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Abstract

Fruits and vegetables are an important source of nutrients for a large number of Kenyans, as well as major earners of foreign exchange, and are commonly grown crop among smallholder farmers, who often sell them for cash. Little is known, however, about the structure of domestic demand for fruits and vegetables in this rapidly urbanizing nation and in Sub-Saharan Africa in general. We apply the Almost Ideal Demand System (AIDS) with seemingly unrelated regression (SUR) to data collected through a household expenditure survey conducted between June and July of 2009.

Inelastic estimates of own-price elasticities for cabbage and tomato, and for all fruits, with the exception of onion and avocado, indicate that these are necessities. The own-price elasticities for the vegetables were negative and in the range of (-0.693) and (-0.792). The own-price elasticities for the fruits range between (-0.577) and (-1.104). Estimated cross-price elasticities also illustrate both substitutability and complementarity in demand.

Expenditure elasticities above unity for kale, onion, mango and avocado suggest they are luxuries. The high expenditure elasticity of demand for some fruits and vegetables means that potential growth in demand could be large. We recommend that public investments address production and marketing systems with the aim of increasing the availability of fruits and vegetables to Nairobi households, also stimulating domestic demand for these crops among smallholder farmers.

1. Introduction

Fruits and vegetables, as a food group, are a vital component of a healthy diet (WHO), contributing to the prevention of chronic diseases, as well as to the alleviation of micronutrient deficiencies, especially in less developed countries (Ruel *et al*., 2005). In Kenya, the horticultural sector is among the leading contributors to the Agricultural Gross Domestic Product (AgGDP) at 33 percent, and continues to grow at between 15 and 20 percent *per* year, employing over six million Kenyans, both directly and indirectly (Republic of Kenya, 2010). Survey data collected from 1997 to 2007 in the major agricultural regions of the country confirms that almost all farming households produced, and over three-quarters sold some fresh produce (Tschirley and Ayieko 2009).

Between 2005 and 2010, the annual urban population growth rate in Kenya was estimated at 4 percent (UN, 2010). About 20 percent of the approximately 38 million national population lives in the urban areas, and the larger percentage of these reside in Nairobi. Urbanization with rising incomes is associated with more focus on healthy food choices, particularly fruits and vegetables (Sindi, 2008). Fresh produce is a major expenditure item among these households, second only to food staples (Ayieko *et al*., 2005; Tchirley and Ayieko, 2009; Musyoka *et al*., 2010). Opportunities exist to meet this domestic demand through smallholder production.

In the past three decades, significant progress has been made in the application of consumer economic theory to analysis of food consumption patterns in developing countries. However, these food consumption patterns remain poorly understood in Sub-Saharan Africa (SSA), particularly for fruits and vegetables. In Tanzania, Weliwita *et al.*, (2003) estimated a linearized Almost Ideal Demand System (AIDS) for twelve (12) food groups, concluding that demand for fruits and vegetables, in addition to most other food groups, was price inelastic. They also found out that household income and family size had significant effects on food demand patterns. Agbola (2003) examined aggregate food demand patterns in South Africa with the Almost Ideal Demand System (AIDS), concluding that demand for fruits and vegetables were dietary necessities but that expenditures would decrease in this food category with rising incomes. In a multi-country analysis of fruit and vegetable consumption across Sub-Saharan Africa (SSA), Ruel *et al*., (2005) found that the consumption of fruit and vegetables ranged between 27 kg and 114 kg *per* person *per* year, far below FAO /WHO recommendations. Kenya's consumption was at the upper limit of the range, with budget shares ranging between three and 13 percent. The authors found out that the demand for fruit and vegetables rose with increase in income, although at a slower rate than increase in income.

In Kenya, Ayieko *et al*. (2005) used ordinary least squares (OLS) to assess urban consumption patterns of fresh fruit and vegetables and the major supply chain systems used in the distribution of fresh produce. The authors found out that fresh fruit and vegetables accounted for slightly over a quarter of average household expenditure on food, second only to staples. Recently, Musyoka *et al*., (2010) used a cross-sectional dataset with the AIDS model, and Nzuma and Sarker (2010) used a time-series dataset to examine the structure of

food demand, but both studies focused on food staples and broadly aggregated groups, which provides limited information regarding specific commodities, price and income elasticities.

Thus, in Kenya, an information gap exists on consumption patterns, price and expenditure elasticities for individual fruits and vegetables in Nairobi. Our objective is to address this gap and provide useful information to guide future policy initiatives in Kenya. We estimate price and income elasticities of demand for fruits and vegetables by applying the almost ideal demand system (AIDS) with seemingly unrelated regression (SUR) to data from a household expenditure survey conducted in Nairobi between June and July of 2009.

We consider main vegetables and fruits that are produced for both subsistence and commercial purposes in Kenya. Among vegetables, these include kales (*sukuma wiki*), cabbages, tomatoes and onions (Omiti, *et al*., 2004; Ayieko, *et al*., 2005). The most common fruits include bananas, oranges, mangoes and avocado, (Ayieko, *et al*., 2005).

Next, we summarize the theoretical background that serves as the basis for our empirical demand analysis. In the third section, we present our empirical strategy, including a description of the data source, the econometric model, and variables. Findings are examined in the fourth section. The final sections present the conclusions of the analysis and draw policy implications.

2. Theoretical foundation

Consumer demand theory lays the theoretical foundation for estimating Marshallian (or uncompensated) demand functions derived from the maximization of utility over quantities of goods consumed subject to an income constraint and a vector of market prices. Optimal quantities depend on prices and income, as expressed in the functions qj=qj(pj,…,pn,x) for j=1,….n.

Marshallian demand functions can be inserted into the utility function to derive the indirect utility function given by $u = u(q(x, p)) = u_I(x, P)$, where q and p are vectors of n quantities and prices and $u_I(x, P)$ is the indirect utility function. Although consumers maximize utility, in practical terms, economists model them as though they minimize costs following a two-step budgeting procedure. The consumer cost function, or expenditure function, is dual to the utility function and expresses the minimum expenditure needed to reach a specified level of utility for a given price vector: $C(u, p) = C(u_I(x, p), p))$. The Hicksian (compensated) demand function, derived from the cost function by applying Shephard's Lemma, generates 'compensated' or 'Slutsky' price elasticities and are equivalent to the uncompensated price elasticities. We estimate both Marshallian and Hicksian demand functions, using the modeling approach in the following section.

3. Econometric strategy

3.1. Data source

The dataset used in this analysis was obtained from an urban household level expenditure survey conducted by the Tegemeo Institute of Egerton University in collaboration with the Kenya National Bureau of Statistics (KNBS) in Nairobi, between June and July 2009. A total of 823 households were interviewed, of which 760 are used to analyze the demand for specific fruit and vegetables. The survey included the households' purchases and consumption of an array of basic food commodities; staples, fresh fruit & vegetables, dairy products, meats and eggs; as well as expenditure on non-food items. Commodity prices were also collected, as well as demographic characteristics of households.

3.2. Econometric model

Deaton and Muellbauer (1980) proposed the Almost Ideal Demand System (AIDS), which takes all commodity groups and treats them as a singular system. Also known as the flexible demand system, we apply this widely used methodology here.

The demand system expresses the dependent variable as budget shares, as follows:

$$S_i = \alpha_i + \sum_j^n \gamma_{ij} \ln P_j + \beta_i \ln(\frac{X}{P}) + u_i \qquad i=1,\ldots,n \qquad (1)$$

Where S_i is the budget share of good *i*; p_j is the price of good *j*; x is the total expenditure of the goods in question; u_i is the random disturbance term assumed to have a mean of zero and constant variance; and *P* is a translog price index defined by

$$\ln P = \alpha_0 + \sum \alpha_j \ln P_j + 0.5 \sum_i^n \sum_j^n \gamma_i \ln P_i \ln P_j \qquad (2)$$

The intercept α_i represents the estimated budget share of commodity when all logarithmic prices and real expenditures are zero, interpreted as the subsistence consumption of commodity *i*. The price index from Equation (1) makes the system non-linear, which normally complicates the estimation process. To keep the specification of the demand system linear, while avoiding the inconsistency of the Stone price index, Moschini (1995) proposed the corrected Stone index:

$$\ln p = \sum_{i=1}^n S_i \ln\left(\frac{p_j}{p_i}\right) \qquad (3)$$

In the current study, the price index (3) is transformed into the log-linear Laspeyres price index which transforms the AIDS model into the linear AIDS.

Several approaches have been followed to incorporate household characteristics in the estimation of complete demand systems. To capture the effects of demographic variables on demand patterns, while preserving the linearity of the system, the intercept of equation (2) is modified by the translating method (Heien and Wessells, 1990):

$$\alpha i = p_{i0} + \sum_{k=1}^s p_{ik} d_k \qquad i=1,\ldots,n \qquad (4)$$

Incorporating (4) into (1) will yield;

$$S_i = p_{i0} + \sum_{k=1}^{s} p_{ik} d_k + \sum_{j-i}^{n} \gamma_{ij} \ln p_j + \beta_i \ln(\frac{X}{p*}) + u_i \qquad (5)$$

The model in (5) is a linear approximation to the AIDS model in (1). $P*$ is the corrected Stone price index; d_k are s demographic variables, p_{i0} and p_{ik} are parameters to be estimated and u_i is the error term. X represents total expenditure on the system of commodities, q_i is the quantity demanded for the ith commodity. P_i is the price index.

Compensated and uncompensated price elasticities can be calculated using the formulas reported by (Hayes et al., 1990) as shown in equation 20 to 23, respectively:

$\varepsilon_{ii} = -1 + \frac{\gamma_{ii}}{s_i} - \beta_i$ (Marshallian own-price elasticity),

$\varepsilon_{ij} = \frac{\gamma_{ij}}{s_i} - \beta_i\left(\frac{s_j}{s_i}\right)$ (Marshallian cross-price elasticity among commodities *i*),

$\delta_{ii} = -1 + \frac{\gamma_{ii}}{s_i} + s_i$ (Hicksian own-price elasticity),

$\delta_{ij} = \frac{\gamma_{ij}}{s_i} + s_j$ (Hicksian cross-price elasticity among commodities *i)* and

$\eta i = 1 + \frac{\beta_i}{s_i}$ (Expenditure elasticities).

Some households may not have purchased for consumption some fruits and vegetables during the survey period, implying zero values for the corresponding observations of the budget shares, creating a potential bias in the OLS estimates when the assumption of zero correlation between independent variables and error term is violated. This problem is solved by using a two-stage estimation procedure proposed by Tobin (1958) that combines a probit analysis with a standard OLS, (Heien and Wessells, 1990). In the first stage, a probit regression is estimated to represent the decision by household (h) to consume the particular commodity (*i*) or not. The maximum likelihood estimates from this are then used to construct the inverse Mill's ratio for each household. In the second stage, the IMR is used as an instrumental variable in the OLS estimation of the demand equations. If the IMR is found to be statistically significant, it is included in the estimation as instrumental variables in the respective budget share equations.

In line with the demand theory, the following restrictions are imposed on equation (5); $\sum_i \alpha_i = 1$, satisfies the adding-up; $\sum_i \beta_i = 0$, $\sum_j \gamma_{ij} = 0$, $\sum_i \gamma_{ij} = 0$ homogeneity; and $\sum_i \gamma_{ji} = \gamma_{ij}$ symmetry (Deaton and Muellbauer, 1980). We estimate models with seemingly unrelated regression (SUR) of Zellner, (1962).

Two independent demand systems of equations are estimated; a demand system with four equations for vegetables and another with four equations for fruits. The vegetable demand model contains more explanatory variables, in addition to those contained in the fruit demand model. As required by demand theory, 20 restrictions each of Slutsky symmetry and linear homogeneity in prices are imposed to either demand system of vegetable model, as

well as the fruits model. Further, to avoid singularity in the demand systems estimation, the fourth equation (onion) is dropped from the vegetable demand system, whereas the fourth equation (avocado) is dropped from the fruit demand system. The parameter estimates of the dropped equations are recovered from the adding up condition.

3.3. Variable definitions

The explanatory variables included in the model are; prices of the kale, tomato, cabbage and onion as well as banana, mango, orange and avocado, the prices of maize flour, rice and wheat flour, table 1. The prices of these cereals are included in the model because they are consumed together in meals with vegetables. Also included in the model are household average expenditures on fruits and vegetables. Other variables included are; size of the household, age and number of years of education of the household head, the female gender of the household head. The household head is the major decision maker on how the household allocates expenditure and what is consumed; a variable indicating whether the household head was engaged in salaried employment or business activities; a variable indicating whether a household owned a refrigerator, and whether a household produced fruits and vegetables in the urban residence. Although demographic variables are not determinants of demand, they influence demand for commodities in the households.

It has been reported that in Rwanda, female-headed households allocated a large share of their budget to fruit and vegetable consumption, (Ruel *et al.*, 2005), as well as in Kenya where more female-headed households were found in the highest fruit and vegetables expenditure quintile, (Ayieko *et al*.,2005). Deaton and Paxson, (1998) presented evidence of economies of scale in food consumption from a number of developed and developing countries. Ruel *et al*., (2005) finds that larger households allocate a lower share of their budget to fruits and vegetables. Ruel, *et al*., (2005) find that households with a larger proportion of older members allocated larger budget share to fruits. However, Ayieko *et al*., (2005) find that older household members fall in the lowest fruit and vegetable expenditure quintile.

Table 1. Model Variables

Variable	Description	Measurement	Expected sign
S_i	Budget share of the jth fruit & vegetable category	Dependent variable	
Vegetable prices	Price of kales, tomato, cabbage	Average prices in Kenya Shilling	-

	and onion		
Fruit prices	Price of banana, mango, orange and avocado	Average prices in Kenya Shilling	-
Maize flour price	Price of maize flour	Average price in Kenya Shilling	-
Rice price	Price of rice	Average price in Kenya Shilling	-
Wheat flour price	Price of wheat flour	Average price in Kenya Shilling	-
Household size	Household size	Number of household members	+
Age	Age of the household head	Years	?
Education	Education of household head	Number of years	- /+
Expenditure on vegetables	Amount spent on vegetables	Average expenditure in Kenya Shilling	+
Expenditure on fruits	Amount spent on fruits	Average expenditure in Kenya shilling	+
Off-farm income	If household head is engaged in salaried employment or business	Dummy 1 if engaged, otherwise 0	+
Female	Sex of household head	Female 1, male 0	?
Fridge	Whether household owns a refrigerator	Dummy variable;(1=own a fridge, 0 otherwise	+
Fruit and vegetables production	Whether household produced vegetables in urban residence	Dummy variable (1=produced vegetables, 0 otherwise	-

4. Findings

4.1. Budget Shares and Prices

Table 2 shows household budget shares allocated to fruits and vegetables. A majority of the urban households consume vegetables together with either *ugali* or rice or *chapati*. *Ugali* is made from maize flour, while *chapati* is made from wheat flour. In the vegetables category, households allocated higher budget shares to tomato and kales; tomato had a budget share of 0.41. This is more than a third of the expenditure households allocated to vegetables. Kales have a budget share of 0.25. Together with onions, the three vegetables account for about 89

percent of household expenditure on vegetables. This result illustrates the importance of the three vegetables in the diets of Nairobi households. Banana and avocado have the highest household budget shares of 0.37 and 0.30, respectively. These two fruits account for over 60 percent of household expenditure on fruits. Oranges and mango account for the remaining expenditure.

Table 2. Budget Shares of Fruits and Vegetables in June-July 2009

Budget Share	
Vegetables	**Proportion**
Kale	0.25
Tomato	0.41
Cabbage	0.11
Onion	0.23
Fruits	
Banana	0.37
Mangoes	0.14
Oranges	0.19
Avocado	0.30

Prices per kilogram (kg) for the fruits and vegetables are presented in table 3. Onion and tomato cost KES 56.86 and 45.68 *per* kg, respectively, whereas kales and cabbage cost KES 17.56 and 39.12 *per* kg, respectively. In nominal terms, households spent an average of KES 877 on vegetables and KES 541 on fruits, respectively during the survey month. In absolute terms, vegetables account for higher cash expenditures among Nairobi households. The possible reason is that these commodities are basic in the diets of a majority of the households, for they are consumed as accompaniments to food staples during the households' main meals.

Table 3. Price *per* Kilogram (KES) of Fruit and Vegetables in June-July 2009

Commodity	**Mean**	**Std. Deviation**
Vegetables		
Kale	17.56	12.86
Tomato	45.68	17.83
Cabbage	39.12	29.69
Onion	56.86	26.34
Fruits		
Banana	27.43	15.04
Mangoes	27.52	33.59

Oranges	29.39	25.34
Avocado	19.87	15.48
Total HH Expenditure on Fruits and Vegetables /Month		
Household Vegetables Expenditure (KES)	877	557
Household Fruit HH expenditure (KES)	541	570

Among the fruits, oranges are more costly, where a kg is KES 29.39, while avocado are the cheaper of the fruits at KES 19.87 *per* kg. Between 2007 and 2009, Kenya experienced unprecedented high food prices, partly due to high international food prices, (Minot, 2010), the 2007/2008 post-election violence (PEV) and a severe drought locally. The high international and local food prices made food to be unaffordable to a majority of the households, whereas the drought dealt a severe blow to domestic food production. These two factors could have affected the availability of fruits and vegetables in the markets, resulting in more costly produce per unit being delivered to the markets.

4.2. Regression Results

4.2.1 Marshallian elasticities

Table 4 reports the Marshallian (uncompensated) own-price and cross-price elasticities for vegetables and cereal products, (henceforth referred to as staples). Also reported in the table are the respective vegetable expenditure elasticities. The price elasticities of demand are reported according to consumer theory where commodities are classified as normal or inferior goods.

Table 4. Marshallian Own-Price, Cross-price and Expenditure Elasticities for Vegetables and Cereal product Prices

Budget Share	Prices	Expenditure Elasticity

	Kales	Tomato	Cabbage	Onion	Maize flour	Rice	Wheat flour	
Kales	**-0.761**	-0.277	-0.072	-0.033	-0.001	-0.004	-0.001	1.142
Tomato	-0.107	**-0.792**	-0.029	0.021	0.006	-0.002	-0.002	0.907
Cabbage	-0.052	-0.023	**-0.693**	0.069	0.001	0.000	0.001	0.699
Onion	-0.039	-0.066	-0.017	**-1.036**	-0.010	0.007	0.005	1.159

The Marshallian own-price elasticities carry the expected negative sign implying that the vegetables are normal goods, whose quantity demanded declines when their prices increase. The demand curve for a normal good is downward sloping; thus, they exhibit inelastic demand. However, the Marshallian own-price elasticity for onion is greater than one, exhibiting elastic demand.

The vegetables are more responsive to own-price changes, although this is more pronounced in the onion and tomato; their own-price elasticities are (-1.036) and (-0.792), respectively table 4. Cabbage is the least responsive to own-price changes (-0.693) among all the vegetables. Musyoka *et al*., (2010), and Weliweta *et al*., (2003) did not estimate the elasticities for the individual vegetables, hence limiting comparability of the elasticities in both studies. However, Musyoka *et al*., (2010) found the own-price elasticity for the aggregate vegetable group to be (-1.66); implying that vegetables had elastic demand.

The cross-price elasticities between kales and tomato, cabbage, as well as onion are negative, implying that these commodities have a complementary relationship. On the other hand, the cross-price elasticity of demand between onion, tomato and cabbage are positive, implying they are substitutes. Tomato and cabbage exhibit a complementarity relationship with kales and onions, respectively. The prices of the staples; rice, maize flour and wheat flour are included in the model because households usually consume vegetables as accompaniments to either *ugali* or *chapati* or rice. *Ugali* is made from maize flour, whereas *chapati* is made from wheat flour. A price change in any of these staples is likely to affect the demand for these vegetables. The cross-price elasticity of demand estimates indicates that maize flour has a complementary relationship with kales and onion, but acts as a substitute to tomato and cabbage.

The most common practice in Kenya is that kales cooked with onion and tomato is eaten with *ugali.* However, it was puzzling as to why maize flour behaves as a substitute to tomato. Rice behaves as a complement to kales and tomato, but behaves as a substitute to onion. Therefore, if the price of rice increased, the demand for kales and tomato would decrease, but that of onion would increase. Wheat flour exhibits a complementary relationship with kales and tomato, but acts as a substitute to cabbage and onion, just the

same way rice does. From their study, Musyoka, *et al*., (2010) found that maize flour, rice and wheat flour behaved as substitutes to the aggregate vegetable category.

The expenditure elasticities (a proxy for income) for the fruits and vegetables are reported in the context of economic theory where an expenditure (income) elasticity in the range of zero and one signifies a commodity to be a necessity and an expenditure elasticity that is greater than one implies the commodity is a luxury. Kales and onion have expenditure elasticities that are greater than one. In economic terms, this implies that these two vegetables are luxuries among households in Nairobi. Of interest is that kale is a vegetable that is commonly consumed among households in Kenya, but seems to behave as a luxury among Nairobi households. Tomato and cabbage are necessities. In their study, Ruel *et al*., (2005) found that the expenditure elasticity for vegetables as a group was 0.61. Perhaps the high level of aggregation of the vegetables into one food group could have resulted in the low expenditure elasticity. Musyoka *et al*., (2010) found the same to be 1.01; similarly, Weliweta *et al*., (2003) found the expenditure elasticity of an aggregate fruit and vegetable group to be (1.079). They posited that it was not unusual to find fruit and vegetables behaving as luxuries for a low income country because households give priority to food that have high sources of energy.

Among the fruits, avocado, oranges and banana are the more responsive to own-price changes than mango (Table 5). Their elasticities are (-1.104, -0.741 and -0.740), respectively. The cross-price elasticities of demand between banana and orange, mango and avocado are of a complementary nature. Orange is a complement to all fruits, except banana, in which the price elasticity between banana and orange is (0.000), implying that a price increase in the orange will not have any effect on the quantity demanded of banana. Avocado behaves as a substitute to banana and orange, but behaves as a substitute to mango in which it exhibits a complementary relationship.

Table 5. Marshallian Own-price, Cross-price and Expenditure Elasticities for Fruits

Budget Share	**Prices**				**Expenditure Elasticities**
	Banana	Orange	Mango	Avocado	
Banana	**-0.740**	0.000	-0.057	0.086	0.711
Orange	-0.082	**-0.741**	-0.132	0.020	0.935
Mango	-0.292	-0.203	**-0.577**	-0.031	1.103
Avocado	-0.130	-0.066	-0.051	**-1.104**	1.350

Mango and avocado are luxury commodities; the expenditure elasticity for avocado is (1.350), whereas that of mango is (1.103). If the income of households increased, demand for these two fruits would increase at a higher rate than the increase in income. Banana and orange are necessities. Their expenditure elasticities are (0.711) and (0.935), respectively.

Little exists in the literature of food demand estimation for comparisons purposes on individual fruits. The reason being that in a majority of the studies, elasticities for fruits and vegetables are estimated for the aggregated commodities. For example, in their analysis, Ruel *et al*., (2005) found the aggregate fruit expenditure elasticity to be one, whereas, Musyoka *et al*., (2010) found the same elasticity to be 1.21.

4.2.2. Hicksian Price Elasticities

The Hicksian price elasticities measure of the substitution effects between two food categories, devoid of the income effect. The Hicksian own-price elasticities are all negative and as expected, smaller in magnitude when compared to the Marshallian elasticities, table 6.

Table 6. Hicksian Own-Price and Cross-price Elasticities for Vegetables

Budget Share	**Prices**						
	Kales	Tomato	Cabbage	Onion	Maize flour	Rice	Wheat flour
Kales	**-0.479**	0.196	0.054	0.229	0.281	0.278	0.280
Tomato	0.117	**-0.416**	0.071	0.229	0.382	0.374	0.374
Cabbage	0.121	0.267	**-0.616**	0.229	0.078	0.077	0.078
Onion	0.247	0.415	0.110	**-0.771**	0.255	0.273	0.270

These elasticities conform to demand theory of a negative sloped demand curve for a normal good. They range between (-0.416) for tomato and (-0.771) for onion. The Hicksian cross-price elasticities are computed as in the formula proposed by Chalfant, (1987). The cross-price elasticities are mostly positive indicating gross substitution among these vegetables and the staples. Kales behave as a substitute to all the three vegetables and so does tomato, cabbage and onion in relation to the other vegetables. This result implies that when the price of kales increase the quantity demand of tomato, cabbage and onion would increase. The same would happen if the price of tomato, cabbage and onion increased. The staples; maize flour, rice and wheat behave as substitutes to the vegetables. This implies that when the price of the staples increase the demand for the vegetables would increase.

As in the case of vegetables, the Hicksian own-price elasticities for fruits are found to be negative and smaller in magnitude when compared to their counterparts, the Marshallian own-price elasticities, table 7. Just as in the Marshallian own-price elasticities, the fruits are more responsive to own prices. On the other hand, the Hicksian cross-price elasticities are positive implying gross substitution among the four fruits. Banana behaves as a substitute to all the other fruits, and so does orange, mango and avocado. This result implies that if the price of banana increased the demand for the other fruits would increase. The same would be repeated if the price of orange, mango or avocado increased; households would substitute among the fruits.

Table 7. Hicksian Own-price and Cross-price Elasticities for Fruits

Budget Share	Prices			
	Banana	Orange	Mango	Avocado
Banana	**-0.477**	0.134	0.045	0.298
Orange	0.264	**-0.565**	0.003	0.298
Mango	0.116	0.004	**-0.418**	0.298
Avocado	0.370	0.188	0.145	**-0.702**

4.2.3. Diagnostic tests

According to table 8, homogeneity in the vegetable demand system is rejected at the one percent level, whereas symmetry could not be rejected at the five percent level. Both homogeneity and symmetry are rejected at the one percent level in the fruit demand system. According to Blanciforti and Green, (1983), homogeneity and symmetry restrictions can be rejected by the data. Christensen *et al*., (1975) also concluded a rejection of homogeneity by using a transcendental logarithmic utility function to estimate the demand system. Deaton and Muellbauer, (1980), who developed the AIDS model, rejected homogeneity based on F-tests. They assumed that the rejection of homogeneity is a symptom of dynamic model misspecification.

Table 8. The constraint tests

VEGETBLES			
	df	**Chi2**	**p-value**
Homogeneity	3	19.439	0.000
Symmetry	3	3.065	0.382
Homogeneity & Symmetry	6	24.322	0.000
FRUITS			
	df	**Chi2**	**p-value**
Homogeneity	3	61.394	0.000
Symmetry	3	38.093	0.000
Homogeneity & Symmetry	6	104.514	0.000

The vegetables and fruits models are significant; however, they are poor fits as shown by the respective R-squared because of the survey (cross-sectional) nature of the dataset

(table not included here). For the vegetable demand system, the R-squared lies between 0.202 for cabbage and 0.335 for kales. In this demand system, kales have a slightly better representation of the sample than the other commodities in the same system. For the fruit demand system, the R-squared falls between 0.125 (orange) and 0.516 (mango). Thus, mango has a better representation of the data in the sample. All the nine symmetry constrained price estimates in the vegetables demand system are significant at the one percent level, whereas three of the expenditure estimates are significant at the one percent level. At the same time, all the nine price estimates in the fruit demand system are significant at the one percent level, whereas two of the expenditure estimates are significant at the one percent level.

The household demographic characteristics have varying effects in the demand for vegetables; household expenditure on vegetables has a positive significant effect at the one percent level in the demand for kales, but a negative significant effect at one percent level in the demand for onions and cabbage. This result implied that an increase in household expenditure on vegetables would result in an increase in the demand for kales, but a decline in the demand for tomato and cabbage. The price of maize flour has a positive significant effect at the one percent level in the demand for cabbage. Price of rice has a negative significant effect at the one percent level in the demand for kale and tomato, whereas price of wheat has a negative significant effect at the one percent level in the demand for tomato.

This result suggests that if the price of maize flour rose, the demand for cabbage would increase. On the other hand if the price of rice increased the demand for kale and tomato would decrease. An increase in the price of wheat flour would result in a decrease in the demand for tomato. Kenya produces only 40 percent and 20 percent, respectively of the wheat and rice consumed domestically, Gitau *et al*., (2010). The shortfall in supply of these two commodities is met through imports. Thus, for the households to continue to consume these two commodities at their increased prices, they would have to reduce the quantity demanded of kale, cabbage and tomato.

The age of the household head has a positive significant effect at the one percent level in the demand for cabbage; but it has a negative significant effect at the one percent level in the demand for kales. This result implies that as the household heads get older, they demand more of cabbage and less of kales. A household owning a fridge has a positive significant effect at the one percent level in the demand for tomato, but a negative significant effect in the demand for kales. This implies that owning a fridge would increase demand for tomato, but decrease demand for kales. Perhaps this result suggests that households owning a fridge probably consume vegetables other than kales. A similar result is seen among the households that produced fruit and vegetables in their urban residence. The household head having a salary or income from business, education level of household head and household size have no effect in the demand for the vegetables; neither does the female gender of household head. Le, (2008) found a similar result from his study. This result could mean that these vegetables are so basic in the diets of households that the three factors above could not have had any effect in vegetable demand.

In the fruit demand system, age of the household head has a positive significant effect at the one percent level in the demand for banana. This implies that as the household heads grow older, they demand more of banana. Participation in salary or business activities has a positive significant effect at the five percent level in the demand for mangoes; household size has a negative significant effect at the one percent level in the demand for oranges and mango. As noted elsewhere in this paper, mango and orange were relatively more expensive *per* kg, compared to banana and avocado. Owning a refrigerator has a positive significant effect at the one percent level in the demand for banana, orange and mango. This result implies that having a refrigerator in the household could increase demand for these fruits. Whether a household produced fruits and vegetables in the urban residence has a positive significant effect at the one percent level in the demand for banana.

5. **Conclusions**

We set out to describe the consumption patterns and assess the responsiveness of Nairobi households to changes in fruit and vegetable commodity prices, as well as assess the effect of demographic characteristics on the demand for these commodities. Our aim was to generate information useful to fruit and vegetable producers and marketers to help them in making decisions regarding their activities geared towards meeting the demand for fruit and vegetables among Nairobi households. The information would also be useful to policy planners to come up with policy interventions geared towards improving the production and availability of fruit and vegetables to Nairobi households that rely on markets for these commodities. Data for the study comes from a household expenditure survey conducted by Tegemeo Institute of agricultural policy and development, between June and July of 2009. The analysis utilizes a dataset of about 760 households. Four (4) commodities from among the vegetables; kales, tomato, cabbage and onion and four (4) others from among the fruits; banana, mango, oranges and avocado, are selected for the analysis. We estimate the AIDS model as a seemingly unrelated regression.

In order to correct for zero expenditure shares during the survey period, IMR for every commodity share equation was estimated and included in the model as an instrument. Demand restrictions of homogeneity and Slutsky symmetry are imposed to the models. Several observations emerge from the analysis. Kale and tomato were important vegetables in the diets of households in Nairobi. The two vegetables account for over 60 percent of the household expenditure budget allocated to vegetables. Among the fruits, banana and avocado emerge as important fruits. The two fruits account for over 60 percent of the household expenditure budget allocated to fruits. Producers and marketers can thus increase production and marketing of these commodities in Nairobi.

The Marshallian own-price elasticities show that the vegetables, except for onion have inelastic demand. On the other hand, all the Hicksian own-price elasticities show that vegetables have inelastic demand. The Marshallian cross-price elasticities between the staples and vegetables are either positive or negative, giving an indication of gross substitution or complementarities between the vegetables and the staples. However, the Hicksian cross-price elasticities between the staples and vegetables are positive, thus exhibiting gross substitution between the staples and vegetables.

In the fruit model, both the Marshallian and Hicksian own-price elasticities range between zero and one; all are negative, except for avocado that exhibits a Marshallian own-price elasticity that is greater than one. It thus has elastic demand, whereas the other fruits have inelastic demand. The expenditure elasticities for some vegetables and fruits are high. Among the vegetables, the expenditure elasticities range between (0.699) and (1.159). In the fruit model the expenditure elasticities range between (0.711) and (1.350). This therefore means that some fruit and vegetables are necessities, whereas others are luxuries. The implication of this is that, an increase in the disposable incomes of households would see a general increase in the demand for these commodities, but more among the luxury commodities than the

necessities. Of interest is the finding that the kale behaves as a luxury commodity. This is despite the fact that kale is viewed as the common man's vegetable because when times are hard in the households, it is the most frequently consumed vegetable in meals.

Household demographic characteristics influence the demand for fruits and vegetables. Their inclusion into the model is thus crucial to assess their effects on demand patterns for these commodities. Household demographic characteristics had positive effects in the demand of some fruits and vegetables and a negative effect on some others. Their inclusion in the analysis was necessary as they play a role in household food demand, and that they also help avoid the problem of omitted variable bias that is inherent in cross-sectional survey data.

5. Policy recommendations

Households spend a sizeable amount of their income (expenditure) on fruit and vegetables. The mean households' expenditure budget is particularly high for tomato and banana. These commodities are highly seasonal and perishable; storage facilities that prolong their shelf life and production systems that ensure constant supply need to be addressed into in order to smooth supply in the markets and avoid the acute seasonal price variations in these commodities.

Some fruits and vegetables in this analysis exhibited inelastic demand. Thus price policies alone would have a minimal effect on their demand. However, a combination of price and income policies would have a positive effect in the consumption of these commodities. Kale behaves as a luxury commodity among the households in Nairobi. Were the price of kales to increase, it would spell dire consequences to households because this would drastically affect the households' ability to access the most commonly consumed vegetable in their diets. Kenya is a net importer of the food staples included in this study. Coupled with what has become a common occurrence in the international food markets concerning surges in the prices of these staples in the recent past, households are most affected by these high food prices. When they become unaffordable, the food security situation of households is also affected. Hence it is imperative that the government puts in place mechanisms that ensure availability of these cereals locally.

Household demographic characteristics influence demand patterns for fruit and vegetable commodities, hence production and marketing efforts need to consider these factors as affecting demand patterns of households. Overall, policy interventions geared towards improving production, distribution of fruits and vegetables, as well as improving households' incomes, and maintaining stable food prices would have a direct effect in the demand for these commodities, more than price policies alone.

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