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Transformation of Global Agri-Food Systems:
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Georg-August-University of Göttingen

GlobalFood Discussion Papers

No. 31

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April 2014

RTG 1666 GlobalFood · Heinrich Düker Weg 12 · 37073 Göttingen · Germany
www.uni-goettingen.de/globalfood

ISSN (2192-3248)

Impacts of supermarkets on farm household nutrition in Kenya

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Abstract. Many developing countries are experiencing a food system transformation with a rapid growth of supermarkets. Research has shown that smallholder farmers can benefit from supplying supermarkets in terms of higher productivity and income. Here, we analyze impacts on farm household nutrition. Building on data from vegetable farmers in Kenya, we show that participation in supermarket channels has sizeable positive effects: calorie, vitamin A, iron, and zinc consumption are all increased by 15% or more. We also analyze impact pathways, using simultaneous equation models. Supermarket-supplying households have higher incomes, a higher share of land under vegetables, and a higher likelihood of male control of revenues. Furthermore, income and the share of land under vegetables have positive impacts, while male control of revenues has negative impacts on dietary quality. The total nutrition effects of supermarket participation could be even more positive if women were able to keep their control over farm revenues in the process of commercialization. The methods developed and used may also be useful for other impact studies to better understand agriculture-nutrition linkages.

Keywords. supermarkets, smallholder farmers, nutrition impact, dietary quality, gender, Kenya

Acknowledgement. The financial support of the German Research Foundation (DFG) through the GlobalFood Research Training Group is gratefully acknowledged.

1. Introduction

In the recent past, many developing countries have experienced a profound food system transformation with a rapid growth of supermarkets (Reardon and Timmer, 2007; Neven et al., 2009). This supermarket growth can be attributed to both demand and supply side factors (Reardon et al., 2003; Mergenthaler et al., 2009). On the demand side, rising incomes, urbanization, and changing lifestyles contribute to preference shifts towards higher-value foods, including processed and convenience products, which modern retailers are better equipped to provide than traditional markets. On the supply side, the supermarket growth was facilitated by policy changes such as market liberalization in the food industry and greater openness for foreign direct investment. This retail revolution has also caused structural changes along the supply chains. Supermarkets try to offer their customers a consistent variety of high-quality products. To ensure continuous supply, supermarkets have established their own procurement systems, involving centralized buying points and contractual arrangements with farmers and traders (Reardon and Berdegué, 2002; Weatherspoon and Reardon, 2003; Rao et al., 2012).

Several studies have analyzed impacts of farmer participation in these new supermarket channels on farm productivity (Hernándezet al., 2007; Nevenet al., 2009; Rao et al., 2012), sales prices (Michelson et al., 2012), household income (Miyata et al., 2009; Rao and Qaim, 2011; Michelson, 2013), and labor markets (Neven et al., 2009; Rao and Qaim, 2013). Most of these studies conclude that supermarkets can contribute to rural economic growth and a modernization of the small farm sector. Strikingly, however, there is no single study that has analyzed possible impacts of supermarkets on farm household nutrition. While recent research has examined how supermarkets may influence dietary habits of urban consumers (Nevenet al., 2006; Pingali, 2007;

Asfaw, 2008; Tessier et al., 2008), a focus on farm household nutrition is important, too. Smallholder farmers make up a large proportion of the undernourished people worldwide.

In this article, we address this research gap and analyze the impacts of supermarkets on farm household nutrition, using detailed survey data specifically collected for this purpose. We contribute to the literature in two ways. First, we add a new perspective to the existing body of literature on supermarket impacts. Second, we contribute conceptually to the analysis of agriculture-nutrition linkages. Given the persistently high rates of rural undernutrition, the international community has shown a renewed interest in better understanding the nutrition and health impacts of agricultural innovations (CGIAR, 2013). Yet, very few studies have evaluated such impacts; identifying suitable methodologies has proven a challenge (de Haen et al., 2011; Masset et al., 2012; Kabunga et al., 2014).

Our study focuses on smallholder farmers in Kenya. Kenya is an interesting example, because supermarkets have rapidly gained in importance there in recent years. Supermarkets in Kenya now account for about 10% of national grocery sales, and over 20% of food retailing in major cities (Planet Retail, 2013). Whereas this share in Kenya is still lower than in middle-income countries in Asia and Latin America, it is already higher than in most other countries of Sub-Sahara Africa. Based on detailed food consumption data, we compare nutritional indicators between farm households with and without supermarket contracts. In addition to calorie intakes, we analyze levels of micronutrient consumption as indicators of nutritional quality. Possible issues of selection bias are addressed with an instrumental variable approach. We also analyze impact pathways. Participation in supermarket channels may affect household nutrition through increasing cash incomes. Moreover, supermarket contracts may influence the farmers' choice of commodities produced, and thus the types of foods available in the household from own production. Finally, there may be changes in gender roles within the farm family that could also affect household nutrition. Earlier research showed that commercialization of agriculture is often associated with men taking over control of resources that were previously controlled by women (Dewalt, 1993; von Braun and Kennedy, 1994). We develop and estimate structural models to analyze such impact pathways.

2. Farm household survey

In 2012, we carried out a survey of smallholder vegetable farmers in Kiambu District, Central Province of Kenya. Kiambu is relatively close to Nairobi and is the capital's main source of horticultural produce (Rao and Qaim, 2011). Some of the farmers in this region produce vegetables for supermarkets, while others sell their vegetables in traditional channels. The two biggest supermarket chains sourcing vegetables from Kiambu are Nakumatt and Uchumi, which are both Kenyan owned. Foreign owned retail chains so far play a much smaller role in Kenya (Planet Retail 2013).

Based on information from the district agricultural office, four of the main vegetable-producing divisions were chosen. In these four divisions, 31 administrative locations were purposively selected, again using statistical information on vegetable production. Within the locations, vegetable farmers were sampled randomly. In total, our data set comprises observations from 384 farm households – 85 that participate in supermarket channels and 299 that sell only in traditional channels. These households were visited, and household heads were interviewed face-to-face, using a structured questionnaire that was carefully designed and pretested. The data collected include general household characteristics, details on vegetable production and marketing, other farm and non-farm economic activities, food and non-food consumption (see below for details), and various institutional variables.

Sample households are typical smallholder farmers with an average farm size of about 2 acres. These households produce exotic vegetables, such as kale, spinach, and cabbage, as well as indigenous vegetables like black night-shade and amaranth. In addition, they are engaged in other agricultural activities such as the production of staple and cash crops like maize, beans, tea, and coffee. Many are also involved in small-scale livestock farming. Table 1 shows sample descriptive statistics for a number of socioeconomic variables that are used as controls in the regression analysis below. In addition to the household head, we captured some information about gender relations within the household. Eighty-nine percent of the sample households are headed by males. Household heads have 9.6 years of formal schooling on average. In contrast, the main female in the household, which in most cases is the spouse of the household head, has a formal education of less than one year. Following Fischer and Qaim (2012), survey respondents were also asked which household member controls vegetable production and revenue. To ensure collection of reliable information, enumerators were trained to ask these questions and confirm the responses from various perspectives. As can be seen in Table 1, males control the revenues from vegetable production in 73% of the sample households.

(Table 1 about here)

In terms of vegetable marketing conditions, supermarket and traditional channels differ considerably. Traditional channel farmers have no advance agreements with their buyers. They either sell to traders at the farm gate or in traditional wholesale markets without any promise of repeated transactions. There is no market assurance in traditional vegetable channels, and prices tend to be volatile. In contrast, supermarket farmers have agreements, either with the supermarkets directly or with specialized agents. These agreements are mostly verbal in nature; they specify vegetable quantities, quality and form of supply. Prices in supermarket channels are stable and mostly higher than in traditional channels. For actual delivery, supermarket farmers are contacted via mobile phone a few days in advance and asked to deliver a certain lot at a particular time. Farmers have to transport their produce themselves to the supermarkets in Nairobi. Vegetables have to be cleaned and bundled before delivery, ready for the supermarket shelves. Payments are usually made with a delay of one or two weeks. Hence, while supplying supermarkets is attractive in terms of price incentives, farmers with high opportunity costs of time and limited access to transportation and credit are less likely to participate. These observations are consistent with earlier research in Kenya (Neven et al., 2009; Rao and Qaim, 2011).

The 299 traditional channel farmers in our sample sell their vegetables only in traditional channels. The 85 supermarket farmers sell most of their vegetables to supermarkets. Only if the quantities produced exceed the contractual agreement, supermarket farmers sell these excess quantities in traditional channels. A few households in our sample sold their vegetables under contract to hotels or schools. As the contracts with hotels and schools are similar to the agreements with supermarkets, these few households are classified as supermarket farmers for the purpose of this analysis.

3. Indicators of household nutrition

3.1 Measurement approach

The main objective of this study is to analyze the impacts of supermarket participation on household nutrition. This requires identification of suitable nutrition indicators that can be used as outcome variables. Various possible indicators exist in the literature (de Haen et al., 2011). Recent studies have used data on food expenditure or households' subjective food security assessment in evaluating impacts of new agricultural technologies (Shiferaw et el., 2014; Kabunga et al., 2014). Other studies have used data on child anthropometrics (Masset et al., 2012). While these approaches are useful to capture certain dimensions of food insecurity and undernutrition, they are not suitable to analyze impacts in terms of household nutrition behavior and dietary quality. In order to examine such aspects, we collected detailed information on household food consumption.

We included a 7-day food consumption recall in the survey. To ensure accurate information, this part of the interview was carried out with the person in the household responsible for food choices and preparation. This person was mostly a female household member who often responded together with the household head. Details on food quantities consumed from own production, purchases, transfers, and gifts were collected for over 180 food items. These data were used to calculate daily calorie availability in each household as well as consumption levels of certain micronutrients. We concentrate on vitamin A, iron, and zinc, because deficiencies in these micronutrients are widespread and constitute serious public health problems in many developing countries (Black et al., 2008; Stein et al., 2008).

To calculate calorie and micronutrient consumption levels, reported food quantities were corrected for non-edible portions. Edible portions were converted to calorie and nutrient levels using food composition tables for Kenyan foods (FAO, 2010; Sehmi, 1993). In a few cases where individual food items could not be found, other international food composition tables were consulted (FAO, 2012; USDA, 2005). To make values comparable across households, we divided by the number of adult equivalents (AE), taking into account household size, demographic structure, and levels of physical activity. One AE is equal to a moderately active adult male. In these calculations, it is assumed that food within the household is distributed according to individual calorie and nutrient requirements (IOM, 2000; FAO, WHO, UNU, 2001).

For micronutrients, losses during cooking had to be accounted for (Bognár, 2002). Furthermore, issues of bioavailability need to be considered. Bioavailability of iron and zinc in particular depends on the composition of meals, as body absorption is influenced by enhancing and inhibiting factors (IZiNCG, 2004; WHO and FAO, 2004). Since we do not have information on the exact composition of meals, we had to make assumptions based on the literature and knowledge about local food habits in the study region. For iron, WHO and FAO (2004) provide a bioavailability range of 5-15%; we assume low iron bioavailability of 5%. For zinc, IZiNCG (2004) differentiates between mixed/refined vegetarian diets and unrefined, cereal-based diets. We assume unrefined, cereal-based diets and low zinc bioavailability of 15%. This is consistent with assumptions made by WHO and FAO (2004) for Kenya.

To determine calorie and micronutrient deficiency, we compare amounts consumed with standard levels of requirements. For calories, a daily intake of 3000kcal is recommended for a moderately active male adult (FAO, WHO, UNU, 2001). Moreover, it is recommended that a safe minimum daily intake should not fall below 80% of the calorie requirement. Based on this, we use a minimum intake of 2400 kcal per AE and categorize households below this threshold as undernourished. Following WHO and FAO (2004), we use daily estimated average requirements (EAR) per AE of 625μg of retinol equivalent (RE) for vitamin A, 18.27mg for iron, and 15 mg for zinc. Households with consumption levels below these thresholds are categorized as deficient.

While our approach of using household food consumption data to measure nutrition is useful to assess possible impacts on food security and dietary quality, it also has a few limitations (de Haenet al., 2011; Fiedler et al., 2012). First, by using a single 7-day recall we cannot account for seasonal variation in food consumption. Second, we are not able to account for intra-household food distribution. Third, the 7-day recall data measure consumption levels, which are only a proxy of actual food and nutrient intakes. Food wasted in the household or portions given to guests or fed to pets cannot always be fully accounted for, which may result in overestimated intake levels (Bouis, 1994). Furthermore, as explained above, issues of bioavailability have to be approximated. While these limitations have to be kept in mind, we do not expect a systematic bias in our impact assessment, because the same issues hold for both supermarket and traditional channel farmers.

3.2 Nutrition indicators by marketing channel

Table 2 shows the calculated nutrition indicators for the full sample of households, and separately for supermarket and traditional channel suppliers. On average, households consume

3258kcal, 1374 µg of vitamin A, 17mg of iron, and 21mg of zinc per day and AE. The standard deviations in the sample are relatively high. About 21% of all households are undernourished. For vitamin A and zinc, the prevalence of deficiency is in a similar magnitude; the prevalence of iron deficiency is much higher with an estimated 64%. The comparison shows that supermarket suppliers have higher levels of calorie and micronutrient consumption than traditional channel suppliers. Likewise, the prevalence of deficiency is somewhat lower among supermarket farmers for all indicators. This points to the possibility of positive nutrition impacts of supermarket participation. However, the differences are relatively small, and the comparison in Table 2 does not control for any confounding factors. More rigorous impact assessment requires econometric approaches, which are discussed in the following.

(Table 2 about here)

4. Supermarket impacts on household nutrition

To analyze net impacts of supermarket participation on farm household nutrition, we regress the nutrition indicators discussed in the previous section on a supermarket participation dummy as treatment variable and a set of control variables. However, since households self-select into the group of supermarket suppliers, the treatment variable is endogenous. This may cause selection bias in estimation. Such bias has to be addressed through appropriate econometric techniques.

4.1 Identification strategy

Supermarket farmers may systematically differ from traditional channel suppliers, so that observed differences in outcome variables cannot be interpreted as net impacts of supermarket participation. Some of these differences may be due to observed factors that one can control for in a simple regression framework. Other differences may be due to unobserved factors, control of which requires an instrumental variable (IV) approach. Finding an instrument that is exogenous, correlated with supermarket participation, but not directly correlated with the nutrition outcome variables is difficult. We tried different possible variables and eventually identified "the number of supermarket farmers among the five nearest neighbors" as a valid instrument. The five nearest neighbors refer to other farmers in our sample based on GPS coordinates. Farmers cannot choose who their neighbors are, so that our instrument can be considered exogenous. On the other hand, previous research has shown that farmers observe what others are doing and are influenced by their social network when making innovation adoption decisions (Maertens and Barrett, 2013). Our data confirm that individuals with more supermarket farmers in their neighborhood are more likely to participate in supermarket channels themselves.

In contrast, the number of neighbors supplying supermarkets does not have a direct effect on household nutrition. All vegetable farmers in Kiambu have similar agroecological conditions, and we do not observe systematic regional patterns of supermarket participation in our sample. Farmers in the same neighborhood are not necessarily similar in terms of social status. Social stratification of neighborhoods, which often exists in urban settings, is not observed in rural areas of Kenya. Supermarket farmers living in the same region may sometimes exchange information on vegetable production and cooperate in terms of transporting their produce to Nairobi. But we have no indication to expect that supermarket farmers are more likely than other neighbors to interact on nutrition, health, or other socially relevant topics.

To identify the unbiased impact of supermarket participation on nutrition, we estimate treatment-effect models as follows:

$$N = \alpha_0 + \alpha_1 SM + \alpha_2 X_1 + \varepsilon_1 \quad (1)$$

$$SM = \beta_1 SMN + \beta_2 X_1 + \varepsilon_2 \quad (2)$$

where *N* is the nutrition indicator of interest, *SM* is a dummy for supermarket participation, and X_1 is a vector of control variables that are expected to influence household nutrition. *SMN* is the number of supermarket farmers among the five nearest neighbors, which we use as instrument, and ε_1 and ε_2 are random error terms. α_1 represents the treatment effect. We estimate separate models for calorie, vitamin A, iron, and zinc consumption. Given that previous research showed that supermarket participation has a positive effect on household income, we expect positive treatment effects.

Control variables used as part of the vector X_1 include education, gender, and age of the household head, as well as education of the main female in the household. We also control for household size, land area owned, and the value of non-land assets (e.g., machinery and irrigation equipment). To avoid endogeneity issues, we use lagged asset values referring to the situation before households had started to supply supermarkets. Possible issues of endogeneity are also the reason why we do not include current household income. In terms of contextual variables, we control for access to road and transport infrastructure, piped water, and distance to the nearest local food market.

4.2 Estimation results

Estimation results of the first-stage selection equations are shown in Table A1 in the Appendix. The outcome equations with the nutritional indicators as dependent variables are shown in Table 3. As expected, the treatment effects are all positive and significant, implying that supermarket participation contributes to improved nutrition. Controlling for other factors, supermarket participation increases calorie consumption by 598 kcal per AE, which implies a 19% increase over mean consumption levels of traditional channel households. Iron and zinc consumption levels are both raised by around 3 mg per AE, implying increases of 15-18%. The increase in vitamin A of 1302µg RE per AE involves almost a doubling of mean consumption levels. This large effect may be due to the specialization on vegetable production in supermarket-supplying households (Rao et al., 2012). Green leafy vegetables are an important source of vitamin A in Kenyan diets, and higher levels of production are likely to cause higher levels of consumption. Further details of impact pathways are analyzed below.

(Table 3 about here)

In terms of control variables, we find that households with older household heads have lower calorie and micronutrient consumption levels. Likewise, larger households have consistently lower consumption levels per AE. This is a typical phenomenon when using data from food consumption recalls (Ecker and Qaim, 2011), as larger households tend to use foods more efficiently with less waste. More household assets significantly increase the consumption of calorie and zinc, but not of vitamin A and iron. This underlines that the economic status of a household alone is not a good predictor of healthy and balanced diets. The lower part of Table 3 shows selected model statistics. The F-test statistics of the excluded instrument refer to the first-stage equations. These statistics confirm that the number of SM farmers among the five nearest neighbors is a strong instrument in all four models.

5. Analysis of impact pathways

5.1 Conceptual framework

Results in the previous section suggest that participation in supermarket channels has positive impacts on household nutrition. So far, however, the pathways through which these impacts occur remain obscure. We hypothesize that nutrition impacts of supermarket participation will mainly occur through three closely related pathways, as shown in Figure 1.The first pathway is through possible changes in household income. Several studies showed that participation in supermarket channels can cause significant income gains (Reardon and Berdegué, 2002; Hernándezet al., 2007; Rao and Qaim, 2011). Higher incomes improve the economic access to food, which may result in higher calorie consumption, especially in previously undernourished households. Moreover, rising incomes may contribute to better dietary quality and higher demand for more nutritious foods, including vegetables, fruits, and animal products (Babatunde and Qaim, 2010). These changes in demand would also result in improved micronutrient consumption.

(Figure 1 about here)

The second pathway may be through altered agricultural production choices at the farm level and thus changes in the availability of home-produced foods. Previous studies showed that the commercialization of agriculture is often associated with on-farm specialization (von Braun and Kennedy, 1994). This has also been observed for farms supplying supermarkets (Rao et al., 2012). As mentioned, the supermarket contracts in Kenya are associated with higher price stability; hence they reduce market risk and provide incentives for farmers to specialize. Similar developments were also observed elsewhere (Michelson et al., 2012). Whether such changes in production choices influence household nutrition in positive or negative directions will depend on the types of commodities that farmers produce under contract. If farmers specialize on cash crops with no or low nutritional value – such as tea, coffee, or cut flowers – dietary quality may not improve. Yet, in our case supermarket farmers specialize on vegetables. This may lead to more vegetable consumption at the household level and thus improve dietary quality. Even if farmers produce vegetables primarily for sale, certain portions that do not meet the stipulated quality standards are likely to be kept for home consumption.

The third pathway is related to possible changes in gender roles and intra-household decision-making. In many African countries, subsistence food crops are often controlled by women, whereas cash crops are predominantly controlled by men. Accordingly, the process of commercialization may be associated with men taking over domains that were previously controlled by women (von Braun and Kennedy, 1994; Fischer and Qaim, 2012). Such changes in gender roles and responsibilities were indeed observed in studies on horticultural supply chains in different African countries (Ezumah and Di Domenico, 1995; Weinbergeret al., 2011). A possible shift from female to male control of vegetable production and revenue may also have nutrition implications. Female-controlled income is often more beneficial for household nutrition, because women tend to spend more than men on food, health, and dietary quality (Hoddinott and Haddad, 1995). Hence, supermarket participation may have a negative partial effect on nutrition through this gender pathway.

5.2 Empirical strategy

In order to test the discussed hypotheses on impact pathways empirically, we develop a structural model with simultaneous equations as follows:

$$N = \alpha_0 + \alpha_1 Y + \alpha_2 SV + \alpha_3 G + \alpha_4 X_2 + \varepsilon_3 \quad (3)$$

$$Y = \beta_0 + \beta_1 SM + \beta_2 X_3 + \varepsilon_4 \quad (4)$$

$$SV = \sigma_0 + \sigma_1 SM + \sigma_2 X_4 + \varepsilon_5 \quad (5)$$

$$G = \delta_0 + \delta_1 SM + \delta_2 X_5 + \varepsilon_6 \quad (6)$$

$$SM = \varphi_0 + \varphi_1 SMN + \varphi_2 X_6 + \varepsilon_7 \quad (7)$$

where *N* is the respective indicator of household nutrition, which depends on household income (*Y*), the share of farm land under vegetables (*SV*) that we use as a measure of specialization, the gender of the household member who controls vegetable revenues (*G*), and a vector of other control variables (X_2), including household size, education, and other socioeconomic factors. Following the discussion above, *Y*, *SV*, and *G* are influenced by supermarket participation, represented by the *SM* dummy, and additional covariates (X_3 to X_5). However, as discussed above, *SM* is endogenous itself because farmers self-select into the supermarket channel. This is modeled in equation (7), where SM is explained by the number of supermarket farmers among the five nearest neighbors, which was used as a valid instrument above, and a vector of other control variables (X_6).

This system of simultaneous equations, where some of the dependent variables are binary, is estimated with a mixed-process maximum likelihood procedure (Roodman, 2011). We estimate a separate system for each nutrition indicator, namely calorie, vitamin A, iron, and zinc consumption. Except for the dependent variable in equation (3), these four systems are specified identically.

5.3 Estimation results

Full estimation results for the four systems of equations are shown in Table A2 to A6 in the Appendix. Results for the main variables of interest are summarized in Table 4. The hypothesized impact pathways are all confirmed. The upper part of Table 4 shows that household income has a positive and significant effect on calorie and micronutrient consumption. Likewise, the share of the farm area grown with vegetables influences nutrition positively. Especially the effect for vitamin A is relatively large: an increase in the area share by 10 percentage points increases vitamin A consumption by almost 400 µg RE per AE, implying a 30% increase over mean consumption levels. This sizeable effect should not surprise given that vegetables are a very important source of vitamin A in the local context. The main staple food in Kenya is white maize, which does not contain vitamin A. Other sources of vitamin A are livestock products, which are only consumed in small quantities, however, due to income constraints. The results in

Table 4 further show that male control of vegetable revenues has large negative effects on calorie and micronutrient consumption, which we attribute to gender differences in income use, as discussed above.

(Table 4 about here)

The lower part of Table 4 shows how supermarket participation affects these important determinants of household nutrition. Depending on the particular model, selling vegetables in supermarket channels increases annual household income by 300,000 Ksh, implying a gain of over 60%. This is consistent with earlier research on supermarket impacts in Kenya (Rao and Qaim, 2011). Moreover, as expected, supermarket participation contributes to a higher degree of on-farm specialization on vegetables. On average, and controlling for other factors, the share of the area grown with vegetables is around 20 percentage points higher for supermarket suppliers than for traditional channel farmers. Finally, supermarket participation has a significant effect on gender roles within the household. Selling to supermarkets increases the likelihood of male control of vegetable revenues by over 20 percentage points. This is in line with the existing literature on agricultural commercialization (Dewalt, 1993; von Braun and Kennedy, 1994; Fischer and Qaim, 2012).

6. Conclusion

Many developing countries are currently experiencing a profound food system transformation, which is associated with a rapid growth of supermarkets. The expansion of supermarkets can also have far-reaching implications for farmers. Recent research has shown that smallholder farmers can benefit in terms of higher productivity and income, provided that they can be linked to the emerging high-value supply chains. In this study, we have analyzed what participation in supermarket channels may mean for farm household nutrition. The analysis contributes to the existing literature in two ways. First, it adds to the knowledge on supermarket impacts; nutrition effects for farm households have not been studied previously. Second, it contributes conceptually to the discussion on agriculture-nutrition linkages by developing a method that is suitable to capture various nutrition dimensions and determinants.

Building on data from smallholder vegetable farmers in Kenya, we have shown that participation in supermarket channels has positive nutrition impacts. We have used detailed food recall data to derive several nutrition indicators, such as calorie, vitamin A, iron, and zinc consumption. While these are not precise measures of individual nutrition status, they provide a reasonable overview of food security and dietary quality at the household level. Controlling for other factors, participation in supermarket channels increases calorie, iron, and zinc consumption by 15-20%. Vitamin A consumption is almost doubled as a result of supermarket participation.

In a further step, we have analyzed impact pathways, using simultaneous equation models. We have shown that supermarket participation affects household nutrition mainly via three pathways, namely through (i) income, (ii) crop production choices at the farm level, and (iii) gender roles. The first pathway has a positive effect on nutrition. Farmers who participate in supermarket channels benefit from income gains, and higher incomes improve the economic access to food. The second pathway has a positive nutrition effect as well. Supermarket farmers sell vegetables under contract. As these supermarket contracts provide market assurance and price stability, farmers have an incentive to specialize on vegetable production. More vegetable production also entails higher quantities of vegetables consumed at the household level. Vegetables are an important source of vitamin A in particular, which also explains the large positive impact of supermarket participation on vitamin A consumption. In contrast, the third pathway has a negative effect on nutrition. Supermarket participation contributes to a shift from female to male control of vegetable revenues, and male household members tend to spend less on nutrition and dietary quality. Such a change in gender roles within the household is not uncommon in the process of agricultural commercialization. The total nutrition effects of supermarket participation are clearly positive, but they could be even more positive if a loss of female control of vegetable revenues could be prevented.

These results have two broader implications. First, the food system transformation and the growth of supermarkets in developing countries can contribute to economic development and improved nutrition in the small farm sector. This is an important finding, because smallholder farmers make up a large proportion of all undernourished people worldwide. Policy support may be required in some cases to link small farms to emerging supply chains and overcome constraints in terms of underdeveloped infrastructure and weak institutions. Second, the analysis of impact pathways underlines that a good understanding of the complex interactions between agriculture and nutrition is required to promote desirable outcomes. This calls for more micro level research along the lines proposed here. A clear message from our findings is that the role of women should be strengthened to further improve nutritional benefits. Gender mainstreaming of programs that try to link smallholders to supermarkets and other high-value supply chains would be an important step in this direction.

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Figure 1. Supermarket participation and farm household nutrition: impact pathways

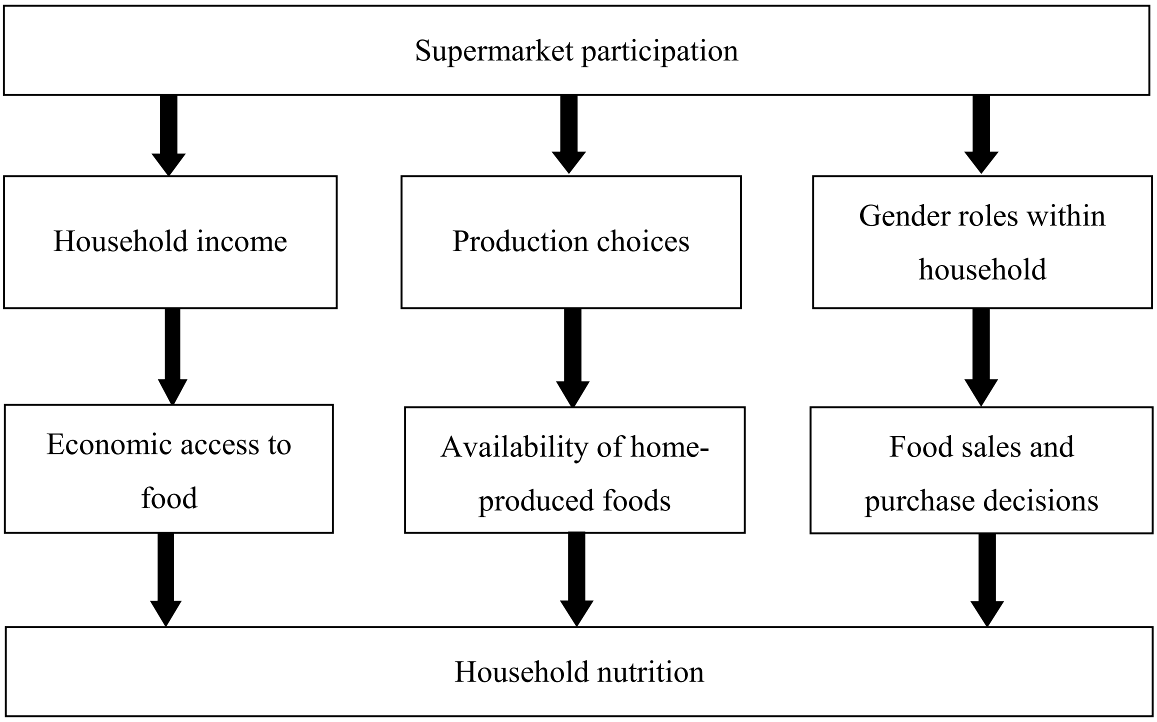

Table 1. Summary statistics of farm and household variables

Variables	Mean	Std. dev.
Farm land owned (acres)	2.06	(2.90)
Share of area grown with vegetable (%)	53.24	(28.98)
Participation in supermarket channels (dummy)	22.14	(41.57)
Annual household income (1000 Ksh)	471.69	(737.83)
Household assets (100,000 Ksh)	2.32	(5.72)
Off-farm income (dummy)	0.70	(0.46)
Annual off-farm income (1000 Ksh)	148.43	(301.69)
Distance to market (km)	3.05	(3.55)
Credit access (dummy)	0.17	(0.38)
SM farmers among 5 nearest neighbors (number)	0.97	(1.38)
Male household head(dummy)	0.89	(0.32)
Age of household head(years)	51.75	(13.54)
Education of household head (years)	9.59	(3.69)
Education of main female (years)	0.97	(3.01)
Male control over vegetable revenue (dummy)	0.73	(0.45)
Number of observations	384	

Notes: Ksh, Kenyan shillings; SM, supermarket. The official exchange rate in 2012 was 1 US dollar = 85 Ksh.

Table 2. Nutrition indicators by marketing channel

Nutrition indicators	Full sample		Supermarket channel		Traditional channel	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Calorie consumption (kcal/day/AE)	3258.03	(1081.9)	3348.27	(1206.2)	3232.37	(1044.7)
Prevalence of undernourishment (%)	20.83	(40.7)	18.82	(39.3)	21.41	(41.1)
Vitamin A consumption (µg RE/day/AE)	1374.68	(926.3)	1449.10	(825.5)	1353.53	(953.3)
Prevalence of vitamin A deficiency (%)	16.41	(37.1)	14.12	(35.0)	17.06	(37.7)
Iron consumption (mg/day/AE)	16.75	(7.2)	17.17	(7.4)	16.62	(7.1)
Prevalence of iron deficiency (%)	64.32	(48.0)	62.35	(48.7)	64.88	(47.8)
Zinc consumption (mg/day/AE)	21.05	(7.8)	21.67	(8.7)	20.88	(7.5)
Prevalence of zinc deficiency (%)	24.22	(42.9)	23.53	(42.7)	24.42	(43.0)
Number of observations	384		85		299	

Notes: AE, adult equivalent; RE, retinol equivalent.

Table 3. Impact of supermarket participation on calorie and micronutrient consumption

Variables	Calorie (kcal/day/AE)	Vitamin A (μg/day/AE)	Iron (mg/day/AE)	Zinc (mg/day/AE)
SM participation (dummy)	597.46**	1302.41***	3.01*	3.21*
	(244.81)	(325.79)	(1.72)	(1.71)
Male household head (dummy)	20.40	25.85	3.19*	-3.38
	(265.22)	(274.47)	(1.71)	(2.14)
Age of household head (years)	-104.29***	-88.23***	-0.40**	-0.45**
	(32.39)	(32.21)	(0.19)	(0.20)
Age squared	1.02***	0.84***	0.00**	0.00**
	(0.32)	(0.30)	(0.00)	(0.00)
Education of household head (years)	3.31	7.87	0.13	0.09
	(17.18)	(12.43)	(0.11)	(0.12)
Education of main female (years)	0.41	35.49	-0.01	-0.20
	(25.78)	(24.04)	(0.17)	(0.22)
Household size (AE)	-270.56***	-155.55***	-1.24***	-2.95***
	(39.11)	(42.57)	(0.16)	(0.38)
Farm land owned (acres)	-42.12*	-17.32	-0.11	-0.14
	(22.65)	(20.69)	(0.14)	(0.14)
Household assets (100,000 Ksh)	27.02**	4.39	0.08	0.18**
	(12.17)	(7.86)	(0.07)	(0.08)
Access to piped water (dummy)	21.47	57.11	-0.01	-0.05
	(37.49)	(50.50)	(0.23)	(0.23)
Distance to tarmac road (km)	29.18	-0.05	0.26**	0.34***
	(20.38)	(15.68)	(0.11)	(0.12)
Public transport in village (dummy)	-221.63*	-102.08	-0.40	-1.10
	(113.60)	(95.59)	(0.72)	(0.77)
Distance to market(km)	15.81	5.35	0.01	0.04
	(10.36)	(10.99)	(0.07)	(0.08)
Constant	6691.20***	3714.59***	29.49***	42.73***
	(753.61)	(862.82)	(4.80)	(5.01)
Wald chi-squared	219.33***	369.27***	237.23***	227.59 ***
F test of excluded instrument	86.95***	86.88***	85.63 ***	87.47***
Number of observations	384	384	384	384

Notes: Coefficients of treatment-effect models are shown with robust standard errors in parentheses. Results of the first-stage selection equation are shown in Table A1 in the Appendix. SM, supermarket; AE, adult equivalent. * denotes significance at 10% level; ** denotes significance at 5% level; *** denotes significance at 1% level.

Table 4. Impact pathways of supermarket participation

	Calorie (kcal/day/AE)	Vitamin A (μg/day/AE)	Iron (mg/day/AE)	Zinc (mg/day/AE)
Effect on nutrition				
Annual household income (1000 Ksh)	0.501**	0.939***	0.003**	0.004**
	(0.21)	(0.23)	(0.00)	(0.00)
Share of area grown with vegetables (%)	26.769***	39.559***	0.147***	0.168***
	(8.20)	(9.35)	(0.05)	(0.06)
Male control over vegetable revenue (dummy)	-1013.312***	-1346.740***	-8.522***	-7.344***
	(285.98)	(151.24)	(1.27)	(2.09)
Constant	3774.757***	86.549	15.308**	25.227***
	(1235.63)	(1352.08)	(7.40)	(8.59)
Effect on annual household income (1000 Ksh)				
SM participation (dummy)	361.894***	297.791**	342.556***	368.007***
	(129.95)	(123.62)	(127.76)	(131.64)
Constant	-48.625	-14.868	-19.836	-16.395
	(230.85)	(227.00)	(229.49)	(225.13)
Effect on share of area with vegetables (%)				
SM participation (dummy)	20.228**	23.138***	23.144***	17.647**
	(8.89)	(7.21)	(8.43)	(8.90)
Constant	104.841***	102.606***	101.230***	106.068***
	(19.55)	(19.28)	(19.72)	(19.55)
Effect on male control over revenue (dummy)				
SM participation (dummy)	0.224**	0.379***	0.213**	0.213**
	(0.10)	(0.07)	(0.09)	(0.10)
Constant	0.602	0.596	0.365	0.563
	(0.48)	(0.45)	(0.45)	(0.48)
Effect on SM participation (dummy)				
SM farmers among 5 nearest neighbors	0.083***	0.075***	0.080***	0.086***
	(0.01)	(0.01)	(0.01)	(0.01)
Constant	-2.708*	-1.915	-2.792**	-2.319
	(1.41)	(1.19)	(1.36)	(1.48)
LR chi-squared	507.93***	485.04***	520.12***	517.00***
Number of observations	384	384	384	384

Notes: Coefficients are shown with standard errors in parentheses. Only the variables of major interest are shown here. Full results of the simultaneous equation models with all control variables are shown in Tables A2 to A6 in the Appendix. SM, supermarket; AE, adult equivalent. * denotes significance at 10% level; ** denotes significance at 5% level; *** denotes significance at 1% level.

Appendix

Tables A1 to A6

Table A1. Factors influencing supermarket participation (first stage of treatment-effect models)

Variables	Calorie (kcal/day/AE)	Vitamin A (µg/day/AE)	Iron (mg/day/AE)	Zinc (mg/day/AE)
SM farmers among 5 nearest neighbors	0.50***	0.33***	0.49***	0.51***
	(0.06)	(0.09)	(0.06)	(0.06)
Male household head (dummy)	-0.75*	-0.90**	-0.70	-0.77*
	(0.45)	(0.36)	(0.45)	(0.45)
Age of household head (years)	0.03	-0.01	0.04	0.01
	(0.05)	(0.04)	(0.05)	(0.05)
Age squared	-0.00	0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Education of household head (years)	0.05*	0.03	0.05*	0.05*
	(0.03)	(0.02)	(0.03)	(0.03)
Education of main female (years)	-0.16***	-0.12**	-0.16***	-0.15***
	(0.06)	(0.06)	(0.06)	(0.05)
Household size (AE)	0.10	0.19***	0.04	0.19**
	(0.06)	(0.06)	(0.03)	(0.09)
Farm land owned (acres)	0.05	0.05**	0.05	0.04
	(0.03)	(0.03)	(0.03)	(0.03)
Household assets (100,000 Ksh)	0.02*	0.02*	0.02*	0.02*
	(0.01)	(0.01)	(0.01)	(0.01)
Access to piped water (dummy)	-0.01	-0.04	-0.01	-0.02
	(0.07)	(0.07)	(0.07)	(0.07)
Distance to tarmac road (km)	0.01	-0.01	0.01	0.00
	(0.03)	(0.02)	(0.03)	(0.03)
Public transport in village (dummy)	0.34*	0.21	0.35*	0.30
	(0.18)	(0.16)	(0.18)	(0.18)
Distance to market (km)	-0.01	-0.00	-0.01	-0.01
	(0.02)	(0.01)	(0.02)	(0.02)
Constant	-2.77**	-1.06	-2.84**	-2.28
	(1.39)	(1.13)	(1.37)	(1.39)
LR chi-squared	120.69***	121.37***	119.26***	122.62***
Number of observations	384	384	384	384

Notes: Coefficients are shown with robust standard errors in parentheses. SM, supermarket; AE, adult equivalent; VA, vitamin A. * denotes significance at 10% level; ** denotes significance at 5% level; *** denotes significance at 1% level.

Table A2. Impact pathways: factors influencing calorie and micronutrient consumption

	Calorie (kcal/day/AE)	Vitamin A (µg/day/AE	Iron (mg/day/AE)	Zinc (mg/day/AE)
Annual household income (1000 Ksh.)	0.501**	0.939***	0.003**	0.004**
	(0.21)	(0.23)	(0.00)	(0.00)
Share of area grown with vegetables (%)	26.769***	39.559***	0.147***	0.168***
	(8.20)	(9.35)	(0.05)	(0.06)
Male control over vegetable revenue (dummy)	-1013.312***	-1346.740***	-8.522***	-7.344***
	(285.98)	(151.24)	(1.27)	(2.09)
Household size (AE)	-303.882***	-201.013***	-1.314***	-3.338***
	(40.84)	(45.74)	(0.15)	(0.44)
Male household head (dummy)	468.183	267.478	8.109***	0.360
	(351.46)	(317.26)	(2.05)	(2.53)
Age of household head (years)	-50.627	-21.048	-0.135	-0.146
	(35.21)	(36.53)	(0.21)	(0.24)
Age squared	0.585*	0.323	0.001	0.002
	(0.32)	(0.33)	(0.00)	(0.00)
Education of household head (years)	11.445	22.031	0.084	0.119
	(23.90)	(25.77)	(0.15)	(0.16)
Education of main female (years)	-2.890	-9.527	0.055	-0.177
	(28.39)	(24.24)	(0.17)	(0.20)
Distance to market (km)	17.355	0.699	0.008	0.046
	(17.78)	(18.48)	(0.10)	(0.12)
Distance to tarmac road (km)	69.113**	70.190**	0.508***	0.612***
	(27.01)	(28.23)	(0.16)	(0.18)
Constant	3774.757***	86.549	15.308**	25.227***
	(1235.63)	(1352.08)	(7.40)	(8.59)
LR chi-squared	507.93***	485.04***	520.12***	517.00***
Number of observations	384	384	384	384

Notes: Coefficients are shown with standard errors in parentheses. SM, supermarket; AE, adult equivalent; VA, vitamin A.* denotes significance at 10% level;** denotes significance at 5% level; *** denotes significance at 1% level. The models for calories and for each micronutrient in Tables A2 to A6 were estimated jointly as simultaneous systems of equations.

Table A3. Impact pathways: factors influencing household income

	Calorie model Annual income (1000 Ksh)	VA model Annual income (1000 Ksh)	Iron model Annual income (1000 Ksh)	Zinc model Annual income (1000 Ksh)
SM participation (dummy)	361.894***	297.791**	342.556***	368.007***
	(129.95)	(123.62)	(127.76)	(131.64)
Wealth index	114.649***	127.732***	114.555***	109.133***
	(34.96)	(31.85)	(35.07)	(34.96)
Male household head (dummy)	91.027	92.247	121.036	59.864
	(104.35)	(104.68)	(103.02)	(105.38)
Age of household head (years)	-3.654	-3.702	-3.998	-4.404
	(2.78)	(2.78)	(2.79)	(2.79)
Education of household head (years)	2.106	0.893	2.889	2.034
	(10.93)	(10.85)	(10.98)	(10.88)
Household size (AE)	56.885***	66.141***	30.569**	97.698***
	(21.41)	(24.18)	(12.70)	(31.28)
Off-farm income (dummy)	197.106***	166.342**	193.911***	188.050***
	(69.71)	(67.61)	(69.10)	(69.22)
Farm land owned (acres)	75.003***	75.389***	76.012***	75.415***
	(12.83)	(12.22)	(12.78)	(12.75)
Credit access (dummy)	32.744	63.122	28.666	19.728
	(82.75)	(69.83)	(81.73)	(82.16)
Constant	-48.625	-14.868	-19.836	-16.395
	(230.85)	(227.00)	(229.49)	(225.13)
Number of observations	384	384	384	384

Notes: Coefficients are shown with standard errors in parentheses. SM, supermarket; AE, adult equivalent; VA, vitamin A.* denotes significance at 10% level;** denotes significance at 5% level; *** denotes significance at 1% level. The models for calories and for each micronutrient in Tables A2 to A6 were estimated jointly as simultaneous systems of equations.

Table A4: Impact pathways: factors influencing share of area grown with vegetables

	Calorie model Vegetable area (%)	VA model Vegetable area (%)	Iron model Vegetable area (%)	Zinc model Vegetable area (%)
SM participation (dummy)	20.228**	23.138***	23.144***	17.647**
	(8.89)	(7.21)	(8.43)	(8.90)
Irrigation (dummy)	11.243***	11.593***	12.265***	11.655***
	(4.30)	(3.80)	(4.55)	(4.52)
Farm land owned (acres)	-2.221***	-1.901***	-2.083***	-2.075***
	(0.54)	(0.52)	(0.56)	(0.55)
Off-farm income (dummy)	-6.283**	-8.920***	-6.756**	-7.717***
	(2.55)	(2.36)	(2.65)	(2.60)
Household assets (100,000 Ksh)	0.388*	0.221	0.275	0.363
	(0.23)	(0.18)	(0.24)	(0.24)
Distance to market (km)	-0.000	0.014	0.046	0.001
	(0.39)	(0.39)	(0.39)	(0.39)
Distance to tarmac road (km)	-1.351***	-1.411***	-1.413***	-1.379***
	(0.51)	(0.51)	(0.51)	(0.51)
Access to piped water (dummy)	-1.268	-0.319	-1.440	-1.447
	(1.19)	(1.08)	(1.29)	(1.24)
Male household head (dummy)	5.354	4.397	4.829	5.713
	(4.41)	(4.37)	(4.42)	(4.39)
Age of household head (years)	-1.147	-1.260*	-1.139	-1.170
	(0.72)	(0.71)	(0.72)	(0.72)
Age squared	0.006	0.007	0.006	0.006
	(0.01)	(0.01)	(0.01)	(0.01)
Education of household head (years)	-2.649**	-1.012	-1.910	-2.670**
	(1.12)	(0.97)	(1.17)	(1.16)
Education squared	0.079	-0.019	0.034	0.083
	(0.06)	(0.05)	(0.07)	(0.07)
Constant	104.841***	102.606***	101.230***	106.068***
	(19.55)	(19.28)	(19.72)	(19.55)
Number of observations	384	384	384	384

Notes: Coefficients are shown with standard errors in parentheses. SM, supermarket; AE, adult equivalent; VA, vitamin A.* denotes significance at 10% level; ** denotes significance at 5% level; *** denotes significance at 1% level. The models for calories and for each micronutrient in Tables A2 to A6 were estimated jointly as simultaneous systems of equations.

Table A5: Impact pathways: factors influencing male control over vegetable revenue

	Calorie model Male control (dummy)	VA model Male control (dummy)	Iron model Male control (dummy)	Zinc model Male control (dummy)
SM participation (dummy)	0.224**	0.379***	0.213**	0.213**
	(0.10)	(0.07)	(0.09)	(0.10)
Member in women's group (dummy)[a]	-0.124***	-0.068**	-0.098***	-0.118***
	(0.04)	(0.03)	(0.03)	(0.04)
Male household head (dummy)	0.351***	0.399***	0.359***	0.368***
	(0.10)	(0.10)	(0.09)	(0.09)
Age of household head (years)	-0.005***	-0.006***	-0.004***	-0.005***
	(0.00)	(0.00)	(0.00)	(0.00)
Education of household head (years)	-0.015**	-0.015***	-0.013**	-0.014**
	(0.01)	(0.01)	(0.01)	(0.01)
Household head married (dummy)	0.136	0.073	0.140*	0.127
	(0.09)	(0.08)	(0.08)	(0.08)
Constant	0.602	0.596	0.365	0.563
	(0.48)	(0.45)	(0.45)	(0.48)
Number of observations	384	384	384	384

Notes: Coefficients are shown with standard errors in parentheses. SM, supermarket; AE, adult equivalent; VA, vitamin A. * denotes significance at 10% level; ** denotes significance at 5% level; *** denotes significance at 1% level. The models for calories and for each micronutrient in Tables A2 to A6 were estimated jointly as simultaneous systems of equations.

[a] This refers to the main female in the household. Women's groups are involved in various activities, including savings and small-scale credit. Such activities may strengthen the role of women within the household.

Table A6: Impact pathways: factors influencing supermarket participation

	Calorie model SM participation (dummy)	VA model SM participation (dummy)	Iron model SM participation (dummy)	Zinc model SM participation (dummy)
SM farmers among 5 nearest neighbors	0.083***	0.075***	0.080***	0.086***
	(0.01)	(0.01)	(0.01)	(0.01)
Farm land owned (acres)	0.013	0.011*	0.015*	0.011
	(0.01)	(0.01)	(0.01)	(0.01)
Own vehicle (dummy)	0.047	0.005	0.057	0.040
	(0.04)	(0.04)	(0.04)	(0.04)
Access to piped water (dummy)	0.005	0.010	0.004	0.003
	(0.02)	(0.02)	(0.02)	(0.02)
Assets before SM (100,000 Ksh)	0.004	-0.000	0.003	0.003
	(0.00)	(0.00)	(0.00)	(0.00)
Distance to tarmac road (km)	0.004	0.007	0.006	0.002
	(0.01)	(0.01)	(0.01)	(0.01)
Male household head (dummy)	-0.148	-0.084	-0.155	-0.163
	(0.12)	(0.10)	(0.12)	(0.12)
Age of household head (years)	0.007	-0.003	0.008	0.002
	(0.01)	(0.01)	(0.01)	(0.01)
Age squared	-0.000	0.000	-0.000	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Education of household head (years)	0.011*	0.012**	0.011*	0.011*
	(0.01)	(0.01)	(0.01)	(0.01)
Education of main female (years)	-0.029**	-0.020*	-0.031**	-0.029**
	(0.01)	(0.01)	(0.01)	(0.01)
Household size (AE)	0.013	0.019	0.005	0.031
	(0.01)	(0.01)	(0.01)	(0.02)
Regional dummies	Yes	Yes	Yes	Yes
Constant	-2.708*	-1.915	-2.792**	-2.319
	(1.41)	(1.19)	(1.36)	(1.48)
Number of observations	384	384	384	384

Notes: Coefficients are shown with standard errors in parentheses. SM, supermarket; AE, adult equivalent; VA, vitamin A. * denotes significance at 10% level; ** denotes significance at 5% level; *** denotes significance at 1% level. The models for calories and for each micronutrient in Tables A2 to A6 were estimated jointly as simultaneous systems of equations.