The role of maize storage in stabilizing annual household maize consumption: an application of generalized propensity score matching

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The role of maize storage in stabilizing annual household maize consumption: an application of generalized propensity score matching

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Abstract

Rural households in developing countries face yield risks and seasonal production amidst the desire for stable household consumption. While storage has been cited as one of the ways of smoothing consumption during the lean periods, there is little empirical evidence on the subject. The current study used a generalized propensity score approach to examine the impact of storage on maize consumption smoothing. Maize was found to be the main crop, mostly grown for home consumption. The amount bought increased during the leaner periods when the prices were higher. In addition, the coefficient of variation for total maize consumption for decreased with increase in the length of storage, indicating that indeed storage helps to smoothen consumption across the year and consequently improve household food security.

Key words: Coefficient of variation, length of storage, generalized propensity score matching

1. Introduction

Maize is one of the major grains in Africa (Mellor et al., 1987) with 95 % of the total maize production constituting a significant part of the daily diet (Hogh-Jensen et al., 2007). In Kenya, the per capita daily maize consumption is 171 g/person/day (Ranum et al., 2014). This accounts for 44 % of the total calories intake (Byerlee and Heisey, 1997). Its production is seasonal with one or two harvests per year, and sometimes fluctuates depending on weather conditions (Proctor, 1994). In the face of seasonal production and yield risks of a major staple, households are left with three options; on farm storage, purchase maize or adjust their consumption patterns. Yet little is known on farm maize storage (technologies, amounts stored and length of storage), household maize consumption trends (purchased or from own production) and maize market participation.

Rural households in developing countries face yield risks and seasonal production amidst the desire for stable household consumption. Households living in these risky environments have developed a range of mechanisms to shield consumption of from these risks, including borrowing and lending (Deaton, 1992), off farm activities as sources if income Lamb (2003), livestock assets (Park, 2006). Most of these methods are only effective if the markets are perfect. In Sub Saharan Africa, most governments engage in establishing strategic food reserves, to provide for market failures, to stabilize food prices to ensure stable consumption.

On farm storage has been cited as one of the ways in which farmers ensure smooth consumption. For example, a study by (Von Braun, 1992) mentions storage (together with production and trade) as one of the key determinants of food availability for the rural households in that it helps to bridge the period between two harvests by ensuring a continuous stable supply of food. Proctor (Proctor) also mentions that storage helps in stabilizing prices by taking the produce off the market during the peak season and releasing it back when the grain is in short supply. However, to the best of our knowledge, there is no empirical study that explores the relationship between storage and household consumption. The current study makes a modest attempt to explore the role of on farm storage of a staple crop in Kenya in stabilizing annual consumption. Specifically, the study describes the household consumption patterns for a period of 12 months and used the coefficient of variation as a measure of variation in maize consumption for the 12 months. Further, we estimated the impact of the length of storage on the coefficient of variation for the household maize consumption.

The study makes the following contributions to science:

1. Contributes to literature on a relatively new methodology for impact assessment (also used by; (Kassie et al., 2014) and (Kluve et al., 2012): Use of a continuous treatment framework as opposed to the frequently used binary treatment,
2. Use of consumption variation as the major outcome: This gives a clear picture of the household maize consumption patterns and sale for 12 months.

2. Methodology

2.1. *Conceptual and methodological frame work*

The study uses an impact assessment framework to examine the effect of storage on household consumption patterns. Most of the literature on impact assessment use a binary treatment approach, in this case the decision to store maize. However, this is only appropriate when there is a randomized assignment in which all treated individuals receive the same dosage. In non-observational studies, selection into the different treatment levels is not random, and the length of storage (dosage) varies significantly across adopters (those who store their maize). A conventional binary treatment approach classifies all adopters identically, despite the fact that their level of storage is different once the decision to store has taken place. In the current study, our key interest was to investigate how effective different lengths of storage are in smoothening household maize consumption.

Given the continuous nature of our treatment, we used the generalized propensity score (GPS) model proposed by Hirano and Imbens (Hirano and Imbens). This method is an extension of the widely used propensity score methodology for binary treatments. Similar to the binary treatment propensity score method, the main assumption while using GPS is– conditional on observable characteristics – the level of treatment received can be considered as random (unconfoundeness). Further, Hirano and Imbens (Hirano and Imbens) show that the GPS has a balancing property similar to the balancing property of the "classic" propensity score. This implies that individuals within the same strata of the GPS should look identical in terms of their observable characteristics, independent of their level of treatment.

The GPS model

The study used the continuous treatment framework. In this section we closely followed Hirano and Imbens (Hirano and Imbens) work on continuous treatment impact evaluation framework using the GPS approach. Suppose we have a random sample of units, indexed by i=1… N. For each unit i there exists a set of potential outcomes Y_i (t) for t ∈ T, referred to as the unit level dose-response function. In the continuous case, T is an interval $[t_0, t_1]$, whereas in the binary case it would be (Mellor et al., 1987). For a continuous treatment framework, the objective is to estimate the average dose-response function (ADRF), μ (t) =E [Yi (t)]. For each unit i, we observe a vector of covariates Xi, the level of the treatment that unit i actually receives, T∈ $[t_0, t_1]$ and the potential outcome corresponding to the level of treatment received, $Y_i = Y_i (T_i)$. The subscript i is dropped in the subsequent sections to simplify the notation.

We assume that $\{Y(t)\}_{t\in T}$,TX are defined on a common probability space, that T is continuously distributed with respect to Lebesgue measure on T , and that Y = Y (T) is a

well-defined random variable (this requires that the random function Y (.) be suitably measurable).
Hirano and Imbens (Hirano and Imbens) generalizes the unconfoundedness assumption for binary treatments made by Rosenbaum and Rubin (Rosenbaum and Rubin) to the continuous case (1) $Y(t) \perp T \mid X$ for all $t \in T$. They refer to this as weak unconfoundedness, since it only requires conditional independence to hold for each value of the treatment, rather than joint independence of all potential outcomes.
By calling $r(t,x)=f_{T|X}(t|X)$ the conditional density of the treatment given the covariates, the Generalized Propensity Score (GPS) is defined as $R = r(T, X)$.

The GPS has a balancing property similar to the balancing property of the propensity score for binary treatments. Within strata with the same value of r (T, X), the probability that T=t does not depend on the value of X, i.e. the GPS has the property that $X \perp 1\{T = t\} \mid r(t, X)$. Hirano and Imbens (2004) emphasize that this is a mechanical implication of the definition of the GPS and does not require unconfoundedness. In combination with unconfoundedness, however, it implies that assignment to treatment is unconfounded given the GPS. That is, Hirano and Imbens (2004) prove that, if assignment to treatment is weakly unconfounded given covariates X, then it is also weakly unconfounded given the Generalized Propensity Score. Given this result, it is possible to use the GPS to remove bias associated with differences in covariates in two steps. The first step is to estimate the conditional expectation of the outcome as a function of two scalar variables, the treatment level T and the GPS R,

$\beta(t,r) = E[Y \mid T = t,R = r]$.

The second step is to estimate the DRF at each particular level of the treatment. This is implemented by averaging the conditional expectation function over the GPS at that particular level of the treatment,
$\mu(t) = E[\beta(t,r(t, X))]$.

The procedure does not average over the GPS R=r(T,X), but instead it averages over the score evaluated at the treatment level of interest r(t,X).

The generalized propensity score approach outlined above was then implemented following two steps. First, we used a normal distribution for the treatment given the covariates
$T_i\ X_i \sim N(\beta_0 + \beta_1 X_i\ \sigma^2)$, to estimate the GPS by maximum likelihood.
In the second stage we model the conditional expectation of Yi given T_i and R_i as a flexible function of its two arguments. We then use a quadratic approximation:
$E[Y_i | T_i, R_i] = \alpha_0 + \alpha_1.T_i + \alpha_2 .T_i^2 + \alpha_3 . R_i + \alpha_4.R_i^2 + \alpha_5.R_i. T_i$

The parameters were estimated using the ordinary least squares by use of the estimated GPS. The above estimated coefficients do not have a causal interpretation, except that testing whether the joint significance of all coefficients associated with GPS were equal to zero and can be used to assess whether the covariates introduce bias (Hirano and Imbens 2004).

Therefore, given the estimated coefficients, we estimated the average potential outcome at treatment level t. This was done for all levels of treatment (months of storage in our case) to obtain an estimate of the entire dose-response function. The dose response function shows how the magnitude and the nature of the causal relationship between the treatment variable and the outcome variable change for different values of the treatment variable, after controlling for covariate biases. Further, a derivative function of the dose response function (marginal treatment effect function) is presented. This shows the marginal effects of a unit change in the treatment variable on the outcome variable. Both results (dose response and marginal effect functions) were presented graphically.

2.2. Study design

The target population comprised of all the maize growing households in the previous Kakamega District (current Kakamega County without the old Mumias Butere and Lugari Districts) of Kenya, selected using a three-stage sampling design. The first stage was the sub locations, the lowest administrative unit in Kenya. The second stage was the village, as defined locally, and the third level was the household.

A list of all the sub locations in Kakamega District, including their number of households was acquired by use of GIS analysis. In the first stage, 13 sub locations were selected using the probability proportionate to size (PPS) method, with size defined as number of households. In the second stage, a fixed number of four villages were selected using PPS, and in the third stage a fixed number of six households was selected by simple random sample (SRS). This resulted to 312 households.

2.3 *Data Collection*

All the 312 households were interviewed from December 4, 2015 to December 20, 2015 by a team consisting of a coordinator, two supervisors and 8 enumerators. Data was collected using a structured questionnaire. The tool was digitized using the CS Pro software and data were collected using tablets. All the data were then exported to SPSS and STATA for management and analysis.

Data was collected on the basic household characteristics, household maize production, maize post-harvest activities, maize storage, consumption and sale. The respondents were asked to state the length of storage in months from when the maize was stored to the time they fetched the last bunch from storage. Data on consumption and sale were collected by asking the respondent, mainly the head or the spouse, the amount of maize consumed per month (maize from own production, from purchase or donations). Data on socio economic characteristics of the household's major decision maker was also collected. This included the age, sex and education level of the household head. Other data included the household size, data on physical assets (Total Livestock Units, TLU, own land size, non-farm income, cash savings available at the beginning of season), social capital (membership to agricultural production networks), use of storage pesticide and the amounts of maize stored. All these variables were hypothesized to be determinants of the length of storage.

2.4 Data analysis

Descriptive statistics were used to characterize the respondents. Cross tabulations were used to generate composite graphs and correlation coefficients to put the predictor variables into perspective. Further, a GPS model was used to examine the impact of the length of storage on consumption patterns. The coefficient of variation was used as a measure of variation in maize consumption. The CV was calculated by first getting the mean monthly consumption for each household and the standard deviation of this mean (from the amount of maize consumed per month). The standard deviation was then divided by the mean to give the coefficient of variation that is used as a measure of variability in maize consumption within a period of 12 months. The lower the CV the lesser the variability/variation.

3. Results

3.1. The farming system of Kakamega

The sampled households were small-scale semi-subsistence farmers. They owned approximately 0.9 hectares of land and were cultivating an average of 0.7 hectares. The average annual income was KES 1,987,000 (US $ 1987). Most of this income was from off-farm activities (70%) while only 30% was from the farm (both crops and livestock).
Maize was found to be the major crop in terms of the area share and total production (Table 1). Almost all the households in the study area grew maize (97%). Maize production accounted for almost 60 % of the cultivated land.

3.2. Descriptive statistics of the participating households

Most households heads were male (84%) (Table 2). The average age of the household head was 52 years with an average of 8 years of formal education. The average household size was 6 members. Fourteen percent of the households had a member registered to an agricultural production network. Nearly all households (95%) had at least one member who owned a mobile phone, while 77% owned a radio set and 14% a TV set. Most of the explanatory variables for the adopters were similar to those of the full sample probably because they accounted for 93 % of the total sample. However, 75 % of the adopters used pesticides compared to 54% for the full sample (see Table 2).

The CV for maize consumption from own production was high (88%) indicating a higher variability for the amount of maize consumed from own production in the last 12 months.

The CV for the total consumption was 43 %.The CV for total consumption for those that stored maize ('adopters') was 43%, equal to that of the total sample. However, the CV for the maize from own production was 81 %, much lower that of the full sample. The average length of storage for the full sample was five months while for the adopters (those who stored their maize) was 6 months.

3.3. *Maize production, consumption and sale*

Most households (97%) produced maize, on average 0.611 tons on 0.35 ha. Only few (27%) grew maize during the short season. The maize that was planted in March/April was mainly harvested in August (60% of the total sample) and September (30%). Those who planted maize during the second season mainly harvested in December (60%) and some in January (40%).

More than half of the maize produced by the household (60%) was consumed at home while the rest was either sold (21%), given to the livestock (12%) or donated elsewhere (7%).
Only 35%of the households sold maize.

The total maize consumption per capita for the whole sample was 108 kg per person per year (295 g/person/day). This accounts for over 80 % of the total consumption from cereals in Kenya (FAOSTAT) .Consumption from own production accounted for 62% of total consumption while the rest was either bought (34%) or donated to the household (4%).Seventy four percent of the total households indicated that they bought maize for home consumption.

Most of the households (61%) who sold maize also purchased maize for home consumption during the lean periods. They sold at an average price of 34 Kenya shillings per kg (0.34 US$) and bought maize at an average price of 40 Kenya shillings (0.40 US$) (Table 3).

3.4. Household maize storage practices

Maize post-harvest practices (from harvest to the time the maize is ready for storage; excluding storage itself) took an average of 30 days, hence maize was mostly put into storage one month after harvest (September/October for the March season and January for the October season). Drying maize, either on cobs or as shelled maize, took on average 11 days. The most common way of drying, both maize on cob and shelled maize, was spreading the maize on the ground either on a tarpaulin, or a mat, (69% for cob and 93% for shelled maize). Some farmers dried the maize on cob directly on the ground (21%), on a rock (6%) or on a concrete floor (1%?).

Local methods were used to test whether the maize was sufficiently dry before storage (biting the grain, listening to the sound and by use of hand i.e. touching; each of these methods accounted for 32% of the total sample). After drying, maize was mostly stored in polypropylene bags (99%), and mostly in the main house (97%). Approximately half of the farmers used pesticides. None of the household was using improved hermetic storage technologies (silo or hermetic bags) (Table 4).

Maize was kept in storage for an average period of 5 months, after the main harvest. However, the length of storage varied across different storage technologies and facilities (Table 5). The use of pesticides increased the length of storage by two months (treated bags was six months while untreated was four months).

3.5. Household monthly maize consumption patterns

We can divide the year into two; the lean period starting from February to July and the post-harvest period starting from August to January. The consumption patterns clearly show how the households start consuming their own maize during the first months after harvest (Figure 1). For the first four months after harvest (September to December) almost all maize comes from own production (approximately 38 kg), only 8-11 kg is purchased. Over the year, the average amount of maize consumed by the household was highest in December (50 kg) and September (48 kg), the months when maize was harvested (Figure 1). However, starting from January the amount consumed from own production decreases gradually to reach its lowest level in July (15 kg/hh), a month before the next main harvest.

To stabilize their maize consumption, farmers complemented their production with purchases, of which the quantity gradually increased from January to July. During June and July, households actually consume more maize from the market than from their own production (Figure 1). However, the curve for total maize consumption was smoother across the months compared to the curve for the maize from own production and from purchase. (Figure 1).

Further, we investigated the relationship between the consumption patterns and the length of storage. The households were divided into 3 groups depending on the length of their maize storage period: those who stored for 1 to 3 months (group 1), 4 to 6 months (group 2) and more than 6 months (group 3), see Figure 2. The curves for consumption from own production were smoother for groups 2 and 3 (those storing for more than three months), than it was for group 1 (storing for 1 – 3 months). In addition, the amount of maize bought by groups 2 and 3 for household consumption were less than the amount bought by the first group. Households storing their maize for 1 to 3 months (group 1) were consuming more maize from purchase than from own production for a period of 5 months in a year compared to 3 months only for group 2 (4 to 6 months). Those in group 3 were always consuming more from own production than from purchase throughout the year (Figure 2).

3.6. Food security, length of storage and consumption patterns

The households were divided into quantiles based on how long they kept their maize in storage. Increased length of storage reduced the variation in the amount of maize consumed, and helped to improve household food security improved (Table 6). Specifically, the months of food insecurity, chronic food security and transitory food insecurity decreased with an increase in the length of storage. On the other hand, break even and food surplus increased.

3.7. Impact of length of storage on consumption variation using the generalized propensity score matching approach

Covariate balancing using GPS (Table 7) improved the balance as shown by the reduced number of t values above 1.9 (absolute value). Figure 3 shows the dose response function graph using the coefficient of variation at the household level for the total maize consumption. The outcome variable was the coefficient of variation for the total maize consumption and CV for the maize consumed from own production. The curve was relatively flat for the first three months of storage and then decreased gradually from the fourth month (Figure 3). This means that the coefficient of variation for total consumption did not vary much in the first three months of storage. However, variation in total maize consumption decreased with an increase in the length of storage. The treatment effect graph is a derivative of the dose response function, i.e the marginal treatment effect. The results of the marginal treatment effect were negative indicating that an increase in the length of storage by one month reduced the coefficient of variation for the amount of maize consumed from own production.

The graphs for the maize consumed from own production follows a similar trend as for total household consumption, i.e. the CV reduces with an increase in the length of storage (Figure 4)

4. Discussions and conclusion

Maize was found to be the major crop in the study area, accounting for 60% of the cultivated land. It was mainly produced for home consumption, only 21 % of the total production was sold. Maize production accounted for two thirds of the total household maize consumption while the rest is mainly bought. Twenty two percent of the households sold maize at harvest bought later during the lean period although the price difference was small. However, results indicate that indeed increasing storage smoothens consumption and helps reduce food security.

In conclusion, the study provides evidence storage helps in smoothing consumption yet few farmers use improved drying and storage methods. Hermetic technologies like metal silo and hermetic bags have been found to be effective in reducing the storage losses as well as increasing the length of storage, (Gitonga et al., 2013; Ndegwa et al., 2015). Policies that promote the use of such technologies are recommended.

Finally, future studies would be more informative if they included all the agro ecological zones in Kenya as well as other African countries.

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Tables

Table 1: Major crops grown, percentage of farmers growing them, amounts harvested and amounts sold

Crop type	Name	Frequencies	Amount harvested (KG)	Amount sold (KG)
Cereals	Maize	97	611	118
	Sorghum	7	10.59	5.90
	Millet	4	35.46	19.73
Legumes	Beans	84	69.85	13.08
	Groundnuts	33	92.92	25.69
Roots and tubers	Sweet potato	50	231.59	15.31
	Cassava	32	135.25	12.34
	Irish potatoes	6	318.75	170.68

Table 2: Descriptive statistics of the variables used in the model

Variable	Full Sample Mean	Full Sample Standard Deviation	Those who stored their maize Mean	Those who stored their maize Standard Deviation
Explanatory variables				
Male headed household (%)	84.29		83.96	
Age of the Household head (years)	51.47	15.29	51.56	15.41
Education level of the household head (years)	7.92	4.32	7.94	4.31
Household Size (Adult equivalent)	5.23	2.17	5.24	2.19
Total Livestock Units TLU	1.24	1.29	1.23	1.26
Total own land (Acres)	2.20	1.80	2.19	1.84
Total off farm income ('000 KES)	140.99	535.38	137.76	544.40
Membership to Agricultural Production Networks (1=yes, 0=otherwise)	14.00		14.68	
Own a mobile phone (1=yes, 0=otherwise)	95.00		95.56	
Own a radio set (1=yes, 0=otherwise)	77.00		77.47	
Amount of cash available by the time of harvest (KES)	2524.26	9512.63	2484.30	9443.44
Pestcide use (1=yes, 0=otherwise)	54.00		75.43	
Length when the first batch is removed after storage (months)	0.45	1.26	0.50	1.25
Outcome variables				
Coefficient of variation for the amount of maize consumed from own production	0.88	0.77	0.81	0.66
Coefficient of variation for the total amount of maize consumed in the household	0.43	0.41	0.43	0.41
Treatment variable				
Length of storage in months	4.91	3.21	5.83	3.05

Table 3 Average amounts bought, amounts sold, buying and selling prices for those buying and selling maize

Variable	Mean kg	Standard deviation
Average amount consumed (kg)	330	200
Average amount sold (kg)	178	204
Average amount purchased (kg)	187	181
Average maize selling price (KES)	40	10
Average maize buying price (KES)	34	9
Total value of the maize sold(KES per kg)	5894	6820
Total value of the purchased maize (KES per kg)	6943	6506

Table 4: Storage items and facilities (percentage of the farmers using them)

Storage Item	Frequencies
Treated polypropylene bags	54
Untreated polypropylene bags	45
Basket	1
Total	100
Storage facility	
Within the main house	97
Separate structure	3
Traditional granaries	1
Total	100

Table 6 Length of storage, food security and consumption stability of the sampled households

Length of storage (months)	Coefficient of variation for total maize consumption	Months of food insecurity	Chronic food insecurity	Transitory food insecurity	Break even food security	Food surplus
0 months	0.609	3.429	0.571	0.143	0.286	0.000
1-3 Months	0.538	3.375	0.068	0.852	0.080	0.000
4-6 months	0.465	2.211	0.009	0.661	0.312	0.018
More than 6 months	0.391	1.574	0.009	0.537	0.380	0.074

Figures

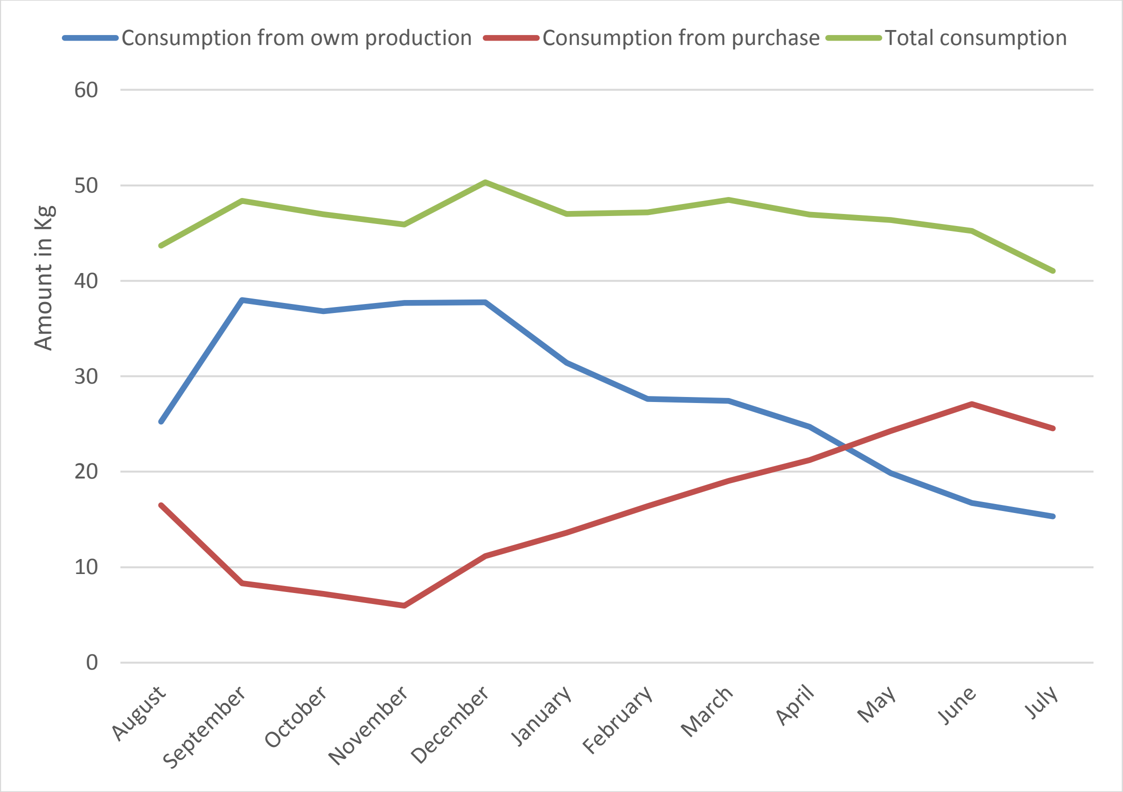

Figure 1: Average amount of maize consumed per month per household

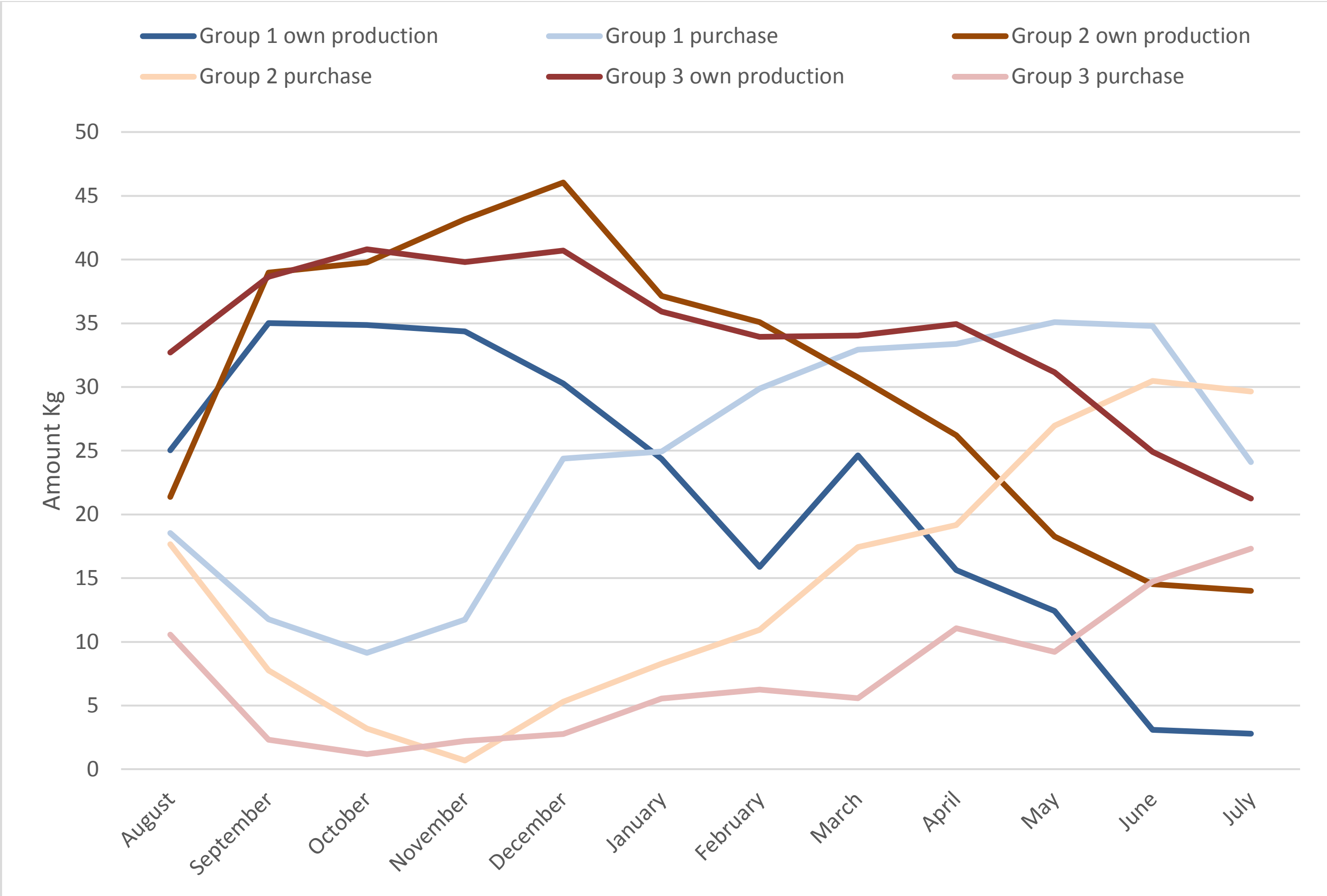

Figure 2: Consumption patterns for different categories (by length of storage)

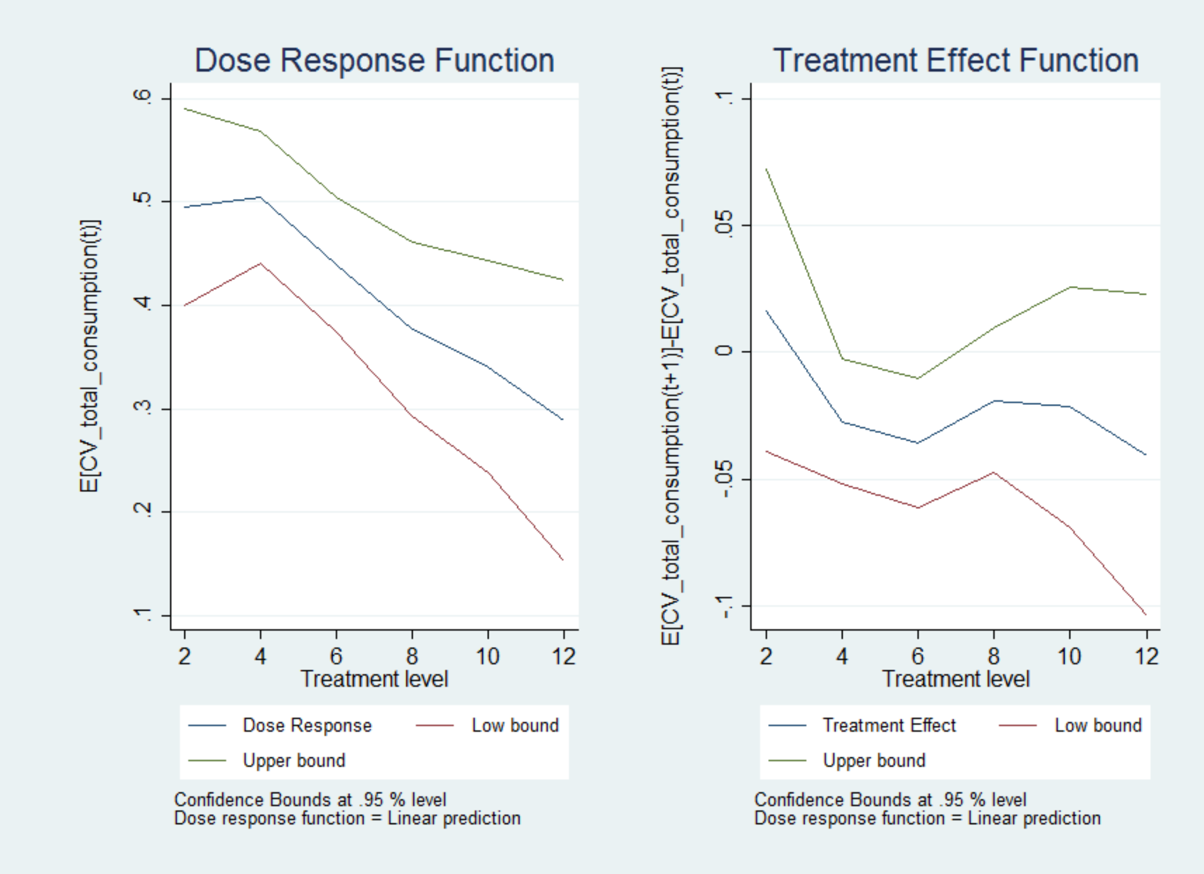

Figure 3: Estimated dose response functions using the total maize consumption as the outcome (Average treatment effect)

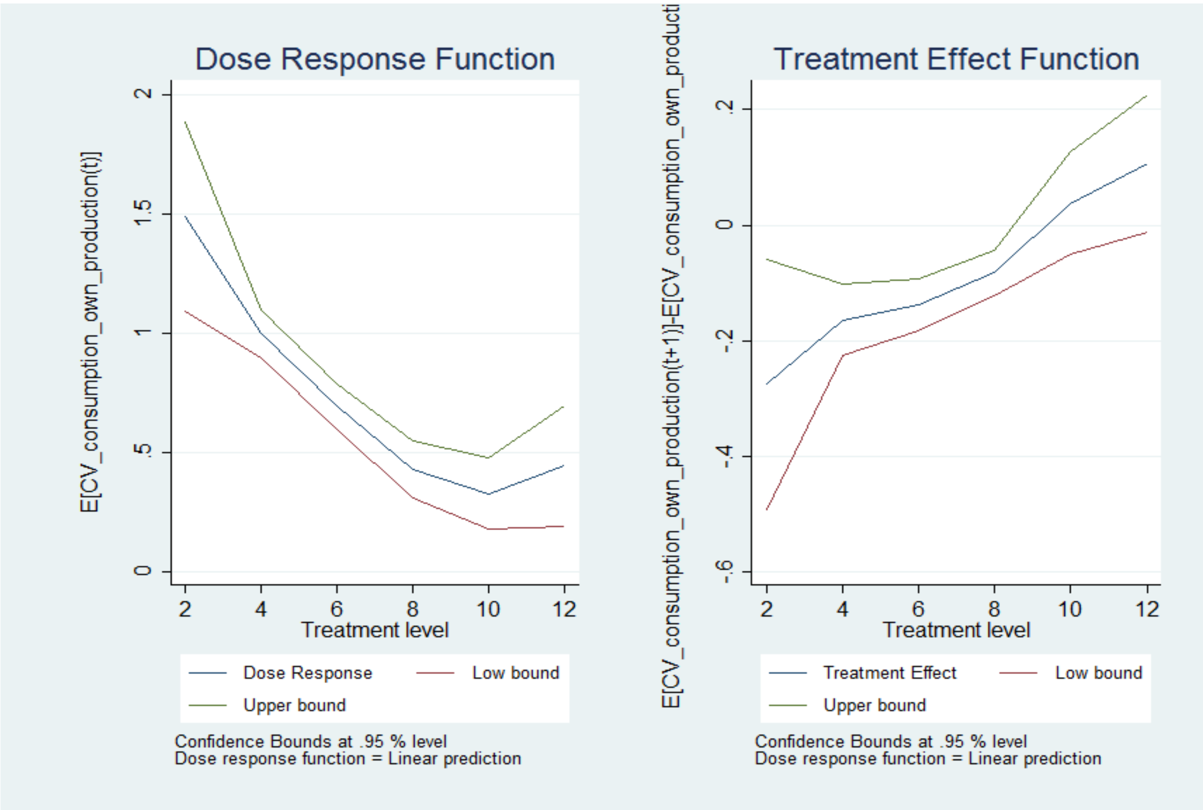

Figure 4: Estimated dose response functions using maize consumption from own production as the outcome (Average treatment effect)