other than through changes in productivity and income resulting from higher rates of fertilizer use. Specific t- and F-test values are presented in the results section and tables.

If we reject the null hypothesis that the coefficient on the residuals is equal to zero in a given second stage regression, we reject exogeneity of subsidized fertilizer. The control function approach controls for endogeneity by including the generalized residuals from the first stage along with the observed subsidized fertilizer and other covariates in the second stage regressions.

[1] A rule of thumb to determine if the IVs are sufficiently strong is if their joint F-statistic is greater than 10.

Standard errors are then bootstrapped because of the inclusion of the generalized residuals. We estimated models in STATA 15, using errors clustered by household in the first state and robust standard errors in the second.

Outcome variables

Our analyses include several sets of outcome variables, including those that measure crop diversity, cowpea farm areas, cowpea revenues, diet quality and cowpea consumption.

Spatial diversity is one of the most commonly recognized concepts of diversity in the ecological literature (Magurran 2004) and has been adapted for analysis of crop diversity in studies conducted by both applied geneticists (e.g., Jarvis et al. 2008) and agricultural economists (Table 1, Meng et al. 1998; Smale 2006). Measures of richness represent the number of distinct plant populations (varieties or crops) in a defined geographical area, such as a region, community, or in our case, an individual farm. Normalizing the count by the number of individuals encountered in the geographical space is recommended. Here, our richness index is the Margalef index, which divides by the logarithm of the total area on the individual farm.

A contrasting concept in the ecological literature is relative abundance (evenness), or the frequency of different types of plant populations encountered in the geographical unit. The Shannon index embodies no particular assumptions about the shape of the underlying distribution in species abundance and has been widely used in the agronomic and ecological literature. By construction, the Simpson index is numerically related to the Herfindahl index of concentration that is applied in economics analysis of industrial organization. Rather than the proportion of individuals, we employ the area share to represent abundance. Attention to the form of the dependent variable is important in regressions with diversity indices, which are often censored either from above or below, or both.

We explore the effects of the fertilizer subsidy on cowpea farm areas with outcome variables measured as the total number of plots planted to cowpea as a primary or as a secondary crop, and the total area shares allocated by the household to these two categories. With respect to the secondary crop, area shares are reported for the entire plot rather than the portion intercropped with cowpeas. Difficult to measure, farmers estimated that about half of intercrops occupy less than one-fifth of the plot. We also tested effects on total cowpea production.

Cowpea revenues are differentiated by gender and by the status of household members (chef, non-chef). We summed these over each category of plot manager and refer to the time period after harvest in late 2017 through April of 2018, as reported by farmers.

Our cowpea consumption indicators are measures of dietary intake. We did not measure the physical amounts consumed. The data were designed to facilitate the construction of both the Women's Dietary Diversity Score (WDDS) and the Minimum Dietary Diversity for Women (MDD-W). Compared with other measurements, dietary diversity can be assessed with relatively simple, low-cost survey techniques. They also correlate well with anthropometric measurements of nutritional status and micronutrient adequacy (Arimond et al. 2010; Ruel et al. 2013). Given the important role of women in achieving food and nutrition security, new dietary diversity indicators have been recently developed: the Women's Dietary Diversity Score (WDDS) and Minimum Dietary Diversity for Women (MDD-W) of reproductive age (FANTA 2018; FAO and FHI 2016). As compared with the Household Dietary Diversity Score, which does not distinguish among members of the household, and the Individual Dietary Diversity Score, which does, the definitions of food groups in these latest indicators also highlights micronutrient adequacy, or diet quality.

In Mali, legumes (other than groundnuts) are grouped together and are represented by cowpea, Bambara groundnut, and soya. In addition to the WDDS and MDD-W scores, we examine the effects of the fertilizer subsidy on the sum of the frequencies of consumption of items included in this group over the 7 days preceding the interview by all women surveyed in the household.

Explanatory variables

Definitions and summary statistics for exogenous variables included in the vector $\boldsymbol{z}$, as well as instruments and the potentially endogenous variable, total kgs of subsidized fertilizer applied by all managers of target crops in the household, are shown in Table 2.

In addition to the instruments described above, other exogenous variables include institutional affiliation (part of the Office du Niger or CMDT). These can influence cropping patterns and the likelihood of growing cowpeas. Price data captured in the survey were poor and secondary data are too invariable to represent individual incentives. Distances related to market access influence access to inputs but also commercialization and consumption. We measure distances in several ways, including the mean distance to the source of fertilizer, distances from the household to the nearest retail store, tarmac road, and the national capital, Bamako. The distance variables were reported by the plot manager (including head of household) and affect the transactions costs for fertilizer and effective prices they face. The number of microfinance organizations per village, as reported in a preliminary community survey with village representatives, is represented in all regressions.

To incorporate plot characteristics, we summarize those at the household level. For instance, literature shows that numbers of soil types on the farm and variation in relief to be related to on-farm diversity in the literature. We also include the number of intercropped plots—since cowpea is often an intercrop—and total amounts of organic fertilizer applied, which is often substituted for fertilizer if more easily obtained. Agronomic recommendations are to use both inputs to improve soil texture as well as nutrient content.

Household characteristics include labor supply in terms of adult family members (most of labor used in production is provided by family members), which is a complementary input with fertilizer, and the number of children, or dependents. Overall farm size is a measure of endowments and capacity to generate crop income, also capturing scale-related effects. Household nonfarm income sums transfers received from family members living outside the home and off-farm earnings of family members, each earned in the previous year. Nonfarm income could contribute to growing additional crops, or diversifying production, or to purchasing food items that contribute to diet quality.

Data

We employ data collected in 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 agro-ecological zone, including the zones of the Niger Delta and the Koutiala Plateau. The farming system of the Niger Delta is based heavily on production of irrigated rice, with surrounding areas of dryland production of millet where we also expect cowpea to be grown; that of the Koutiala Plateau is based on sorghum and a cotton-maize rotation in a rainfed system. The sample was also stratified by zone of operation of structured extension services (“encadrement”), including the ON (for gravity-fed, irrigated rice) and CMDT (for cotton). The third stratifying variable was the pilot zone for the electronic voucher, as compared to the paper voucher, which is universally available to growers of target crops. A random sample of 60 standard enumeration (SE) areas was selected with probability proportionate to size in each of the agro-ecological zones. In each SE, 20 household farms (*Exploitations Agricoles Familiales*, or EAF) were randomly selected from a list frame (a total of 2400 households). Detailed information on the fertilizer subsidy and input use was collected only on plots of target crops (rice, maize, millet, sorghum, cotton) in multiple visits.

Crop diversity variables are constructed over a sample of 11,971 plots inventoried among 2400 households during the first visit. Due to political insecurity in some areas surveyed, several enumerator areas were dropped from later rounds of the survey. The analytical sample in our regressions with most outcome variables is 2329 households. The survey team asked to interview all women of reproductive age (15-50) within households surveyed concerning dietary patterns in the last of four visits. Not all households, and not all eligible women consented to these interviews. Our analytical sample for diet quality variables is averaged over women respondents in 2192 households.

Descriptive statistics

Cowpea represents only a little over 3% of all primary crops on plots inventoried by household during the 2017-18 in the two agroecological zones (Table 3). On the other hand, cowpea represents the majority (79%) of secondary crops reported by households. The most common primary crop on plots where cowpea is secondary are millet, sorghum, and maize—the main dryland cereals of Mali and also those targeted by the subsidy program (as noted in the introduction, other crops targeted are rice and cotton).

Plots where cowpeas are grown as a primary crop for grain are generally small; 90% are under a hectare in size and the mean is 0.58 ha (Table 4). Observations number only 9 for forage cowpea, all of which are grown as a primary crop, and these are all 1-2 ha in size. Mean areas of plots where cowpea is the secondary crop are considerably larger, averaging 3.5 ha, with a much greater range. We cannot ascertain from the data whether secondary crop implies intercropping at the full scale of the plot; farmers' estimates for the plots planted to millet, sorghum and maize indicate that half of intercrops occupy under a fifth of the plot.

The pattern of cultivation differs between the two agroecological zones, reflecting the fact that drier areas of the Delta du Niger lie in the cowpea basin of Mali. Plot numbers and mean plot areas are greater in this zone relative to the Plateau of Koutiala (Table 5).

Considering all households in our analytical sample (that is, where cowpeas were and were not grown) cowpeas as a primary crop represent just under 1% of area farmed per family on average, in either zone; plots where cowpeas are grown as a secondary crop represented 16% of the area in the Delta and only 4% on the Plateau (Table 6). Among growers of cowpea, area shares of cowpeas grown as a primary crop averaged 5% on the Plateau and nearly twice that much in the Delta (9%); mean area shares of plots where cowpeas are grown as a secondary crop are 30% on the Plateau and 61% in the Delta. These differences are statistical (<1%) and meaningful. Thus, cowpea's role as a secondary crop appears to be substantial.

About four out of five plots where cowpea is planted as the primary crop are managed by men, and 86% of plots where cowpea is a secondary crop are managed by men (Table 7). Within households, the head manages about half of the primary cowpea plots and just under half (44%) of the secondary cowpea plots. Sons were second in terms of representation, followed by wives and brothers of the head. Many different household members manage cowpea plots (Table 8).

Plots planted to cowpeas as either a primary or secondary crop constituted only 1-2% of plots managed by women in households surveyed on the Plateau of Koutiala. Crops most frequently managed by women in that zone were groundnut, lowland rice, sorghum and okra. In the Delta du Niger, cowpeas were planted as primary on 8% of plots managed by women and secondary on 16% (Table 9). Most frequently grown primary crops in the Delta du Niger were groundnut, millet, onion, sesame, cowpea and okra; cowpea was by far the most frequent secondary crop on women's plots in that zone.

Suspecting that our data may understate the role of women in managing cowpea production in Mali, we examined other data sources. Data collected in 2014/15 under the *Guiding Sustainable Investments in Agriculture* (GISAIA) project in 58 villages of the Cercles of Kati, Dioila, and Koutiala in Koulikoro and Sikasso regions. The male head of household managed 70% of the plots were cowpea was grown as either a primary or secondary crop, and sons or brothers of the head were about as likely to manage cowpea plots as his wives. That survey included 4617 inventoried plots. Guirkinger et al. (2015) report data collected in 2008 in 17 randomly sampled villages in the Cercles of Koutiala, Sikasso, and San. They report that cowpea was grown on 4.4% of collective plots managed by the head, 3.9% of individual plots managed by other male household members, and 2.3% of individual plots managed by females. The regions of Koulikoro and Sikasso have the second largest areas planted to cowpea in Mali. The cowpea percentage of all household plots, and of women's plots, may be higher in drier areas of Segou and Mopti regions, which have the largest cowpea areas, than in Sikasso, for example (Figure 1).

Receipt of subsidized fertilizer is negatively associated with growing cowpea as a secondary crop on plots of target crops (Table 10). At the household level, which includes the inventory of plots for all crops, there is a negative association between subsidy receipt and the count of plots, mean plot area, and average area share where cowpea is grown as a primary crop but the difference is not statistically significant (Table 11). The negative association is of larger magnitude for the plots where cowpea is grown as a secondary crop, and this difference is highly significant (< 1%). The descriptive data therefore suggest that the subsidy is correlated with a lower incidence of intercropping.

Results of first-stage regression

The first-stage reduced-form regression predicting total subsidized fertilizer (kgs) received by farm households is shown in Table 12. The model is a Tobit because of the large number of observations concentrated at zero. The dependent variable has been logged to reduce skewness.

Each instrumental variable is statistically significant (under 1 and 5%) with the expected positive sign. The value of the F statistic (3, 2309) is 100.15, with Prob > F = 0.0000. A mere 3 households out of entire sample reported receiving the subsidy only via an e-voucher, 114 received both the subsidy through both paper and evoucher, and 876 received only the paper form. A total of 1208 observations were located within the evoucher pilot zone, but clearly, the evoucher played no role in the positive effect of this instrument. Past CMDT training suggests a strong link to this formalized structure and its range of services. Previous years applying for and receiving the subsidy are also an indicator of access and capacity.

Location in the Office du Niger has a weakly negative sign, but this may reflect that households surveyed in this zone include those farming in the millet and sorghum-based drylands. A more direct explanation is that mean farm sizes in our ON households are about half those of CMDT households (5.6 vs. 10.9 ha, respectively); crop counts, including but not limited to subsidy target crops, are 2.5 on average among ON households and 5.9 among CMDT households. Location in the CMDT zone has the strongest marginal effect of any variable in the regression. The count of dominant soil types (1-3) on the farm is positively associated with the amount of subsidized fertilizer received, as are the numbers of intercropped plots. Dispersion of plots and distance to the nearest store makes moving heavy inputs such as fertilizer costlier in terms of labor time or transport. The higher the number of stores in the village, the more subsidized fertilizer applied. While stores are not usually sources of subsidized fertilizer, these represent access to other inputs and information. Greater human capital as measured by the numbers of adults in the family and the maximum education among plot managers plays an important role in obtaining and utilizing the subsidy. Nonfarm income, which combines transfers and wage or salary income from outside the farm, has a weak but positive effect on subsidy receipts.

We also tested whether the number of female plot managers in the household influenced total subsidized fertilizer received. The effect was negative with a p-value of 7%, without altering the signs and significance of other variables except for an even more negative and significant sign for the ON. This result suggests either that female plot managers grow crops that are less likely to be targeted or that they are less able to obtain the subsidy even though it is in principle available to all. In fact, our initial plot inventory shows that over 90% of all plots planted to crops targeted by the subsidy program are managed by men. Women frequently manage plots of vegetables and legumes, such as onion, okra, cowpea, groundnut, hot pepper, and hibiscus. They grow some sesame and fonio. We know that their plot sizes are considerably smaller because they are allocated individual fields on marriage into the family rather than conferred either the *grands champs* managed by the chef or the individual fields passed through the patrilineal succession. In our initial plot inventory, reported plot sizes averaged 2.2 ha among all male plot managers and 0.65 among female plot managers.

Considering only plots planted to crops targeted by the subsidy in our sample, the gender differential is 2.33 vs. 0.79 ha. In this subsample of target crop plots, 92% of plot managers are men. Among target crop plots, women are more likely to manage millet or sorghum plots and men are more likely to manage rice plots in the Delta du Niger. In the Plateau de Koutiala, women are more likely to manage small sorghum fields or rice plots in flooded lowlands and men are more likely to manage cotton, millet and maize plots as part of a rotation.

Results of second-stage regression

Second-stage regression results are grouped by category of outcome variable and related hypothesis. Specifically, we test a) the effect of fertilizer subsidies on crop diversity; b) the gender- and youth-differentiated effects of fertilizer subsidies on cowpea cultivation, quantities sold and revenues; and c) the effect of the fertilizer subsidy on diet quality, including the consumption of pulses (*niebe, vouandzou, soja*).

Crop diversity

The amount of subsidized fertilizer applied by the household appears to be associated with higher numbers of primary crops grown but lower richness when crop counts are standardized by the square root of farm size in the Margalef index (Table 13).

Other coefficients are also of interest in these models. Location in the ON reduces the crop count by nearly 2 (1.9), while location in the CMDT raises it by 0.5 relative to the other areas. Thus, formal extension structure is not necessarily a negative factor in supporting crop numbers grown per farm or per unit of farm area. As expected, a higher number of soil types is related positively to crop richness since it enables farmers to grower a wider range of crop species. Market infrastructure variables show mixed results. The greater the distance to the nearest store, the lower is average crop richness on farms. Improved seed or seed of crops such as vegetables might be available from retailers. However, distance from Bamako bears a positive sign, as does distance from the tarmac road. These signs are consistent with the hypothesis in the literature that farmers in more isolated areas are more likely to be subsistence-oriented and seeking to satisfy their consumption needs by maintaining crops that are more diverse. Larger farmers have larger numbers of crops and lower richness per unit of area. Human capital variables--the supply of family labor and the education of plot managers are associated with less crop richness. Again, this finding is consistent with the notion that human capital enables the household to specialize and commercialize their farm production.

The effect on the overall evenness of all crops is strongly positive as measured by the Shannon index and weakly positive with the Simpson index (Table 14). However, higher amounts of subsidized fertilizer applied by the household are associated with greater unevenness between crops that are targeted by the subsidy and those that are not. Concentration in target crops is greater in the ON and evenness lower, while the opposite is the case in the CMDT zone. Numbers of soils and relief types influencing crop evenness positively, but the average time it takes to reach plots reduces it. The number of intercropped plots is negatively associated with concentration of farm area in target crops compared to non-target crops, but positively associated with overall proportional abundance of crops on farms. Market variables are again significant in the evenness indices. Non-farm incomes received in the period before the survey appear to both favor concentration in target crops but also overall evenness among crops.

Cowpea farm areas

The amount of subsidized fertilizer used by the household has no discernible effect on the number of primary plots planted to cowpeas, but it reduces the number of plots in which cowpea is grown as a secondary crop (Table 15). Similarly, on average, subsidized fertilizer has no apparent influence on the area (ha) of the primary plot planted to cowpea, but is negatively related to the area (ha) of the plot where cowpea is planted as a secondary crop, and to the share of those plots in the total farm area managed by the household during the cropping season of the survey (Table 16).

Gender and status-differentiated production and sales

Regressions indicated no effect of subsidized fertilizer on overall cowpea production or sales for the household as a whole. Using the same dataset, Smale et al. (2020) found that the fertilizer subsidy contributed positively and significantly to the value of production of crops targeted by the subsidy (cotton, maize, sorghum, millet, rice) by the same percentage change for both male and female plot managers. Effects on sales of target crops were also strong for male plot managers but weak for female plot managers.

The subsidy seems to have weakly enhanced revenues from cowpea sales by male plot managers but reduced cowpea revenues among female plot managers (Table 17). There was no observable relationship between the subsidy and cowpea revenues when household members were grouped as chef and non-chef (including men with lesser decision-making status and women) (Tables 18).

Diet quality and cowpea consumption

We find no significant effect of total subsidized fertilizer applied by the household on the average diet quality of all female household members of reproductive age, whether diet quality is measured by the WDDS or the MDD-W (Table 19).

More than half the women interviewed for diet information in our sample did not consume the minimum number of food groups needed for an adequate diet (MDD-W) at the time of the survey. Smale et al. (2020) found that subsidized fertilizer significantly contributes to the chances that female plot managers will meet this threshold, and to consumption of iron-rich foods. Positive effects appear to be offset by the negative association of diet quality with all subsidized fertilizer received by other plot managers—perhaps because it leads to greater farm orientation toward targeted cereals and cotton for the household as a whole.

The food groups as defined by the diet quality literature do not include cowpea taken alone. For Mali, cowpea was grouped with Bambara groundnut and soybean (excluding groundnut), although these crops were rarely planted. When measured only in terms of the 24-hour period preceding the survey, we found no effect of subsidized fertilizer applied by the household on consumption of these legumes (Table 20). Taking the week before the survey into account, the subsidy had a positive effect on the frequency of consuming these legumes, including cowpea.

Conclusions

In this paper, we have added to a limited literature about the impacts of fertilizer subsidies in the Sahelian region of West Africa. We have generated new information about the potentially distortionary effects of fertilizer subsidies on the production of economically minor crops with key agronomic and nutritional attributes, using cowpea as an example. We have also contributed new findings related to the intrahousehold effects of fertilizer subsidies on gender-differentiated crop revenues and women's dietary intake.

We applied a Control Function Approach to test and control for the endogeneity of the amount (kgs) of subsidized fertilizer applied by households, employing data collected in a detailed survey implemented by the Institut d'Economie Rurale and Michigan State University (IER/MSU) in 2017-18. We constructed crop diversity variables over a sample of 11,971 plots inventoried among 2400 households. Confronted by political insecurity, the team was obliged to crop several enumeration areas from later survey rounds. The analytical sample in our regressions with most outcome variables is 2329 households. Since not all households and/or women consented to dietary intake interviews, our analytical sample for these variables numbers 2192 households.

We find that cowpea represents slightly over 3% of all primary crops but almost 80% of all secondary crops on plots inventoried by households. 90% of plots were cowpeas are grown as a primary crop are under a hectare in size, while mean areas of plots where cowpeas are grown as a secondary crop average 3.5 ha. Observations number only 9 for forage cowpea, all of which are grown as a primary crop on 1-2 ha. The pattern of cultivation differs between the two agroecological zones included in our sample, reflecting the fact that drier areas of the Delta du Niger lie in the cowpea basin of Mali. Plot numbers and mean plot areas are greater in this zone relative to the Plateau of Koutiala.

Men manage about four out of five plots where cowpea is planted as the primary crop, and men manage an even higher number of plots where cowpea is a secondary crop. Within households, the head manages most of these plots, followed by his sons, his wives, and brothers. Many different household members manage cowpea plots.

We tested several hypotheses in our regression framework. We found that the more subsidized fertilizer applied by the household, the higher the number of rimary crops grown but the lower the crop richness index when we control for farm size. Further, the greater the amount of subsidized fertilizer is positively associated with a shift of area shares toward crops targeted by the subsidy.

While amount of subsidized fertilizer used by the household has no discernible effect on the number of primary plots planted to cowpeas, it significantly reduces the number of plots in which cowpea serves as the intercrop. Similarly, although subsidized fertilizer has no apparent influence on the area (ha) of the primary plot planted to cowpea, it is negatively related to the area (ha) of the plot where cowpea is planted as a secondary crop, and to the share of those plots in the total farm area managed by the household.

The subsidy seems to have a weakly positive effect on revenues from cowpea sales by male plot managers but reduced cowpea revenues among female plot managers. We find no significant effect of total subsidized fertilizer applied by the household on the average diet quality of all female household members of reproductive age. Taking the week before the survey into account, the subsidy has a positive association with the frequency of women's consumption of legumes, including cowpea, Bambara groundnut, and soja.

Implications

Can we rewrite the story of legume displacement during the Green Revolution in South Asia in Mali and other countries today? Our findings have several obvious implications for agricultural policy. First, if the government of Mali is concerned about nutritional security beyond the consumption of adequate starchy staples such as those now targeted by the fertilizer subsidy program, the design of the subsidy could be revisited to incorporate crops such as cowpea—perhaps in the form of seed as part of a seed-fertilizer package of variable size. We did find mention of cowpea in references to early years of the national subsidy program, following the global food crisis in 2008 (Ministère de l'Economie des Finances, 2016) but not in the latest document (ibid., 2019). Other countries, such as Malawi and Zambia, have experimented with related approaches.

Secondly, the negative association between the subsidy and the production of cowpea as an intercrop raises concerns not only for nutritional but also for agronomic reasons. This finding deserves additional research with other datasets to confirm whether it is a recurring pattern or specific to the farming systems we studied. Often, measuring the extent of intercropping on farms is made difficult by definitional problems. "Intercropping" of a plot could refer to only a row, or corner of the plot or to the entire plot—depending also on its size.

We were surprised to find that women managed so few of the cowpea plots in this data set or in other studies conducted in Mali that we found in the published literature. This finding raises questions about the extent to which cowpea is a women's crop *per se*, and in what way. Revisiting this topic to ascertain the meaning and validity of the term "women's crop" may be an important avenue for future research on gender roles in the cowpea value chain—also with ramifications for agricultural policy.

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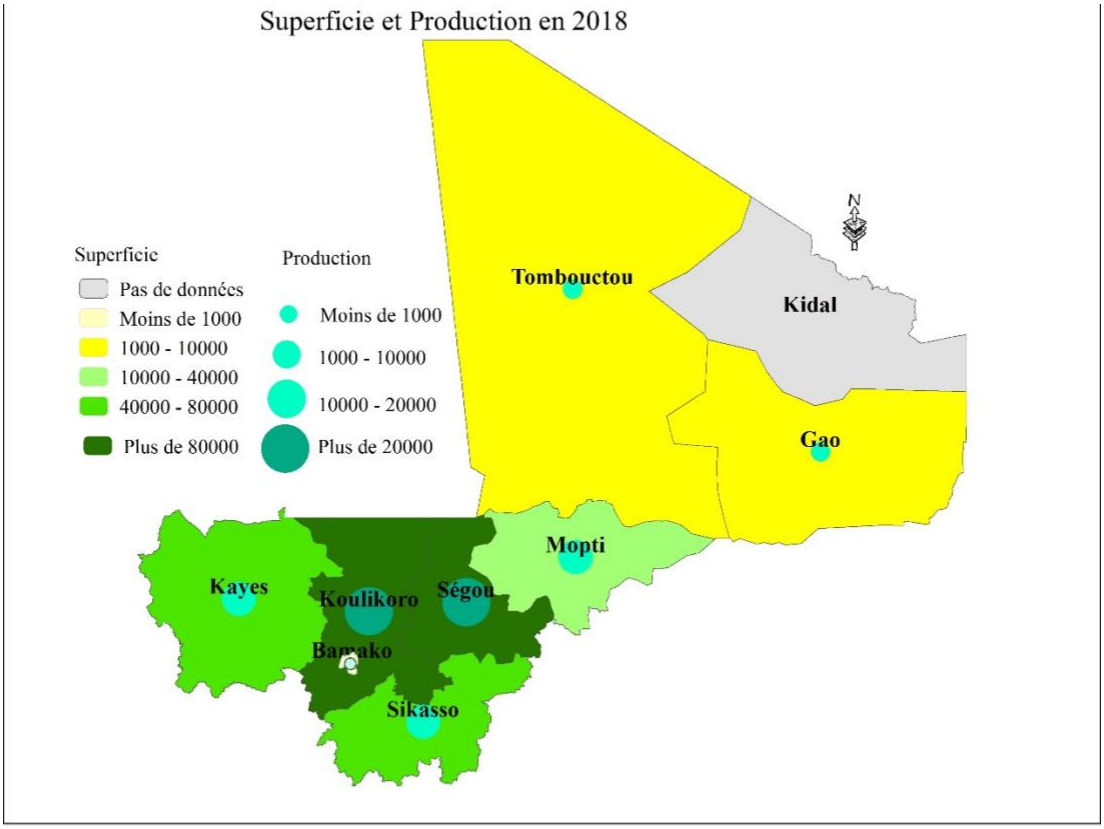
Figure 1. Cowpea production and area in Mali, by region, 2017-18



Source: A.K. Traoré, September 2020.

Table 1. Definitions and summary statistics for outcome variables

Category	Variable	Definition	Mean	Sdev	Min	Max
Crop diversity		*spatial diversity indices adapted from ecology*				
	Count	number of crops grown by household	4.38	2.04	2.00	11.00
	Margalef	(count-1) divided by natural log total farm area	1.63	0.81	0.27	6.14
	Shannon	$-\Sigma\alpha_i \ln\alpha_i$, i=any crop grown by household	0.93	0.75	0.00	2.45
	Herfindahl+	$\Sigma\alpha_i^2$, i= all target vs non-target crops	0.64	0.30	0.21	1.00
	Simpson	1-Herfindahl index calculated over all crops	0.42	0.31	0.00	0.88
Cowpea farm areas		*numbers of plots on farm and farm area shares*				
	number of plots, primary	number of plots in household with cowpea primary crop	0.14	0.43	0.00	6.00
	number of plots, secondary	number of plots in household with cowpea secondary crop	0.41	1.11	0.00	14.00
	area share, primary	total area in primary cowpea plots/total farm area	0.01	0.03	0.00	0.77
	area share as secondary crop	total area in secondary cowpea plots/total farm area	0.11	0.25	0.00	1.00
Cowpea revenues		*FCFA from all cowpea sales from harvest to April 2018:*				
	men	all male plot managers in household	110	2771	0	100000
	women	all female plot managers in household	767	6848	0	125000
	chef	household head	405	4698	0	125000
	non-chef	all plot managers other than household head	481	5737	0	112500
Cowpea consumption		*focus on women of reproductive age in household*				
	WDDS	average minimum dietary diversity score (see text)	5.16	1.27	1	9
	MDD-W	average women's dietary diversity score (see text)	0.68	0.40	0	1
	frequency	sum, frequency of pulse consumption in preceding 7 days	2.61	5.58	0	35

Source: Authors based on PRePoSAM data. See text for details on indices.

Table 2. Definitions and summary statistics for explanatory variables

Variable	Definition	Mean	Sdev	Min	Max
subsidized fertilizer	total kgs of subsidized fertilizer applied by household	989	1019	0	11300
Office du Niger zone	household located in Office du Niger zone=1, else=0	0.33	0.47	0	1
CMDT zone	household located in CMDT zone=1, else=0	0.33	0.47	0	1
soil types per farm	count of soil types on farm	1.13	0.60	0	3
relief types per farm	count of relief types on farm	0.86	0.44	0	2
time to reach plot	mean hours to reach plots on farm	19.0	14.1	0	110
distance to subsidized fertilizer	mean distance to source of subsidized fertilizer (km)	2.78	9.29	0	300
distance to nearest store	distance to nearest retail store (km)	2.76	13.62	0	142
distance to tarmac	distance to nearest tarmac road (km)	15.0	17.3	0	95
distance to Bamako	distance to Bamako (km)	385	85	183	826
village stores	no of stores in village	1.99	2.02	0	10
intercropped plots	number of intercropped plots on farm	0.53	1.25	0	14
organic manure applied	total ks of organic manure applied by household	306	2732	0	96000
adult labor	number of household members > 14 years	8.13	5.12	0	33
children	number of household members <= 14 years	7.13	5.24	0	32
education of plot manager	highest education of plot managers in household	1.86	3.28	0	16
farm size	farm size in ha	9.43	7.56	0.3	44
non-farm income	nonfarm income and transfers received by household in year preceding survey (FCFA)	237213	589994	0	11600000
evoucher pilot zone	location in pilot zone for evoucher	0.51	0.50	0	1
subsidy experience	maximum years receiving subsidy among members	5.20	3.40	0	10
CMDT training	household member received past training from CMDT	0.14	0.35	0	1

Source: Authors based on PRePoSAM data.

Table 3. Frequency of crops grown on primary and secondary plots by households surveyed

	Primary crop		Secondary crop	
	Freq.	Percent	Freq.	Percent
Rice	2,771	23.15		
Millet	2,002	16.72	11	0.88
Sorgho	1,574	13.15	59	4.75
Maize	1,515	12.66	14	1.13
Cotton	1,435	11.99	1	0.08
Groundnut	1,211	10.12	43	3.46
Cowpea (for grain)	**330**	**2.76**	**980**	**78.84**
Sesame	233	1.95	11	0.88
Okra	134	1.12	48	3.86
Hot pepper	121	1.01	7	0.56
Soybean	116	0.97	1	0.08
Fonio	104	0.87		
Onion	101	0.84	6	0.48
Bambara groundnut	87	0.73	9	0.72
Sugar pea	47	0.39		
Watermelon	45	0.38	3	0.24
Igname	28	0.23	1	0.08
Tomato	20	0.17	6	0.48
Sweet potato	18	0.15	2	0.16
Manioc	13	0.11		
Cowpea (for forage)	**9**	**0.08**		
Green bean	8	0.07	2	0.16
Shallot	8	0.07	5	0.4
Cabbage	7	0.06		
Tobacco	5	0.04		
Green sorrel	4	0.03	11	0.88
Sweet peas	3	0.03		
Cucumber	2	0.02		
Ginger	2	0.02		
Irish potato	2	0.02	1	0.08
Melon	2	0.02	1	0.08
Barley	1	0.01		
Eggplant	1	0.01	1	0.08
Sweet pepper	1	0.01	1	0.08
Red sorrel	11	0.09	17	2.09
Squash			2	0.16
Total	11,971	100	1,243	100

Source: Authors based on PRePoSAM data.

Table 4. Cowpea plot areas, by plot type

	n	mean	sd	min	max
plot area where cowpea primary	330	0.581	0.488	0.100	5
plot area where cowpea grown for grain secondary	980	3.542	5.262	0.100	65
plot area where cowpea grown for forage is primary	9	1.444	0.527	1.000	2

Source: Authors based on PRePoSAM data. Plot areas based on farmer estimates.

Table 5. Cowpea plot areas, by agroecology

	n	mean	sd	min	max
Plateau de Koutiala					
plot area where cowpea primary (grain, forage)	190	0.541	0.372	0.1	3
plot area where cowpea is secondary (grain)	209	1.894	1.321	0.25	8
Delta du Niger					
plot area where cowpea primary (grain, forage)	149	0.684	0.632	0.1	5
plot area where cowpea is secondary (grain)	771	3.989	5.814	0.1	65

Source: Authors based on PRePoSAM data. Plot areas based on farmer estimates.
Difference-of-means test significant (1%) between zones.

Table 6. Cowpea area share of all crops grown by households, by agroecology

	n	mean	sd	min	max
All households (including non-growing), primary					
Plateau de Koutiala	988	0.009	0.024	0	0.235
Delta du Niger	1343	0.008	0.040	0	0.766
Both zones	2,331	0.008	0.034	0	0.766
All households (including non-growing), secondary					
Plateau de Koutiala	988	0.037	0.126	0	1
Delta du Niger	1343	0.160	0.302	0	1
Both zones	2,331	0.108	0.251	0	1
Households growing, primary					
Plateau de Koutiala	172	0.049	0.036	0.005	0.235
Delta du Niger	107	0.089	0.080	0.008	0.5
Both zones	279	0.065	0.060	0.005	0.5
Households growing, secondary					
Plateau de Koutiala	124	0.298	0.222	0.013	1
Delta du Niger	353	0.607	0.273	0.007	1
Both zones	477	0.527	0.294	0.007	1

Source: Authors based on PRePoSAM data. Plot areas based on farmer estimates.

Difference-of-means test significant (1%) between zones except for all household plots where grown as primary.

Table 7. Cowpea plot management, by gender

	Primary crop		Secondary crop	
	Freq.	Percent	Freq.	Percent
Male	268	79.06	844	86.12
Female	71	20.94	136	13.88
Total	339	100	980	100

Source: Authors based on PRePoSAM data.
Includes cowpeas grown as either grain or forage.

Table 8. Cowpea plot management, by relationship to head

	Primary crop		Secondary crop	
	Freq.	Percent	Freq.	Percent
Chef EAF	171	50.44	426	43.47
Son	69	20.35	292	29.8
Brother	25	7.37	101	10.31
Wife	35	10.32	65	6.63
Daughter-in-law	18	5.31	39	3.98
Nephew	2	0.59	20	2.04
Sister-in-law	10	2.95	20	2.04
Daughter	1	0.29	4	0.41
Sister	1	0.29	4	0.41
Mother	3	0.88	2	0.2
Grandson	1	0.29	2	0.2
Grand-daughter			2	0.2
Father			1	0.1
Niece	2	0.59	1	0.1
Other relative			1	0.1
Grandmother	1	0.29		
Total	339	100	980	100

Source: Authors based on PRePoSAM data.
Includes cowpeas grown as either grain or forage.

Table 9. Percent of female-managed plots planted cowpeas, by agroecological zone

	Primary crop			Secondary crop		
	No	Yes	All	No	Yes	All
Plateau de Koutiala	822	12	834	817	17	834
	98.56	1.44	100	97.96	2.04	100
Delta du Niger	687	59	746	627	119	746
	92.09	7.91	100	84.05	15.95	100
Total	1,509	71	1,580	1,444	136	1,580
	95.51	4.49	100	91.39	8.61	100

Source: Authors based on PRePoSAM data.
Includes cowpeas grown as either grain or forage.

Table 10. Cowpea grown as a secondary crop on plot targeted by the subsidy

	cowpea grown as secondary crop			
	yes	no	all plots	plot area (mean ha)
no subsidy	2,874	669	3,543	0.724
	81.12	18.88	100	
subsidy	5,397	237	5,634	0.139
	95.79	4.21	100	
Total	8,271	906	9,177	0.365
	90.13	9.87	100	

Source: Authors based on PRePoSAM data.

Table 11. Cowpea plot count, total area and area share on household farm, by receipt of fertilizer subsidy

	Cowpea a primary crop			Cowpea a secondary crop		
	Count	Area (ha)	Area share	Count	Area (ha)	Area share
		mean			mean	
no subsidy	0.165	0.112	0.011	0.949	3.188	0.288
subsidy	0.135	0.081	0.008	0.329	1.197	0.078
Total	0.139	0.086	0.008	0.418	0.086	0.108

Source: Authors based on PRePoSAM data.
Differences not statistically significant for plots where cowpea is a primary crop.
Differences significant at < 1% for plots where cowpea is a secondary crop.

Table 12. First-stage Tobit model predicting total subsidized fertilizer (kgs) received by household

	Margins (APEs)	Delta se		pval
Office du Niger zone	-0.809	0.443	*	0.068
CMDT zone	2.291	0.442	***	0.000
soil types per farm	1.969	0.325	***	0.000
relief types per farm	-0.552	0.477		0.248
time to reach plot	-0.827	0.167	***	0.000
distance to subsidized fertilizer	-0.029	0.010	***	0.004
distance to nearest store	-0.034	0.024		0.153
distance to tarmac	-0.060	0.016	***	0.000
distance to Bamako	-0.015	0.010		0.125
village stores	0.018	0.002	***	0.000
intercropped plots	0.538	0.081	***	0.000
organic manure applied	0.000	0.000		0.541
adult labor	0.160	0.049	***	0.001
children	0.000	0.043		0.992
education of plot manager	0.098	0.047	**	0.038
farm size	0.339	0.044	***	0.000
non-farm income	0.000	0.000	*	0.071
evoucher pilot zone	1.965	0.321	***	0.000
subsidy experience	0.917	0.055	***	0.000
CMDT training	0.999	0.478	**	0.037
Observations	2,329			

Source: Authors based on PRePoSAM data. F(3, 2309) = 100.15, Prob > F = 0.0000.

Table 13. Second stage regression predicting effects of fertilizer subsidy on crop richness

	Margalef	Robust se		pval	Crop count	Robust se		pval
subsidized fertilizer	-0.003	0.001	**	0.054	0.011	0.004	***	0.003
Office du Niger zone	-0.766	0.039	***	0.000	-1.872	0.075	***	0.000
CMDT zone	0.238	0.042	***	0.000	0.532	0.097	***	0.000
soil types per farm	0.180	0.034	***	0.000	0.335	0.071	***	0.000
relief types per farm	-0.100	0.045	**	0.027	0.060	0.082		0.469
time to reach plot	0.000	0.001		0.742	-0.002	0.002		0.214
distance to subsidized fertilizer	0.003	0.001	**	0.046	0.001	0.004		0.840
distance to nearest store	-0.005	0.001	***	0.000	-0.008	0.002	***	0.000
distance to tarmac	0.000	0.001		0.769	0.004	0.002	**	0.023
distance to Bamako	0.001	0.000	***	0.000	0.003	0.000	***	0.000
village stores	0.012	0.007	*	0.092	0.063	0.017	***	0.000
intercropped plots	0.059	0.014	***	0.000	0.177	0.034	***	0.000
organic manure applied	0.000	0.000		0.940	0.000	0.000		0.922
adult labor	-0.005	0.004		0.136	-0.002	0.008		0.815
children	-0.004	0.003		0.225	0.011	0.008		0.155
education of plot manager	-0.008	0.004	*	0.054	-0.032	0.009	***	0.000
farm size	-0.028	0.003	***	0.000	0.047	0.006	***	0.000
non-farm income	0.000	0.000		0.225	0.000	0.000		0.171
Constant	1.534	0.088	***	0.000	2.530	0.180	***	0.000
Observations	2,329				2,329			
R-squared	0.353				0.564			

Source: Authors based on PRePoSAM data. Coefficient of generalized residuals from first stage is not significant. Margalef=OLS model; Cropcount=OLS (also estimated with Poisson but signs and significance do not change).

Table 14. Second stage regressions predicting effects of fertilizer subsidy on crop evenness

	Herfindahl+	Robust se		pval	Shannon	Robust se		pval	Simpson	Robust se		pval
subsidized fertilizer	0.003	0.001	***	0.000	0.008	0.001	***	0.000	0.001	0.001	*	0.067
residual, stage 1	0.000	0.000	**	0.020								
Office du Niger zone	0.239	0.013	***	0.000	-1.066	0.036	***	0.000	-0.452	0.016	***	0.000
CMDT zone	-0.050	0.013	***	0.000	0.307	0.032	***	0.000	0.115	0.012	***	0.000
soil types per farm	0.004	0.011		0.712	0.113	0.027	***	0.000	0.055	0.012	***	0.000
relief types per farm	-0.015	0.016		0.340	0.102	0.041	**	0.012	0.051	0.018	***	0.004
time to reach plot	0.000	0.000		0.988	-0.002	0.001	**	0.027	-0.001	0.000	**	0.018
distance to subsidized fertilizer	-0.001	0.000		0.130	-0.001	0.002		0.448	0.000	0.001		0.665
distance to nearest store	0.001	0.000	***	0.006	-0.002	0.001	***	0.001	0.000	0.000		0.553
distance to tarmac	-0.001	0.000	**	0.025	0.003	0.001	***	0.000	0.001	0.000	***	0.000
distance to Bamako	0.000	0.000	***	0.000	0.002	0.000	***	0.000	0.001	0.000	***	0.000
village stores	-0.002	0.002		0.480	0.034	0.006	***	0.000	0.014	0.002	***	0.000
intercropped plots	-0.023	0.004	***	0.000	0.065	0.013	***	0.000	0.033	0.006	***	0.000
organic manure applied	0.000	0.000		0.514	0.000	0.000		0.942	0.000	0.000		0.871
adult labor	-0.002	0.001	*	0.093	0.002	0.003		0.446	0.001	0.001		0.474
children	0.000	0.001		0.993	0.006	0.003	**	0.047	0.002	0.001		0.100
education of plot manager	0.001	0.002		0.430	-0.021	0.004	***	0.000	-0.009	0.002	***	0.000
farm size	0.000	0.000		0.120	0.000	0.000	**	0.040	0.000	0.000	**	0.024
Constant	0.837	0.027	***	0.000								
Observations	2,329				2,329				2,329			

Source: Source: Authors based on PRePoSAM data. Coefficient of generalized residuals from first-stage is not significant in Simpson or Shannon. Herfindahl+=Tobit with upper limit 1; Shannon and Simpson=Tobit with lower limit 0. Residual not significant in Shannon or Simpson equation.

Standard errors in Herfindahl+ regression have been bootstrapped because residuals from stage 1 have been included to control for endogeneity.

Table 15. Second stage regression predicting number of plots planted to cowpea as primary or secondary crop by household

	Cowpea primary	se		pval	Cowpea secondary	se		pval
subsidized fertilizer	-0.001	0.001		0.430	-0.016	0.006	***	0.004
Office du Niger zone	-0.179	0.024	***	0.000	-0.306	0.095	***	0.001
CMDT zone	-0.028	0.033		0.387	-0.547	0.123	***	0.000
soil types per farm	-0.039	0.023	*	0.084	-0.052	0.096		0.586
relief types per farm	0.016	0.025		0.513	0.160	0.117		0.174
time to reach plot	0.001	0.001	**	0.014	0.000	0.002		0.871
distance to subsidized fertilizer	-0.001	0.001	*	0.056	0.002	0.002		0.406
distance to nearest store	-0.001	0.000	***	0.000	-0.015	0.005	***	0.005
distance to tarmac	0.000	0.001		0.981	-0.003	0.003		0.342
distance to Bamako	0.000	0.000	**	0.039	-0.001	0.001		0.214
village stores	0.004	0.006		0.490	0.002	0.021		0.923
intercropped plots	-0.009	0.008		0.262	1.174	0.022	***	0.000
organic manure applied	0.000	0.000	***	0.002	0.000	0.000	***	0.010
adult labor	-0.005	0.002	**	0.046	-0.088	0.027	***	0.001
children	0.009	0.003	***	0.001	0.028	0.016	*	0.085
education of plot manager	0.001	0.003		0.738	-0.046	0.016	***	0.004
farm size	0.006	0.002	***	0.001	0.040	0.009	***	0.000
non-farm income	0.000	0.000		0.721	0.000	0.000		0.122
Observations	2329				2329			

Source: Authors based on PRePoSAM data. Coefficient of generalized residuals from first-stage is not significant. Tobit models. Results from OLS, and Poisson regressions are similar in signs and significance.

Table 16. Second stage regression predicting area planted to cowpea as primary or secondary crop by household

	Cowpea primary (ha)	se		pval	Cowpea secondary (ha)	se		pval	Cowpea secondary (area share)	se		pval
subsidized fertilizer	-0.005	0.006		0.413	-0.169	0.054	***	0.002	-0.013	0.002	***	0.000
Office du Niger zone	-1.371	0.218	***	0.000	0.952	0.801		0.235	-0.019	0.038		0.613
CMDT zone	-0.101	0.136		0.455	-4.180	1.140	***	0.000	-0.157	0.043	***	0.000
soil types per farm	-0.117	0.122		0.338	-0.873	1.003		0.384	-0.019	0.040		0.623
relief types per farm	0.123	0.162		0.450	3.025	1.251	**	0.016	0.088	0.048	*	0.065
time to reach plot	0.008	0.003	**	0.016	0.018	0.021		0.399	0.000	0.001		0.972
distance to subsidized fertilizer	-0.013	0.008		0.115	-0.027	0.063		0.666	-0.001	0.002		0.639
distance to nearest store	-0.028	0.015	*	0.068	-0.104	0.035	***	0.003	-0.005	0.001	***	0.000
distance to tarmac	0.000	0.003		0.950	0.008	0.027		0.775	-0.003	0.001	**	0.028
distance to Bamako	-0.001	0.001	*	0.079	-0.005	0.005		0.283	0.000	0.000	**	0.048
village stores	0.013	0.026		0.614	-0.236	0.186		0.206	-0.011	0.009		0.216
intercropped plots	-0.053	0.039		0.167	6.176	1.122	***	0.000	0.277	0.019	***	0.000
organic manure applied	0.000	0.000	**	0.016	-0.003	0.001	**	0.010	0.000	0.000	***	0.001
adult labor	-0.019	0.014		0.158	-0.681	0.180	***	0.000	-0.036	0.007	***	0.000
children	0.034	0.013	**	0.010	0.329	0.154	**	0.032	0.005	0.006		0.325
education of plot manager	-0.009	0.016		0.585	-0.353	0.141	**	0.013	-0.016	0.006	***	0.004
farm size	0.029	0.008	***	0.001	0.516	0.077	***	0.000	0.024	0.003	***	0.000
non-farm income	0.000	0.000		0.403	0.000	0.000		0.344	0.000	0.000	**	0.028
Observations	2329				2329				2329			

Source: Authors based on PRePoSAM data. Coefficient of generalized residuals from first-stage is not significant. Tobit models. Residual not significant in these regressions. Area of plot (ha) on which cowpea is grown as a primary or secondary crop.

Table 17. Second-stage regression predicting cowpea revenues of men and women in farm household

	Men's cowpea revenues	se		pval	Women's cowpea revenues	se		pval
subsidized fertilizer	-1.5	20.9		0.941	-5.0	2.8	*	0.075
Office du Niger zone	-1551.4	350.7	***	0.000	-230.9	150.1		0.124
CMDT zone	-937.5	698.1		0.179	61.6	246.3		0.803
soil types per farm	672.8	498.5		0.177	-152.0	79.9	*	0.057
relief types per farm	-795.1	425.3	*	0.062	219.9	138.2		0.112
time to reach plot	-13.4	8.0	*	0.092	10.1	12.6		0.423
distance to subsidized fertilizer	-10.2	8.5		0.230	-6.6	4.7		0.156
distance to nearest store	-11.7	7.3		0.108	-1.3	1.2		0.243
distance to tarmac	-7.9	10.0		0.433	0.7	3.8		0.859
distance to Bamako	-4.0	2.1	*	0.062	-0.5	0.5		0.332
village stores	105.2	122.4		0.390	-30.4	29.7		0.306
intercropped plots	35.4	112.2		0.753	141.4	71.8	**	0.049
organic manure applied	0.0	0.0	*	0.068	0.0	0.0		0.288
adult labor	-14.6	36.1		0.686	39.1	20.8	*	0.060
children	29.0	32.2		0.369	4.4	23.8		0.853
education of plot manager	-37.1	32.6		0.256	6.8	14.8		0.648
farm size	26.8	24.4		0.272	-13.2	9.7		0.171
non-farm income	0.0	0.0	***	0.006	0.0	0.0		0.169
Observations	2329				2329			

Source: Authors based on PRePoSAM data. Coefficient of generalized residuals from first stage is not significant. Tobit models. Residuals from first-stage regression not significant.

Table 18. Second stage regression predicting cowpea revenues of chef and all other household members

	Chef's cowpea revenues	se		pval	Non-chef cowpea revenues	se		pval
subsidized fertilizer	-5.0	11.8		0.674	-1.6	17.5		0.929
Office du Niger zone	-680.0	217.9	***	0.002	-1102.4	312.9	***	0.000
CMDT zone	-422.4	306.6		0.168	-453.4	678.9		0.504
soil types per farm	461.5	380.9		0.226	59.3	335.4		0.860
relief types per farm	-337.2	292.9		0.250	-238.0	340.2		0.484
time to reach plot	-4.8	5.9		0.418	1.5	13.8		0.915
distance to subsidized fertilizer	-6.2	7.1		0.383	-10.6	6.6		0.108
distance to nearest store	-3.0	6.6		0.647	-10.1	3.3	***	0.002
distance to tarmac	1.8	6.7		0.787	-9.0	8.5		0.287
distance to Bamako	-3.7	1.5	**	0.015	-0.8	1.6		0.601
village stores	75.9	46.8		0.105	-1.1	118.1		0.993
intercropped plots	54.4	55.7		0.328	122.4	119.4		0.306
organic manure applied	0.0	0.0		0.222	0.0	0.0		0.138
adult labor	-48.3	20.2	**	0.017	72.7	36.5	**	0.046
children	-0.3	17.9		0.986	33.7	35.9		0.348
education of plot manager	-22.4	18.4		0.226	-8.0	30.9		0.797
farm size	24.7	20.6		0.231	-11.2	16.3		0.493
non-farm income	0.0	0.0		0.129	0.0	0.0	***	0.007
Observations	2329				2329			

Source: Authors based on PRePoSAM data. Coefficient of generalized residuals from first-stage is not significant. Tobit models. Other members of the household, including women and other men, manage non-chef plots.

Table 19. Second stage regression predicting average diet quality of women of reproductive age in household

	WDDS	se		pval	MDD-W	se		pval
subsidized fertilizer	-0.002	0.004		0.653	-0.001	0.001		0.319
Office du Niger zone	0.175	0.072	**	0.015	-0.010	0.022		0.640
CMDT zone	-0.420	0.077	***	0.000	-0.089	0.025	***	0.000
soil types per farm	0.192	0.063	***	0.002	0.052	0.020	***	0.009
relief types per farm	0.187	0.085	**	0.027	0.022	0.025		0.372
time to reach plot	-0.004	0.002	*	0.064	-0.001	0.001		0.152
distance to subsidized fertilizer	-0.001	0.002		0.525	0.001	0.001		0.519
distance to nearest store	-0.007	0.003	**	0.026	-0.001	0.001	*	0.057
distance to tarmac	-0.003	0.002	*	0.089	-0.001	0.000	*	0.078
distance to Bamako	0.000	0.000		0.653	0.000	0.000	*	0.062
village stores	-0.005	0.016		0.736	-0.002	0.005		0.603
intercropped plots	0.042	0.020	**	0.033	0.004	0.008		0.652
organic manure applied	0.000	0.000		0.385	0.000	0.000		0.294
adult labor	0.003	0.007		0.687	0.012	0.003	***	0.000
children	0.003	0.007		0.712	0.001	0.002		0.764
education of plot manager	0.029	0.008	***	0.000	0.004	0.003		0.116
farm size	-0.001	0.005		0.884	0.001	0.002		0.436
non-farm income	0.000	0.000	***	0.000	0.000	0.000		0.267
Observations	2,192				2,192			

Source: Authors based on PRePoSAM data. Coefficient of generalized residuals from first-stage is not significant. WDDS models is Poisson (signs and significance do not change with OLS); MDD-W is a probit model.

Table 20. Second stage regression predicting frequency of pulse consumption by women of reproductive age in households

	Frequency 24 hours	se		pval	Frequency 7 days	se		pval
subsidized fertilizer	0.004	0.002		0.100	0.028	0.012	**	0.021
Office du Niger zone	-0.091	0.055	*	0.095	-0.419	0.242	*	0.083
CMDT zone	0.079	0.054		0.145	0.699	0.311	**	0.025
soil types per farm	0.000	0.047		0.992	0.238	0.233		0.308
relief types per farm	-0.060	0.064		0.343	-0.826	0.284	***	0.004
time to reach plot	0.000	0.001		0.856	-0.014	0.007	**	0.032
distance to subsidized fertilizer	-0.003	0.003		0.320	-0.042	0.020	**	0.039
distance to nearest store	-0.026	0.007	***	0.000	-0.030	0.015	*	0.053
distance to tarmac	-0.003	0.001	**	0.024	-0.008	0.006		0.211
distance to Bamako	0.001	0.000	***	0.000	0.008	0.001	***	0.000
village stores	0.016	0.010		0.119	0.105	0.054	*	0.053
intercropped plots	0.018	0.016		0.259	0.014	0.072		0.845
organic manure applied	0.000	0.000		0.599	0.000	0.000	*	0.077
adult labor	0.018	0.005	***	0.000	0.127	0.028	***	0.000
children	0.011	0.005	**	0.018	0.056	0.024	**	0.021
education of plot manager	-0.004	0.006		0.475	0.001	0.027		0.978
farm size	0.008	0.003	**	0.017	0.037	0.017	**	0.032
non-farm income	0.000	0.000	**	0.014	0.000	0.000		0.473
Observations	2,192				2,192			

Source: Authors based on PRePoSAM data. Coefficient of generalized residuals from first-stage is not significant. Includes consumption of all women interviewed in households of reproductive age.
Pulse category includes cowpea, Bambara groundnut, soy (excludes groundnut).
Model is negative binomial. Residual not significant.