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Agricultural Commercialisation and Nutrition in Smallholder Farm Households

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Abstract

Commercialisation of smallholder agriculture is important for rural economic growth. While previous studies have analysed effects of commercialisation on productivity and income, implications for farm household nutrition have received much less attention. We evaluate the effects of commercialisation on household food security and dietary quality with a special focus on calorie and micronutrient consumption. We also examine transmission channels by looking at the role of income, gender, and possible substitution effects between the consumption of own-produced and purchased foods. The analysis uses survey data from farm households in Kenya and a control function approach. Generalised propensity scores are employed to estimate continuous treatment effects. Commercialisation significantly improves food security and dietary quality in terms of calorie, zinc and iron consumption. For vitamin A, effects are insignificant. Commercialisation contributes to higher incomes and increased nutrients from purchased foods, but it does not reduce the consumption of nutrients from own-produced foods. Enhancing market access is important not only for rural economic growth, but also for making smallholder agriculture more nutrition-sensitive.

Keywords: *Agricultural commercialisation*; *nutrition*; *dietary quality*; *gender roles*; *Africa*.

JEL classifications: *I15, Q12, Q13, Q18*.

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1. Introduction

In spite of global efforts to eradicate hunger, more than 800 million people remain chronically undernourished worldwide, and at least 2 billion people suffer from micronutrient deficiencies (IFPRI, 2018; FAO, 2019). A large proportion of these people are smallholder farmers in developing countries who depend on agriculture as a source of food and income. A key question is therefore how to make smallholder agriculture more nutrition-sensitive (Fan and Pandya-Lorch, 2012; Pingali and Sunder, 2017; Ruel *et al*., 2018).

Much of the recent literature on nutrition-sensitive agriculture focuses on the link between on-farm production diversity and farm household diets (Ruel *et al*., 2018; Sibhatu and Qaim, 2018; Ickowitz *et al*., 2019). A few studies have also pointed at the importance of markets for improving diets, yet capturing farmers' access to markets only in terms of simple proxies such as market distance (Fan and Pandya-Lorch, 2012; Hirvonen and Hoddinott, 2017; Koppmair *et al*., 2017; Ickowitz *et al*., 2019). Moreover, the dietary indicators that are typically used have limitations. Most studies use household dietary diversity scores, which are suitable for measuring household food security, but not dietary quality (Verger *et al*., 2019).

Another strand of the literature has analysed the effects of agricultural commercialisation on household welfare. But most studies look at welfare only in terms of income, asset ownership, or poverty (Tipraqsa and Schreinemachers, 2009; Muriithi and Matz, 2015; Ogutu and Qaim, 2019), not nutrition. Commercialisation may influence nutrition through various channels, including changes in income, availability of own-produced foods, and gender roles within the household (von Braun and Kennedy, 1994). Income gains can increase economic access to food, but a substitution of purchased food for own-produced food may also change dietary quality, possibly increasing the consumption of calories but not necessarily micronutrients (Remans *et al*., 2015). Changes in gender roles may occur because men often take stronger control of farm production and income during the process of commercialisation (von Braun and Kennedy, 1994). And male-controlled income is often less spent on dietary quality than female-controlled income (Hoddinott and Haddad, 1995; Fischer and Qaim, 2012).

A few recent studies have analysed the impact of contract farming on household food security (Chege *et al*., 2015; Chiputwa and Qaim, 2016; Bellemare and Novak, 2017). But these studies compared farm households that sell in different marketing channels with no differentiation between more and less commercialised households. Very few studies have explicitly analysed the effects of commercialisation on nutrition, and those that did looked at nutrition primarily in terms of calorie consumption and child anthropometrics (von Braun and Kennedy, 1994; Carletto *et al*., 2017), rather than dietary quality. We are not aware of any previous study that has examined the effects of agricultural commercialisation on micronutrient consumption, although micronutrient malnutrition is now a bigger health concern than calorie undernourishment in many developing countries (IFPRI, 2018).

We add to the existing literature in three ways. First, we analyse the effects of commercialisation on dietary quality, measured in terms of calorie and micronutrient consumption. We focus on iron, zinc and vitamin A. Deficiencies in these three micronutrients are responsible for major health problems in the developing world. Second, we differentiate between calories and micronutrients consumed from own-produced and purchased foods, to better understand transmission channels of dietary change and possible substitution of food sources during the process of commercialisation. In terms of transmission channels, we also look at changing income and gender roles. Third, in addition to estimating average effects of commercialisation, we model continuous treatment effects, which can help identify possible non-linearities with increasing levels of commercialisation.

Our analysis uses data from a survey of smallholder farm households in Western Kenya. In Kenya, smallholder farming accounts for 75% of total agricultural output (Olwande *et al.*, 2015). As in most other countries of sub-Saharan Africa, issues of poverty and malnutrition are widespread in the Kenyan small farm sector (KNBS, 2015).

2. Conceptual Framework

Figure 1 shows a simple conceptual framework that guides our empirical analysis. Commercialisation can affect farm household nutrition through various channels. Market sales can reduce the availability of own-produced foods and thus limit consumption through the subsistence pathway. Yet a fall in total food consumption may be prevented through food purchases from the market that are possible through higher cash earnings. Research shows that commercialisation is typically associated with income gains through agricultural intensification and use of better technology (von Braun and Kennedy, 1994; Muriithi and Matz, 2015).

Commercialisation may also influence the types of crops grown or the livestock species kept on the farm. Closer market integration allows farmers to better harness comparative advantages, so higher levels of specialisation are generally expected. A focus

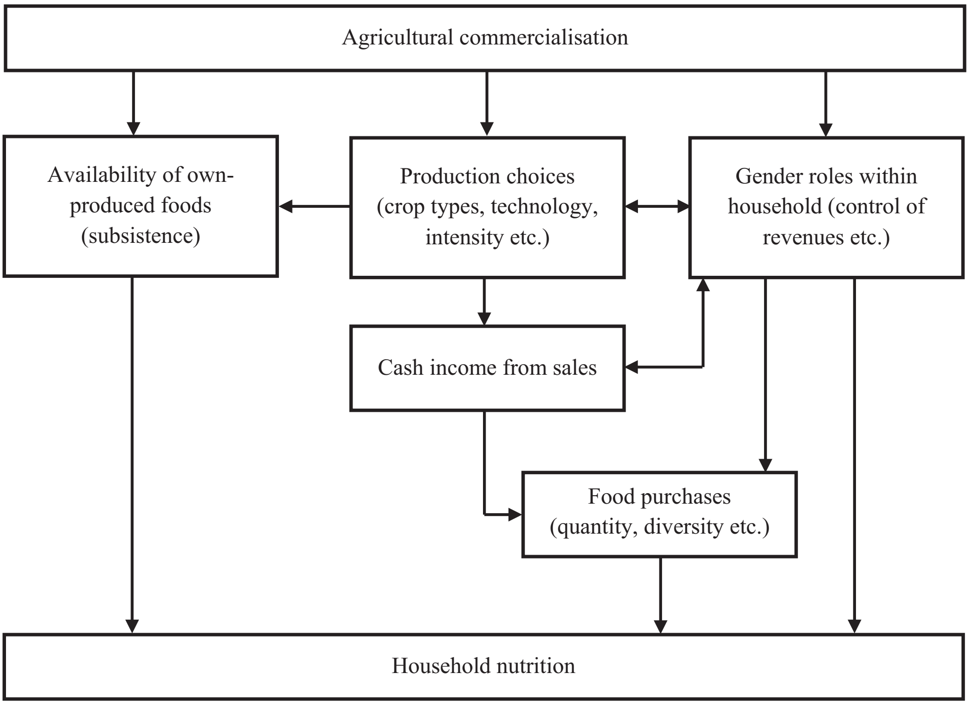

Figure 1. Agricultural commercialisation and household nutrition
Source: Adapted from von Braun and Kennedy (1994) and Chege *et al.* (2015).

on the production of non-food cash crops could further reduce the availability of own-produced foods. Yet, in specific situations, it is also possible that farmers further diversify production, especially when markets emerge for certain niche products that are not traditionally grown for own consumption (Tipraqsa and Schreinemachers, 2009).

Levels of commercialisation, types of crops grown, and technologies used can also have important effects on gender roles within the household (Haddad *et al.*, 1997). Subsistence crops are often produced and controlled by women, whereas crops that are primarily produced to generate cash are typically controlled by men (von Braun and Kennedy, 1994; Fischer and Qaim, 2012). Research shows that female-controlled income is particularly beneficial for household nutrition, as women tend to spend more on food and dietary quality than men (Hoddinott and Haddad, 1995). Hence, commercialisation may possibly have a negative partial effect on household nutrition through this gender pathway.

To better understand the role of the different transmission channels and the overall effect of commercialisation on nutrition, crucial questions are to what extent own-produced food is replaced by purchased food, and whether this replacement makes diets more or less nutritious. It is often assumed that the subsistence pathway is particularly important for dietary quality, because purchased food may be more processed and less nutritious (Remans *et al.*, 2015). We analyse these questions in the empirical analysis below.

3. Estimation Strategy

3.1. Basic model

We begin by estimating the overall effect of commercialisation on nutrition with regression models of the following type:

$$N_i = \alpha_0 + \alpha_1 C_i + \alpha_2 \boldsymbol{X}_{i1} + \varepsilon_{i1}, \quad (1)$$

where N_i is the nutrition outcome variable for household i. We use different nutrition variables, namely calorie and micronutrient (vitamin A, zinc and iron) consumption levels, in separate regression models. Details of the nutrition variables are described further below. C_i is the level of commercialisation, $\boldsymbol{X}_i$ is a vector of control variables, and $\varepsilon_{i1}$is a random error term. The level of commercialisation (C_i) is defined as the proportion of farm output sold. Control variables ($\boldsymbol{X}_i$) include age, gender and education of the household head, as well as other farm, household and contextual characteristics that may affect diets and nutrition.

We are particularly interested in the treatment effect α_1. A positive α_1 would mean that commercialisation contributes to improved nutrition. It is possible that the sign of α_1 differs between the nutrition variables. For instance, if it is true that households substitute energy-dense purchased foods for more nutritious own-produced foods we would expect a positive coefficient α_1 in the calorie model and negative coefficients in the micronutrient models.

3.2. Addressing issues of endogeneity

If X_i in equation (1) includes all the factors that influence commercialisation, and there is no correlation between C_i and ε_{i1}, ordinary least squares (OLS) would produce unbiased estimates of α_1. However, it is possible that there are unobserved factors that jointly influence C_i and N_i, which would lead to endogeneity bias. For instance, unobserved heterogeneity could occur through differences in farmers' ability or entrepreneurial skills, which are difficult to measure in household surveys. Furthermore, there could be issues of reverse causality, where better nutrition would make farmers more productive, thus possibly contributing to higher levels of commercialisation. Finally, measurement error could be a cause of endogeneity, even though we put substantial effort into the collection of high-quality data.

We account for potential sources of endogeneity using a control function (CF) approach (Wooldridge, 2015). The CF approach entails predicting residuals from a first-stage model of the determinants of commercialisation, and including the predicted residual term as an additional regressor (a control function) in the nutrition outcome model in equation (1). This requires at least one valid instrument in the first-stage regression. A valid instrument must be strongly correlated with commercialisation (instrument relevance), but uncorrelated with omitted variables that may affect nutrition (instrument exogeneity), except indirectly through commercialisation (Imbens and Wooldridge, 2009). We identified two instruments for commercialisation that fulfil all requirements of validity. The first instrument is the average number of motorcycles owned by households living in the same ward, and the second instrument is the average number of main market sellers in the ward.[2]

The first instrument – average number of motorcycles in the ward – was constructed by counting the number of motorcycles owned by sample households in each ward (excluding the farmer of interest) and then dividing by the number of households. Fewer than 10% of the sample farmers own a motorcycle (or other motorised means of transportation). But the distance to the market is often too far to make significant sales without a motor vehicle. As most of the local roads are not paved and public transport hardly exists, owners of motorcycles usually offer transport services to other households living in the same area. Farmers often use these services, as do local traders who buy at the farm gate and sell in the marketplace. Hence, more motorcycles in the ward means better market access.

Indeed, the number of motorcycles in the ward is significantly correlated with the degree of commercialisation (Table A1 in the online Appendix), which is the condition for instrument relevance. As we use the average number of motorcycles in the ward, rather than individual ownership, this instrument is neither directly correlated with any of the household nutrition variables, nor is it significant when included as an additional regressor in equation (1). Results of these tests are shown in Table A2 in the online Appendix. Nevertheless, one could imagine that the number of motorcycles could also be a proxy for higher levels of wealth and income in the ward. Moreover, motorcycles could also be used to transport inputs or extension officers who deliver agricultural, health and nutrition training to local farm households, which might influence nutrition indirectly through various hidden channels. To test for these possibilities, we correlated the instrument with several indicators of living standard and wealth at the ward level, such as average education, household income, farm size and

[2]A ward is an administrative unit in Kenya that is larger than a village, but smaller than a sub-county. Ward-level or other regional characteristics were previously used as instruments for endogenous household variables (e.g. Porter, 2016; Arslan *et al.*, 2017; Hirvonen and Hoddinott, 2017; Ma *et al.*, 2018). The advantage of regional instruments is that they are usually not influenced by individual households, so they are less likely to be endogenous than household-level instruments. Regional instruments may not fully account for household-level heterogeneity.

productive assets (Table A3 in the online Appendix). We also correlated the instrument with household-level nutritional knowledge scores and the use of various purchased farm inputs, such as seeds, fertilisers and pesticides (Table A4 in the online Appendix). All these correlation coefficients are statistically insignificant, so the conditions for instrument exogeneity seem to be fulfilled.

The second instrument – number of main market sellers in the ward – was constructed by counting the number of sample households in each ward that sell at least some of their produce in the main agricultural market (excluding the farmer of interest). This number was divided by the number of households surveyed in the ward. The main agricultural market in each ward is larger than the village markets and is typically the most important point of sale for larger quantities of farm output. In our sample, 32% of the households sell at least part of their produce in the main market, and these households tend to be more commercially-oriented (Table A5 in the online Appendix). Other households sell smaller quantities of farm output in the village markets or to traders at the farm gate.

Using the number of main market sellers in the ward as an instrument for own commercialisation is motivated by the recent literature on the role of neighbourhood effects and social networks for farmers' technology adoption and marketing decisions (Krishnan and Patnam, 2013; Andersson *et al*., 2015; Magnan *et al*., 2015). Social networks in the neighbourhood not only improve the flow of information but can also facilitate the coordination of joint transport and marketing activities (Andersson *et al*., 2015). Indeed, the number of main market sellers in the ward is highly correlated with the evel of commercialisation (Table A1 online). At the same time, the instrument is uncorrelated with all of the nutrition outcomes (Table A2 online).

One could argue that farm households selling in the main markets may cluster in certain locations that are richer and more developed than others. However, farm households in rural Kenya do not actively decide their location, as they live on their land, which is usually inherited from one generation to the next. We tested whether the instrument is correlated with mean wealth characteristics at the ward level, but neither of the correlation coefficients was significant (Table A3 online). Nor did we find significant correlation between the number of main market sellers and individual input use or nutrition knowledge (Table A4 online), making it unlikely that the instrument would affect nutrition through channels other than commercialisation.

Using both instruments, we formally tested for over-identification. Based on the test results (Table A1 online), we could not reject the null hypothesis of instrument exogeneity. We acknowledge that completely eliminating all possible sources of endogeneity is challenging with cross-section data, but based on the various tests our instruments seem to be valid, so that cautious causal inference should be in order.

Using the CF approach, a statistically significant coefficient of the predicted residual term in equation (1) would imply that commercialisation is endogenous and would also correct for the resulting bias. An insignificant residual term would fail to reject the null hypothesis of exogeneity; in that case, OLS would be preferred. Since C_i is a censored variable, we estimate the first-stage regression using a generalised linear model (GLM) with a binomial family and a logit link. This is important to obtain consistent residual predictions for use in the second-stage regression (Papke and Wooldridge, 1996).

3.3. Analysing transmission channels

An important question to better understand the transmission channels between commercialisation and nutrition is to what extent purchased foods are substituted for own-produced foods and how this affects dietary quality. To analyse this, we re-estimate the models in equation (1), but differentiating between calories and micronutrients from purchased and own-produced foods. If households primarily purchase energy-dense foods in the market, we would expect a positive effect of commercialisation on calorie consumption, but not micronutrient consumption from purchased foods. The effects of commercialisation on calorie and micronutrient consumption from own-produced foods will depend on possible changes in farm productivity and production diversity.

Beyond analysing possible substitution effects in household food sources, we also examine the possible role of income and gender. Based on the conceptual framework above, we model income and gender pathways using the following equations:

$$N_i = \beta_0 + \beta_1 Y_i + \beta_2 G_i + \beta_3 \boldsymbol{X}_i + \varepsilon_{i2}, \tag{2}$$

$$Y_i = \delta_0 + \delta_1 C_i + \delta_2 \boldsymbol{X}_i + \varepsilon_{i3}, \tag{3}$$

$$G_i = \gamma_0 + \gamma_1 C_i + \gamma_2 \boldsymbol{X}_i + \varepsilon_{i4}. \tag{4}$$

Equation (2) models nutrition (N_i) as a function of household income (Y_i) and gender roles within the household (G_i), measured in terms of a dummy that takes a value of one if a male household member controls the farm revenues, and zero otherwise. Given the discussion above, we would expect a positive coefficient estimate for β_1 and a negative estimate for β_2. In equations (3) and (4), income and gender roles are treated as endogenous and modelled as functions of commercialisation (C_i). We would expect positive coefficient estimates for δ_1 and γ_1, meaning that commercialisation increases household income and the likelihood of male control of farm revenues (von Braun and Kennedy, 1994; Hoddinott and Haddad, 1995). In all three equations we control for other socioeconomic variables ($\boldsymbol{X}_i$).[3]

To interpret the coefficients of the outlined income and gender pathways in a causal sense would require estimation of equations (2) to (4) as a simultaneous equations system with additional instruments for Y_i and G_i. This is not possible in our case, because the gendered control of farm revenues differs between crops, meaning that G_i is a crop-specific variable, whereas Y_i and N_i are measured at the household level. We therefore estimate the different equations separately, using different units of observation, as further explained below. Consequently, we will interpret these estimation results on income and gender pathways only in terms of associations without drawing immediate causal inference.

3.4. Continuous treatment effects

We use equation (1) to estimate average treatment effects of commercialisation on nutrition. But commercialisation is a continuous variable, and it is possible that the

[3]Note that G in equation (4) may also depend on Y. However, as Y is determined by X, including both Y and X as explanatory variables might lead to issues of collinearity.

effects vary depending on the level of commercialisation. To account for possible non-linearity, we use the generalised propensity score (GPS) approach to estimate continuous treatment effects (Hirano and Imbens, 2004; Läpple and Thorne, 2019). The GPS method controls for observed heterogeneity between households with different treatment exposure, but not for possible unobserved heterogeneity.

The GPS approach involves three stages. First, the generalised propensity scores are generated based on observed covariates. Second, the conditional expected values of the outcome variables (nutrition indicators) are estimated as a function of treatment exposure (level of commercialisation) and the GPS. Third, the average dose-response function is estimated. The dose-response function depicts for every treatment exposure level the direction and magnitude of the relationship between commercialisation and nutrition, after controlling for observed covariate bias (Hirano and Imbens, 2004). We estimate the dose-response function by averaging the expected nutrition outcome at each level of commercialisation (C) as follows:

$$E\left[\hat{N}_i(C)\right] = \frac{1}{n}\sum_{i=1}^{n}\left[\hat{\alpha}_0 + \hat{\alpha}_1 C + \hat{\alpha}_2 C^2 + \hat{\alpha}_3 \hat{r}(C, \boldsymbol{X}_i) + \hat{\alpha}_4 \hat{r}(C, \boldsymbol{X}_i)^2 + \hat{\alpha}_5 C \hat{r}(C, \boldsymbol{X}_i)\right], \quad (5)$$

where n is the number of observations, $\hat{\alpha}$ are parameters estimated at the second stage, and $\hat{r}(C, \boldsymbol{X}_i)$ is the predicted value of the conditional density of treatment at varying levels of commercialisation. Results of the dose-response functions are presented graphically.

4. Data and Variable Measurement

4.1. Farm household survey

This study uses data collected through a survey of smallholder farm households in Kisii and Nyamira counties in Western Kenya between October and December 2015. Like many other parts of sub-Saharan Africa, agriculture in the study region is largely semi-subsistent. Higher levels of commercialisation are curbed primarily by high transport and transaction costs related to poor infrastructure and other market failures. Malnutrition is widespread (KNBS, 2015).

A recent census of farm households in Kisii and Nyamira was not available. However, many farmers are organised in farmer groups, for which official registries exist. From a list of active farmer groups in the two counties, we randomly selected 48 for inclusion in the survey. These groups varied in size, most of them had around 20–30 members. Prior to the survey, we updated group membership lists together with the group leaders. Depending on group size, we randomly selected 15–20 member households from each group, resulting in a total sample of 824 households, distributed over 8 different sub-counties and 26 wards.

Face-to-face interviews were carried out in the local language with the household head. A carefully designed and pre-tested questionnaire was used, capturing details of household demographics, agricultural production and marketing, other economic activities, food and non-food consumption, and contextual characteristics. All details of agricultural production and marketing were captured for a period of 12 months. For food consumption, we used shorter recall periods, as explained in more detail below. The analysis is carried out with 805 households for which complete data for all relevant variables are available.

4.2. Measuring nutrition

There are various ways to measure nutrition at individual and household levels, including clinical measures, anthropometric measures, and food consumption-based measures (de Haen *et al.*, 2011; IFPRI, 2018). Clinical and anthropometric measures are the most precise indicators of individual nutrition status, but they are less suitable for assessing details of food sources and dietary quality, which is the focus of our study. We use food consumption data from our survey, from which we calculate various measures of food security and dietary quality.

The survey questionnaire included a food consumption recall, capturing the quantity of more than 130 different food items consumed by all household members over a period of 7 days. Survey respondents were also asked to specify the source of each food item consumed, including market purchases, own production, gifts, and other sources. To increase data accuracy, this part of the questionnaire was carried out with the person responsible for food preparation in the household. Based on the food quantities consumed, we calculated edible portions, which were converted to calorie and micronutrient levels using food composition tables for Kenya (Sehmi, 1993).

We divided calorie and micronutrient consumption at household level by adult male equivalents (AE) to make the values comparable (Chege *et al.*, 2015; Chiputwa and Qaim, 2016; Coates *et al.*, 2017). These consumption values per AE are the nutrition variables (N_i) used as outcomes in the regression models. For the descriptive analysis, we calculated some additional indicators to further illustrate the local nutrition situation. We use minimum consumption thresholds to characterise undersupplied households (Chege *et al.*, 2015). A household is considered undernourished when it consumes <2,400 kcal per AE and day. A household is deficient in vitamin A when it consumes <625 μg of retinol equivalents (RE) per AE and day. For zinc and iron, the thresholds are 15.0 mg and 18.3 mg, respectively.

Using household-level food consumption data to assess diets and nutrition has become common in the food economics literature (de Haen *et al.*, 2011; Zezza *et al.*, 2017), even though this approach also has drawbacks. First, it measures food availability, not actual intake. Second, possible issues of intra-household distribution are not accounted for. For a subsample, we also collected individual-level nutrition data for adults and children. Table A6 in the online Appendix shows positive and significant correlations between the household-level and individual-level measures, which is in line with recent research in other geographical contexts (Coates *et al.*, 2017; Koppmair *et al.*, 2017; Sununtnasuk and Fiedler, 2017). However, the correlations are relatively small, meaning that the household consumption variables are only crude proxies of individual intakes.

Diets and nutrition often vary seasonally following the agricultural production cycle (Sibhatu and Qaim, 2017). Such seasonal variation is not captured in our cross-section data. However, in the study area seasonal variation is relatively small. In Kisii and Nyamira, farmers typically have two production seasons per year. But due to abundant rainfall, some cropping also occurs outside these regular seasons, so really lean months are hardly discernible. Our survey was conducted between October and December 2015, with some of the households interviewed earlier and others later during this period. Since harvesting of the regular long-rain season crop is typically completed in the month of September, calorie and nutrient consumption could possibly be higher in October and November, the two months immediately following the harvest, than in December. We did not find significant correlations between a 'December survey' dummy and the nutrition indicators (Table A7 in the online Appendix). Nevertheless, to avoid possible bias due to seasonality, we use the 'December survey' dummy as an additional control variable in the regression models.

4.3. *Measuring commercialisation*

While 97% of the households in our sample sell some of their farm produce, more than half of the farm output is kept for home consumption, indicating that commercialisation is limited. Thirty-two per cent of the households sell in the agricultural main market, around 50% sell in local village markets, and 73% sell at least some of their harvest at the farm gate (Figure A1 in the online Appendix). The share of output sold varies by type of crop grown (Table A8 in the online Appendix). While the majority of the households (70%) cultivate at least one type of cash crop, cash crop production accounts for only 11% of the total value of production and for 23% of total sales. That is, the sales of food crops and livestock products generate larger total cash revenues than the sales of cash crops.

To properly capture the level of commercialisation across all farm enterprises (food crops, cash crops and livestock), we constructed a commercialisation index defined as the share of the total value of farm output sold during the 12-months period covered by the survey. This index has also been used elsewhere (von Braun and Kennedy, 1994; Tipraqsa and Schreinemachers, 2009; Carletto *et al.*, 2017). The commercialisation index is a continuous variable ranging between zero and one. For its construction, price data were required to value the quantities of farm output. Prices may vary, even for identical commodities, and may not be observed for all households. We used average sales prices reported by sample households to value farm output.

We correlated the commercialisation index with several alternative measures of commercialisation, such as the absolute value of product sales, the share of land under cash crops, the value of farm inputs used, and indices that separately measure the share of crop and livestock sales. All these measures are positively correlated with our commercialisation index at high levels of statistical significance (Table A9 in the online Appendix).

5. Descriptive Statistics

5.1. *Socioeconomic characteristics*

Table A10 in the online Appendix presents summary statistics for the full sample, also differentiated by level of commercialisation. For these descriptive statistics, we subdivide the sample into commercialisation quartiles and compare the 25% most commercialised households (MC25%) with the 25% least commercialised households (LC25%). The average household sells 44% of its total farm output. This share ranges between 70% for the most commercialised and 16% for the least commercialised households. The level of commercialisation is positively associated with farm size, education, household income, and several other socioeconomic variables.

Sample farms are highly diversified, producing sbout 13 different crop and livestock species on average. They produce a number of different food crops, such as maize, beans, sweet potatoes, bananas, and different types of leafy vegetables. Many also keep chicken, sheep, goats, and sometimes cattle. In terms of cash crops, tea, coffee and sugarcane are grown by many farmers.

5.2. Nutrition outcomes

Table 1 shows summary statistics for the nutrition variables. About 27% of the households are undernourished (calorie-deficient). Even higher proportions are deficient in zinc, iron and vitamin A. More commercialised households consume significantly higher amounts of calories and micronutrients. Thus, they are also less affected by nutritional deficiencies than less commercialised households. For vitamin A deficiency, the difference is not statistically significant.

Figure A2 in the online Appendix shows a breakdown of the sources of calorie and micronutrient consumption. For calories, zinc and iron, market purchases are as important as, or even more important than, own production, even for the least commercialised households. Interestingly, for more commercialised households the role of own production for diets does not decrease. This is a first indication that the cash income generated through output sales may be used to buy additional food, rather than replacing own-produced food. Higher productivity on more commercialised farms allows larger market sales without reducing home consumption. For vitamin A, the situation is different. Own production plays the dominant role for vitamin A, especially in the least commercialised households. Tables A11–A13 in the online Appendix show further details of which food groups are particularly important for micronutrient consumption from market and own-produced sources. All micronutrients are obtained from various food sources, yet with notable differences. For iron

Table 1

Summary statistics of nutrition indicators by level of commercialisation

Variables	Total mean	MC25% mean	LC25% mean	Mean difference
Total calorie consumption (kcal/day/AE)	3,286.1 (1,273.7)	3,584.4 (1,294.9)	2,973.1 (1,065.5)	611.4***
Prevalence of undernourishment (%)	26.6 (44.2)	17.9 (38.4)	33.7 (47.4)	–15.8***
Total vitamin A consumption (μg RE/day/AE)	1,242.6 (1,393.2)	1,406.1 (1,542.6)	1,140.1 (1,231.1)	266.0*
Prevalence of vitamin A deficiency (%)	36.7 (48.2)	33.3 (47.3)	37.6 (48.6)	–4.3
Total zinc consumption (mg/day/AE)	19.7 (8.7)	21.1 (8.7)	18.3 (7.7)	2.8***
Prevalence of zinc deficiency (%)	32.4 (46.8)	24.4 (43.0)	40.1 (49.1)	–15.7***
Total iron consumption (mg/day/AE)	22.1 (13.3)	25.0 (15.2)	18.6 (9.8)	6.4***
Prevalence of iron deficiency (%)	47.2 (50.0)	40.3 (49.2)	56.9 (49.6)	–16.6***
Observations	805	201	202	403

Note: Standard deviations are shown in parentheses. MC25%, 25% most commercialised households; LC25%, 25% least commercialised households; AE, male adult equivalent; RE, retinol equivalent. *, **, and *** significant at 10%, 5%, and 1% level, respectively.

and zinc, staple foods such as maize are the most important source, whereas for vitamin A, the most important sources are vegetables and fruits.

6. Regression Results

6.1. Endogeneity tests

In all models, except for own-produced vitamin A, the CF residual-terms are statistically insignificant (Table A14 in the online Appendix). Hence, we cannot reject the null hypothesis that commercialisation is exogenous and proceed with OLS. However, for comparison we also show results of the CF models in the online Appendix (Tables A1, A15 and A16). OLS and CF model results are similar and support the same conclusions.

6.2. Basic model results

The estimation results of the basic model with total calorie and micronutrient consumption levels as dependent variables are shown in the upper part of Table 2. Commercialisation has positive and significant effects on all nutrition indicators, except for vitamin A. The commercialisation index ranges between zero and one, meaning that a 10% point increase in the level of commercialisation increases the consumption of calories by 68.0 kcal (about 3% of the minimum consumption threshold), of zinc by 0.34 mg (2%), and of iron by 0.55 mg (3%) per AE and day. These effects support the hypothesis that commercialisation improves farm household nutrition.

As robustness checks, we carried out the model estimates with alternative commercialisation measures as treatment variables, such as the share of different types of crops sold, the share of livestock products sold, the area under cash crops, and the value of cash crops sold (Tables A20–A25 in the online Appendix). While the coefficient estimates vary in size, these robustness checks confirm the general conclusion that commercialisation has positive effects on nutrition in our sample.

6.3. Purchased and own-produced foods

The middle and lower parts of Table 2 show results of model estimates where the nutrition outcome variables were disaggregated by consumption of calories and micronutrients from purchased and own-produced foods. Commercialisation has positive and significant effects on the consumption of calories and all three micronutrients from purchased foods. A 10% point increase in the level of commercialisation increases calorie consumption from purchased foods by 45.9 kcal, vitamin A consumption from purchased foods by 27.4 μg, zinc consumption by 0.30 mg, and iron consumption by 0.39 mg per AE and day.

An obvious interpretation of these positive effects on calories and nutrients from purchased foods is that the additional cash income generated from farm output sales improves households' economic access to food and dietary quality. More commercialised households do not only purchase energy-dense foods, but also foods that contribute to improved micronutrient consumption, such as fruits, vegetables and livestock products.

The lower part of Table 2 shows that commercialisation has no significant effects on the consumption of calories and micronutrients from own-produced foods. This is

Table 2
Commercialisation effects on calorie and nutrient consumption

	Calories (kcal/day/AE)	Vitamin A (μg RE/day/AE)	Zinc (mg/day/AE)	Iron (mg/day/AE)
Effects on total consumption				
Commercialisation (0–1)	679.95***	136.88	3.45**	5.55**
	(204.33)	(227.20)	(1.31)	(2.22)
	[0.03]	[0.34]	[0.03]	[0.03]
Effects on consumption from purchased foods				
Commercialisation (0–1)	459.27***	274.35**	2.97***	3.87***
	(163.17)	(123.79)	(1.06)	(1.40)
	[0.03]	[0.03]	[0.03]	[0.03]
Effects on consumption from own-produced foods				
Commercialisation (0–1)	246.27	–188.87	0.61	0.88
	(175.89)	(163.20)	(1.43)	(1.80)
	[0.12]	[0.16]	[0.34]	[0.34]

Note: Coefficient estimates of OLS models are shown with robust standard errors clustered at farmer group level in parentheses. Adjusted *P*-values (*q*-values) are shown in square brackets, following the two-stage procedure for multiple hypotheses testing explained by Benjamini *et al.* (2006). Other covariates were included for estimation but are not shown here for brevity. Full model results are shown in Tables A17–A19 online. AE, male adult equivalent; RE, retinol equivalent. **, *** significant at 5% and 1% level, respectively.

interesting, because – *ceteris paribus* – higher sales of farm outputs could mean lower availability of food and nutrients for home consumption. That such a decrease in the consumption of own-produced foods is not observed is likely due to higher yields on more commercialised farms. Indeed, the level of commercialisation is positively associated with input use and land productivity (Table A10 in the online Appendix). These results imply that commercialisation does not lead to a simple substitution of purchased foods for own-produced foods. Rather, more commercialised households add purchased foods to their diets.[4]

6.4. *Income and gender pathways*

The positive effects of commercialisation on the consumption of calories and micronutrients from purchased foods suggest that the cash income pathway plays an important role. This is analysed more explicitly in Table 3. The estimates reveal a significantly positive association between the level of commercialisation and household income. Controlling for other factors, a 10% point rise in the level of commercialisation is associated with almost 25,000 Ksh higher income (27% of mean income of the least commercialised households). The other models in Table 3 confirm that gains in household income are significantly associated with higher calorie and micronutrient consumption. For vitamin A, the association is not statistically significant.

[4]For vitamin A from own-produced foods, commercialisation has a negative coefficient (Table 2). While this negative coefficient is not statistically significant, it is possible that the consumption of certain own-produced vitamin A rich foods is reduced in more commercialised households. This is further analysed with the GPS approach below.

Table 3

Commercialisation, income, and calorie and nutrient consumption

	Household income	Calories (kcal/day/AE)	Vitamin A (μg RE/day/AE)	Zinc (mg/day/AE)	Iron (mg/day/AE)
Commercialisation (0–1)	249.139***				
	(42.186)				
Household income (1,000 Ksh)		1.022***	0.482	0.006***	0.012***
		(0.192)	(0.290)	(0.001)	(0.003)

Note: Coefficient estimates of OLS models are shown with robust standard errors clustered at farmer group level in parentheses. Other covariates were included for estimation but are not shown here for brevity. Full model results are shown in Table A26 in the online Appendix. AE, male adult equivalent; RE, retinol equivalent; Ksh, Kenyan shillings. *** significant at 1% level.

Table 4

Crop commercialisation and male control of sales revenues (probit models)

	Male control of revenues from maize sales Marginal effects	Male control of revenues from bean sales Marginal effects
Maize/bean commercialisation (0–1)	0.365***	0.271***
	(0.122)	(0.100)
Age of household head (years)	–0.002	0.001
	(0.003)	(0.002)
Male household head (dummy)	0.684***	0.219***
	(0.041)	(0.050)
Education of household head (years)	–0.018	–0.001
	(0.013)	(0.008)
Household head married (dummy)	–0.988***	–0.676***
	(0.009)	(0.187)
Sub-county dummies	Yes	Yes
Observations	191	275
Log pseudo likelihood	–81.729	–108.437
Pseudo R-squared	0.177	0.148

Note: Robust standard errors clustered at farmer group level are shown in parentheses. Only maize/bean selling households were included. **, *** significant at 5% and 1% level, respectively.

To evaluate possible effects of commercialisation on gender roles, we look at who within the household controls the revenues from farm output sales. Most households sell different crops, for which the control of revenues can vary (Table A27 in the online Appendix). Hence, calculation of a single variable that captures gendered revenue control across households and crops is not straightforward. For this part of the

Table 5
Income, gender roles, and consumption of purchased calories and nutrients

Variables	Calories (kcal/day/AE)	Vitamin A (μg RE/day/AE)	Zinc (mg/day/AE)	Iron (mg/day/AE)
Maize-selling households				
Household income (1,000 Ksh)	1.100***	0.671***	0.005***	0.008**
	(0.173)	(0.209)	(0.001)	(0.003)
Male control of maize revenue (dummy)	–314.030*	–233.409**	–1.850*	–0.271
	(160.900)	(113.886)	(1.069)	(2.026)
Bean-selling households				
Household income (1,000 Ksh)	0.516*	0.470**	0.002	0.008**
	(0.294)	(0.182)	(0.002)	(0.003)
Male control of bean revenue (dummy)	–86.712	–113.559*	–0.820	1.086
	(145.604)	(60.946)	(0.980)	(2.024)

Note: Coefficient estimates of OLS models are shown with robust standard errors clustered at farmer group level in parentheses. Other covariates were included for estimation but are not shown here for brevity. Full model results are shown in Tables A28 and A29 in the online Appendix. AE, male adult equivalent; RE, retinol equivalent; Ksh, Kenyan shillings. *, **, and *** significant at 10%, 5%, and 1% level, respectively.

analysis, we focus on two of the most important food crops in the study region, namely maize and beans. Most of the sample households grow these crops primarily for home consumption; 25–30% of the households also sell some maize and beans to generate cash income. We focus on the subsample of households that sold some of their maize and beans.

For both crops, the question 'who controls the revenues?' was asked with three possible answers, namely 'male control', 'female control' or 'joint control'. Based on these data (Table A27 in the online Appendix), we constructed separate dummy variables for both crops that take a value of one if a male household member controls the revenues alone, and zero if a female member controls the revenues either alone or jointly with a male member. Table 4 presents estimation results of models with this 'male control' dummy as dependent variable. The level of commercialisation is positively and significantly associated with male control of revenues. This is consistent with earlier research showing that commercialisation can be associated with women losing control of agricultural income (von Braun and Kennedy, 1994; Chege *et al.*, 2015).

Table 5 shows that male control of maize revenues is associated with lower consumption of calories, vitamin A and zinc from purchased foods (for beans, only the association with vitamin A is statistically significant). In other words, women spend more on food and dietary quality than men, which seems especially relevant for vitamin A. As the models control for total household income, this negative gender pathway is a partial effect, which does not imply that the total effect of commercialisation on nutrition is negative. But the analysis suggests that the total nutrition effects of commercialisation could be even more positive, especially for vitamin A, if the loss of female control of revenues were avoided.

6.5. Continuous treatment effects

We now estimate continuous treatment effects with the GPS approach. Results of the model to estimate the propensity scores with the level of commercialisation as dependent variable are shown in Table A30 in the online Appendix. Table A31 shows covariate balancing tests, comparing four different treatment groups that vary in their level of commercialisation. Before matching, most of the covariates for these four groups differ significantly. After matching, most of the differences turn insignificant.

Figure 2 presents the estimated dose-response functions.[5] The consumption of total calories, zinc and iron increases continuously with the level of commercialisation, which is consistent with the parametric results discussed above. For zinc, a consumption maximum is reached at a commercialisation level of about 0.7. Yet, this maximum is above the recommended minimum consumption of 15.0 mg of zinc per day, so a slight reduction beyond that point is not of nutritional concern. For calories, zinc and iron, the consumption increases from purchased foods are also continuous, whereas the consumption from own-produced foods follows an inverse U-shape with increasing levels of commercialisation. It is plausible that the benefits of subsistence (such as avoiding high transaction costs and market risk, or preferences for home-produced foods) are reduced in relative importance at higher levels of commercialisation where economies of scale begin to play a larger role.[6]

We now turn to the discussion of the vitamin A results, which are different from those of calories, zinc and iron. The parametric results above did not find a significant effect of commercialisation on total vitamin A consumption. The non-parametric results in Figure 2 provide interesting additional insights. The non-linear dose-response function on the left panel shows that total vitamin A consumption decreases at low levels of commercialisation, whereas for commercialisation levels above 0.5, positive treatment effects are observed. The middle and right panels explain this non-linear effect: commercialisation decreases vitamin A consumption from own-produced foods, and at low levels of treatment exposure this decrease is stronger than the increase from purchased foods. This comparison is reversed at higher levels of commercialisation. These results clearly suggest that vitamin A supply deserves special attention during the process of commercialisation.

7. Conclusion

Using data from smallholder farm households in Kenya, we show that commercialisation has positive effects on food security and dietary quality. Higher levels of

[5]That the functions for total calorie and micronutrient consumption all lie above the respective minimum consumption thresholds, even at low levels of commercialisation, should not lead to the conclusion that nutritional deficiencies are not a problem among sample households. The dose-response functions are average estimates at each level of commercialisation. The descriptive statistics in Table 1 show that nutritional deficiencies are widespread in spite of sample mean consumption levels being above the minimum thresholds.

[6]With full commercialisation (level of commercialisation equal to 1), the consumption of calories and nutrients from own-produced foods should be zero. Figure 2 shows positive values, which is due to boundary problems in the dose-response estimations. There are hardly any farmers in the sample with commercialisation levels equal to 0 or 1, so the estimates for these boundary values of the treatment variable are imprecise.

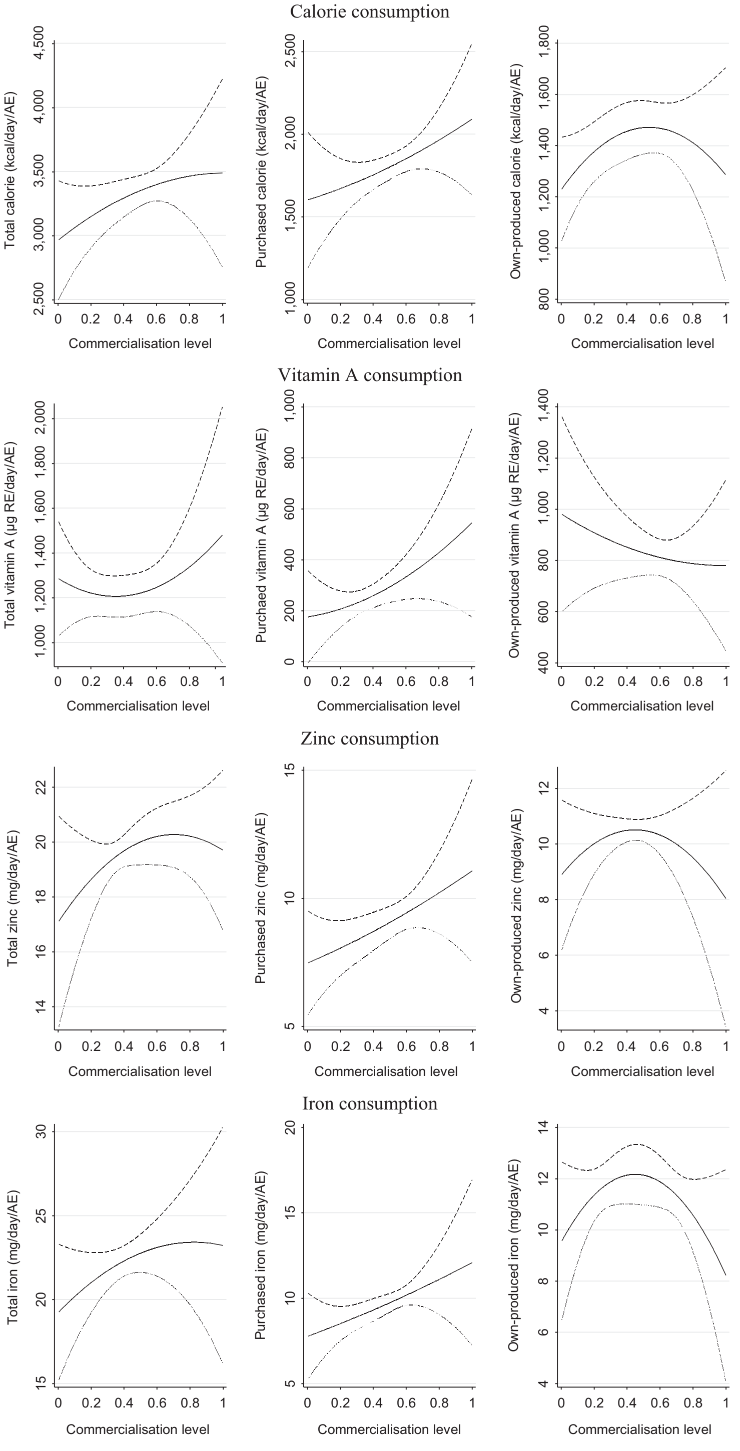

Figure 2. Dose-response functions of commercialisation effects on calorie and nutrient consumption. Solid lines, estimated average dose-response functions; dashed lines, 95% confidence upper bound; tight dotted lines, 95% confidence lower bound. Intervals obtained through bootstrapping.

commercialisation significantly contribute to improved calorie, zinc and iron consumption. For vitamin A, the effects of commercialisation were found to be insignificant. The positive effects for most dietary indicators are primarily due to rising cash incomes, allowing households to purchase more food from the market. However, rather than substituting for own-produced foods, purchased foods are added to the diet with increasing levels of commercialisation. Hence, commercialisation contributes to higher levels of dietary diversity.

We also analysed how commercialisation may affect gender roles within farm households. While we were unable to prove causality, commercialisation is associated with a lower likelihood of farm revenues being controlled by female household members. And male-controlled income is associated with lower consumption of calories and micronutrients, after controlling for total household income. These results confirm earlier research showing that women tend to spend more on dietary quality than men (Hoddinott and Haddad, 1995; Fischer and Qaim, 2012).

Overall, we conclude that commercialisation can contribute to improved nutrition in the small farm sector. An important policy implication is that enhancing market access is a key strategy to make smallholder agriculture more nutrition-sensitive. The role of women should receive particular attention. The evidence suggests that women may lose decision-making power with increasing levels of commercialisation, but this may possibly be prevented through more gender-sensitive approaches and awareness-building initiatives (Meemken and Qaim, 2018). We also stress that commercialisation alone will not suffice to address all types of malnutrition. Especially to increase vitamin A consumption, more specific, complementary interventions may also be needed.

While several tests confirmed the robustness of our findings, a few limitations remain. First, the analysis relies on cross-section data, which limits the strength of the identification strategy. If the instruments chosen are not valid, the estimates may suffer from endogeneity bias. Follow-up studies with panel data and observed changes in the level of commercialisation over time could be interesting to corroborate the findings. Second, the 7-day food consumption recall data provide a reasonable snapshot of diets at the household level, but they do not account for seasonality and intra-household food distribution. The collection and use of higher-frequency, individual-level nutrition data would be very useful for more detailed analyses. Third, the use of 12-months recall data for farm production and marketing activities is likely associated with certain levels of imprecision. In this respect, higher-frequency data collected in various seasons of a year could reduce possible measurement errors.

Two final issues that deserve discussion are those of internal and external validity of the results. In terms of internal validity for the study region in Western Kenya, it should be mentioned that our sample was drawn from households that are organised in farmer groups. Many but not all smallholders in Kenya are organised in groups. The reason that we focused on farmer groups is that this allowed us to randomly sample from existing lists in the absence of county and village census data. Based on our field observations, farm households organised in groups do not differ notably from other farm households in the study region. If so, then our results are valid for Western Kenya more generally. In terms of external validity, the concrete results are context-specific and should not be generalised. Nevertheless, some broader lessons are indicated. The sample from Western Kenya consists of farm household with very small areas of land on which various food and cash crops are grown. Market access is limited due to poor infrastructure and inefficient institutions. Much of the food crop production is for subsistence, and food insecurity and nutritional deficiencies are widespread. These are all characteristics that are typical of the African small farm sector more broadly, so the nutrition effects of commercialisation may also be similar. One characteristic of the study region in Western Kenya that is more location-specific is the fact that seasonality in agricultural production and consumption is not very pronounced. This is related to ample rainfall in various months of each year. Effects of commercialisation may be different in regions with stronger seasonality and higher risk of drought.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table A1. Commercialisation effects on total calorie and nutrient consumption.

Table A2. Associations between instruments and nutrition outcomes.

Table A3. Correlation between instruments and mean wealth characteristics at ward level.

Table A4. Correlation between instruments and selected household socioeconomic characteristics.

Table A5. Mean differences in selected variables between main market sellers and non-sellers.

Table A6. Correlation between household-level and individual-level nutrition outcomes.

Table A7. Correlation between survey in December and nutrition variables.

Table A8. Share of households producing and selling cash crops, food crops, and livestock products.

Table A9. Correlation between commercialisation index and other measures of commercialisation.

Table A10. Summary statistics by level of commercialisation.

Table A11. Overall consumption of micronutrients from different food groups by level of commercialisation.

Table A12. Consumption of purchased micronutrients from different food groups by level of commercialisation.

Table A13. Consumption of own-produced micronutrients from different food groups by level of commercialisation.

Table A14. Testing for endogeneity of commercialisation using control function approach.

Table A15. Commercialisation effects on purchased calorie and nutrient consumption.

Table A16. Commercialisation effects on own-produced calorie and nutrient consumption.

Table A17. Commercialisation effects on total calorie and nutrient consumption.

Table A18. Commercialisation effects on purchased calorie and nutrient consumption.

Table A19. Commercialisation effects on own-produced calorie and nutrient consumption.

Table A20. Crop commercialisation effects on total calorie and nutrient consumption.

Table A21. Livestock commercialisation effects on total calorie and nutrient consumption.

Table A22. Maize commercialisation effects on total calorie and nutrient consumption.

Table A23. Bean commercialisation effects on total calorie and nutrient consumption.

Table A24. Tea commercialisation effects on total calorie and nutrient consumption.

Table A25. Cash crop commercialisation effects on total calorie and nutrient consumption.

Table A26. Commercialisation, income, and calorie and nutrient consumption.

Table A27. Control of revenues from maize, beans, tea, and coffee (%).

Table A28. Income, gender roles, and consumption of purchased calories and nutrients (maize).

Table A29. Income, gender roles, and consumption of purchased calories and nutrients (beans).

Table A30. GLM (Fractional logit) regression for estimating propensity scores.

Table A31. Covariate balancing tests for generalised propensity score matching (t-statistics for mean differences across four treatment groups).

Figure A1. Share of households selling in different markets (only market sellers included, n = 784).

Figure A2. Share of calorie and nutrient consumption from different sources.

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