Can Smallholder Fruit and Vegetable Production Systems Improve Household Food Security and Nutritional Status of Women?
Evidence from Rural Uganda

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Abstract

This paper aims to empirically infer potential causal linkages between fruit and vegetable (F&V) production, individual F&V intake, household food security, and anemia levels for individual women caregivers of childbearing age. Using a unique and rich dataset collected from rural smallholder Ugandan households, we show that the use of a qualitative tool to measure household food insecurity is robust and applicable in other contexts. We also show, using robust econometric methods, that women living in F&V-producer households have a significantly higher intake of F&Vs than those living in nonproducer households. Furthermore, F&V-producer households are potentially more food secure, and women caregivers in producer households have significantly higher levels of hemoglobin, rendering the prevalence rates of anemia lower among F&V-producer households. We argue that these effects, modest as they are, could be further improved if there were deliberate efforts to promote the intensification of smallholder F&V production.

Keywords: Fruits and vegetables (F&V); women caregivers; household food security; F&V intake; hemoglobin; anemia; Uganda

1. Introduction

Food insecurity and micronutrient deficiencies are leading causes of disease and mortality globally, and are more pronounced in developing countries (FAO IFAD and WFP, 2013). Poor rural households in rural communities must either produce sufficient food (on-farm) or earn an off-farm income that allows them to buy sufficient food to fulfill their nutritional needs. These households, often ill equipped to produce their own food amidst unfavorable climate, labor inefficiencies, poor infrastructure and institutional or market failures (World Bank, 2007), face the anxiety of meeting their food needs and may opt to consume cheaper or low-quality foods or simply go for a day or more without food, with women and children suffering disproportionately. Solutions to reducing food insecurity and addressing micronutrient deficiencies require integrated and multifaceted approaches that are also well supported empirically with evidence-based investment and decision-making (Mallett et al., 2012). Indeed, recent efforts increasingly emphasize pathways through which agriculture leverages affect nutrition and health outcomes, especially for women and children (Herforth, 2012; IFPRI, 2012).

Using a concrete case of rural Ugandan households, we empirically demonstrate that the expansion or intensification of smallholder fruit and vegetable (F&V) production systems can potentially increase F&V intake and reduce household food insecurity and anemia for women of childbearing age. Multi-sectoral food-based strategies, including education-awareness programs and promotion of nutrient-dense food production and consumption, are believed to be more sustainable and culturally acceptable than supplementation or fortification (Ruel, 2001; Hawkes and Ruel, 2006). Yet, rigorous empirical studies based on sufficient datasets that combine aspects of agriculture, nutrition, and health economics are rare and deemed inconclusive to support policy intervention (Ruel and Alderman, 2013).

Available studies that mainly focus on the linkage between F&V consumption and health outcomes are largely descriptive, reporting that F&V-rich diets help prevent a number of non-communicable diseases, including cardiovascular diseases, diabetes, cancer, respiratory diseases, and obesity, as well as preventing mineral and vitamin deficiencies (Steinmetz and Potter, 1996; Ness and Powles, 1997; John et al., 2002; Hung et al., 2004; Reddy and Katan, 2004; Estruch et al., 2013). Compelling evidence also indicates that F&V-rich diets have the potential to significantly reduce childhood and maternal micronutrient deficiencies (for a review, see Knai et al., 2006). Although there are initiatives to increase F&V demand, many have not been as effective, because F&V consumption still lies far below the World Health Organization's (WHO's) recommended levels (Thow and Priyadarshi, 2013). The focus on supply-side interventions by promoting F&V production, even at the small scale, inter alia, will likely support F&V demand-side interventions. However, no study has yet established the links between F&V production and consumption and their effects on food security and nutrition outcomes.

This study analyzes the relationships between F&V production and intake for rural Uganda, contributing to the literature in three main ways. First, we contribute methodologically and show that the use of the Household Food Insecurity Access Scale (HFIAS), a recently developed qualitative tool to measure macronutrient (or food) insecurity at the household level (Coates et al., 2006), is robust in studies of this nature, as also reported by Kabunga, et al. (2014). The use of HFIAS simplifies the somewhat complex and expensive processes of quantitative food-security assessment, such as dietary recalls and anthropometrics. Second, we contribute empirically by showing that household-level F&V production substantially influences the F&V intake of individuals (specifically women) living in these households and that F&V production is an essential component to household food security, especially for those that are most vulnerable. Third and most important, we show evidence that there is a link between F&V production and intake of individual women and their anemia levels. To measure household-level food security, we use two quantitative food-insecurity indices derived from the qualitative HFIAS tool. We use finger prick blood from women of reproductive age (15–49 years) in study households to measure hemoglobin levels, which are, in turn used to determine anemia incidences.

We use a uniquely designed dataset of 3,630 households collected from October 2012 to December 2012 in six districts distributed across two major agroecological zones of Uganda. The dataset includes variables ranging from household socioeconomics, agricultural production, and household food security to nutrition, health metrics, and anthropometry indicators, as well as measured biomarkers for women and children. To estimate the net effects of F&V production, we account for other potential confounders that may simultaneously affect the mentioned outcomes by employing propensity score matching (PSM) approaches. Our aim is not necessarily to model the effect of F&Vs in the form of deliberate actions of smallholder F&V production initiatives (as these are yet to happen anyway) on household food security and anemia. Rather, we attempt to quantify these gains from a policy perspective by showing that if more specific nutrient-dense F&V are supported to scale by supply-side intervention (literally through smallholder F&V gardens), the benefits could be beyond what is estimated here.

The rest of the paper is organized as follows: Section 2 gives a brief background to F&V production in Uganda, making an argument for promotion of smallholder F&V production systems. Section 3 describes the data sources and selected variables of interest. Section 4 discusses how to derive food-insecurity access scales using HFIAS. Section 5 presents the empirical strategies used to isolate and infer potential casual effects of F&V production on outcomes and discusses the results. Section 6 concludes.

2. Fruits and Vegetables in the Ugandan Context

Availability, Intake, and Health Benefits

Maternal and child morbidity and mortality rates are high in Uganda (UBoS and ICF International, 2012). Maternal and young child mortality is particularly linked to micronutrient deficiencies, as is morbidity (Black et al., 2013). The daily consumption of sufficient amounts of F&Vs is widely recognized as an important element in meeting vitamin and mineral needs in a diet. Relative to components of other Ugandan diets, F&Vs are nutritionally dense, containing significant amounts of plant-based vitamins, minerals, proteins, and biofunctional components. If regularly and sufficiently consumed as part of a balanced diet, F&Vs can promote health and help reduce the risk of noncommunicable diseases. Moreover, F&V-rich diets can potentially reduce childhood and maternal micronutrient deficiencies, which are reportedly high in Uganda (UBoS and ICF International, 2012).

Globally and in Uganda, per capita F&V consumption falls short of daily recommended intake levels by 20 to 50 percent (WHO, 2006). The annual per capita F&V consumption for Ugandans is about 64 kilograms (kg), accounting for approximately 44 percent of the WHO recommendation of 145 kg, even though Uganda can potentially produce more than 225 kg, or 155 percent of the WHO recommendation, of F&Vs annually per capita (Ganry et al., 2009). A number of factors on both the demand and supply side may explain the wide gap between F&V intake and potential availability. On the demand side, income levels, market prices, and household preferences are key determinants (Ruel et al., 2005). Household preferences, in particular, further depend on awareness of the importance and nutritional benefits of F&V consumption for household members. Supply-side factors require an understanding of farming systems in Uganda and how F&V production is linked to F&V consumption, as it is unclear whether stable F&V prices alone can lead to increased consumption.

Considering that most rural Ugandan households grow much of the food they consume and face relatively larger transaction costs in relying extensively on the market to meet their food needs, it becomes implicitly difficult to separate a household's consumption decisions from its production decisions (Singh et al., 1986), including for F&Vs.

Making a Case for Increased F&V Production

Uganda's economy is founded on agriculture. A variety of F&Vs are either collected wild, semicultivated, or cultivated in gardens found in dooryards and backyards, as well as in agricultural fields and fallowed land (Musinguzi et al., 2006). Most F&Vs grow conventionally under low-input regimes, occasionally appearing in crop mixes and marginal land peripheries. In addition, women manage most of the F&V production in Uganda for household food security, without overtly challenging cultural or social restrictions (Rubaihayo, 2002). Research in Uganda and elsewhere reports that traditional F&Vs, often not targeted by agricultural extension or policy, constitute a vital part of food and nutrition security by providing direct food, cash income, and insurance against drought and other crop failure (see Rubaihayo 2002, for Uganda; Ogoye-Ndegwa 2003, for Kenya; Mavengahama, McLachlan, and de Clercq 2013, for South Africa). There is also potential for expanded high-value domestic and export markets, though this is not yet at the large scale. Domestic demand for fresh F&Vs is growing due to increasing population and an emerging middle class that demands high-value food products. On the other hand, Ugandan rural smallholder farmers face policy-related and structural constraints to sustainable F&V production for their own consumption and for the market. Indeed some fruits (especially apples and strawberries) are imported from South Africa to satisfy the local market and the demand for processed fruit juices as well as fresh chilled and frozen vegetables outstrips local production. Thus, there exist opportunities for investment in fruit juice processing for local and export markets as well as investments in integrated production and marketing systems by largescale F&V growers, possibly linked to organized groups of smallholder outgrowers.

In the context of this research, the promotion and intensification of smallholder F&V production systems are viewed as a possible strategy to increase F&V availability and household income and, consequently, to improve the welfare of households. Smallholder F&V gardens (kitchen or home gardens) are valued for their potential and actual benefits to household welfare, especially as nutrient-dense plant food sources in some developing countries in Asia, Central and Eastern Europe, Latin America, and even Africa (for a review, see Galhena et al., 2013). These gardens also seem a plausible intervention avenue for intensive F&V production for household use and for sale, as investments in this sector potentially have positive effects on employment and wage economy, with high economic returns to land as compared with other major crops. Moreover, growing demand for F&Vs in developing countries and a sustained demand in export markets create opportunities for the rural poor to integrate into high-value markets and improve welfare outcomes (Miyata et al., 2009; Asfaw et al., 2010; Kersting and Wollni, 2012).

Yet, for these benefits to be achieved, strategies need to be implemented in a consultative manner, particularly in research, infrastructure, and institutional development. The scope of this study is only limited to production–consumption–utilization linkages: we use a rich dataset, with components on agricultural production and household and individual metrics, to reveal empirically the links between F&V production and intake, household food security and anemia prevalence for women of child bearing age. Although the data were collected nonexperimentally from a representative sample of rural Ugandan households, without any knowledge of established or imminent intensified F&V production initiatives,[1] we still use matching methods to eliminate biases that may inherently exist in these populations.

3. Data and Descriptive Analysis

Household Survey

Our analysis is based on a unique cross-sectional dataset that was collected September 2012–December 2012. In addition to serving our own research agenda, the dataset served as a baseline for a USAID–funded program implementation in rural Uganda. The survey targeted a sample of 3,630 households in six districts of Uganda, with an average of 600 households per district. We adopted multistage sampling strategies to ensure representativeness. We randomly selected six out of 18 districts originally identified by USAID's Feed the Future initiatives for wide-scale program implementation of development interventions in agriculture, nutrition, and health. Program implementation was designed to follow two phases: Phase 1 districts would receive treatment in the first year of implementation while Phase 2 districts, comparable in most agroecological and locational characteristics to Phase 1 districts, would be kept as control areas until a later date when similar treatments would also be implemented there.

In the program implementation Phase 1, districts of Kisoro (in southwestern Uganda) and Agago and Dokolo (in northern Uganda) were selected; for implementation Phase 2, districts of Kamwenge (southwestern) and Kole and Lira (northern) were selected. In each Phase 1 district, three subcounties that had been identified to benefit from program implementation (hereon, *study subcounties*) were

[1] There is no known policy or deliberate programs to support intensive F&V gardening for nutrition or economic benefits, except a few isolated pilot projects initiated by Makerere University and local nongovernmental organizations (such as Volunteer Efforts for Development Concerns, Agency for Accelerated Regional Development, and Women and Rural Development Network, among a few others). All of these initiatives are location specific and on a limited scale.

purposely selected, while another subcounty that was comparable in agroecological conditions with the rest was randomly selected to act as a counterfactual to track the implementation progress. In each Phase 2 district, no subcounties had been identified as program beneficiaries; thus, we randomly selected four subcounties from the Phase 2 districts. In all selected subcounties for Phase 1 and Phase 2 districts, smaller administrative units (*parishes*) were further randomly selected. However, for logistical and operational reasons, we randomly sampled 25 percent of all villages in the parish for the study.

The final list of households was reached after carefully designing a sampling framework that emphasized representativeness at the village level based on the probability of selection proportional to the rural population size (PPS) approaches, using household census data from the Uganda Bureau of Statistics. In Phase 1 districts, a ratio of five households in the three study subcounties for one in the counterfactual was followed; this allowed for a substantial overrepresentation of program households in the sample, while giving due consideration to village size as determined by the PPS approach. Thus, there are about 500 households from study subcounties as compared with 100 from a counterfactual subcounty. In Phase 2 districts, households were equally distributed across all four subcounties based on PPS as established at the village level. Due to our PPS approaches, our sample is considered self-weighting.

The survey was conducted by closely supervised research teams that had been carefully selected and trained prior to data collection. Data were collected using predesigned questionnaires loaded on computer-assisted personal interviewing equipment (Android tablets). Operationally at the village level, a research supervisor would consult with the village leaders and generate a numbered list of all eligible households within the village. From this list, we selected households using a random number generator on the tablet. With the help of a village guide, we would then locate and interview the household in the local language.

The survey questionnaire captured data on household demographics, assets, and various farm and off-farm income sources, as well as details on access to and use of health and nutrition information and facilities. In addition, anthropometric data and finger prick blood samples were collected from the main caregiver (in most cases, a woman of reproductive aged 15–49 years). The questionnaire also included an agricultural module, which provided data on F&V-production activities, among other enterprises in which the household was involved. We were thus able to isolate and classify households as either F&V producers or not. The questionnaire also required the caregiver to list all food foods and food groups she consumed in the 24 hours preceding the interview. Based on this, we can categorize caregivers as F&V consumers or not, assuming habitual behavior. To estimate household food security, the questionnaire included an HFIAS tool (Coates et al., 2007), details of which are described further below.

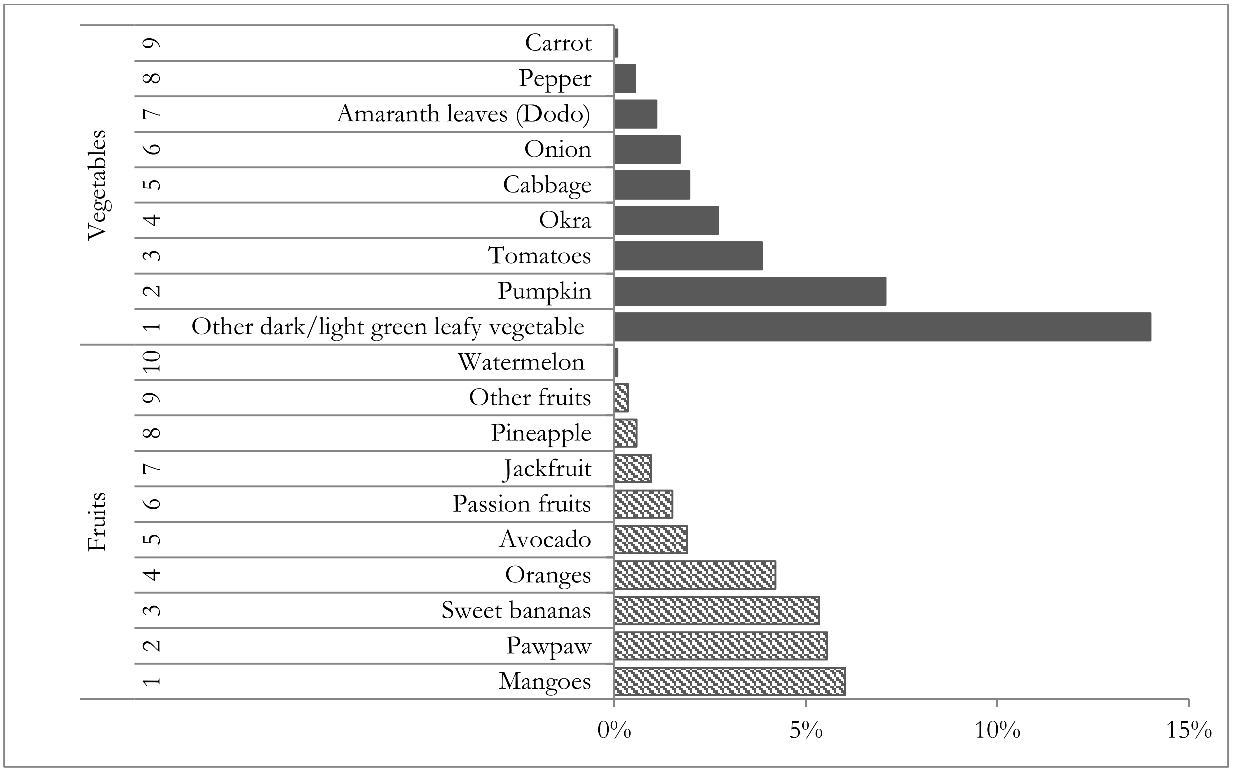
Identifying F&V Producers

We aimed to measure household-level food security and anemia effects of a household's own F&V production. F&V production was indicated by whether a household reported having any type of F&V crop productively growing (cultivated or wild) on their farm in the previous year. There are different ways to classify F&V crops, ranging from botanical to composition and color, as well as whether a crop or its edible part is consumed raw or cooked (for details, see Pennington and Fisher, 2009). In the context of this study, we consider both indigenous and exotic F&Vs, grown widely by rural Ugandan smallholders reportedly for their dietary benefits and for their monetary value. Some crops classified as F&Vs in other contexts (such as green banana or plantain, beans, and potatoes

[Pennington and Fisher 2009]) are not classified as such here because no household reported consuming them in raw form.

Figure 3.1 presents the various F&V crops and the incidence of their production by Ugandan smallholders. The production of specific F&Vs is generally low, with a few more households producing vegetables (21 percent) than fruits (18 percent). The most common vegetables, produced by 14 percent of all households, are indigenous and comprise dark and light green leafy vegetables of various species. This is followed by pumpkin (7 percent), tomatoes (4 percent), okra (3 percent), and cabbages (2 percent). For fruits, the most common are mangoes (6 percent), papaya (6 percent), dessert bananas (5 percent), and oranges (4 percent).

Figure 3.1─Common fruit and vegetables produced and their incidences



Source: Author calculation based on survey data, 2012

To determine F&V producers, we enumerate each household that reported producing either a fruit or vegetable in the past year (Figure 3.1). Each F&V producer is assigned 1; otherwise, 0 to generate a dummy variable that is used in subsequent analysis to classify households as F&V producers or nonproducers. Our data show that 31 percent of sampled households are classified as F&V producers. As Table 3.1 shows, we find substantial variations across sampled districts, with relatively high F&V production rates in the northern districts of Agago (46 percent) and Kole (50 percent); the lowest rates are reported in Dokolo (5 percent).

Table 3.1─Fruit and vegetable production, disaggregated by district

Classification	District						Total [a]
	Agago	Dokolo	Kamwenge	Kisoro	Kole	Lira	
Producers	268	27	138	175	307	194	1,109
Nonproducers	318	580	462	428	304	413	2,505

Source: Author calculation based on survey data 2012

Notes: [a] Total does sum up to 3,630 households because of missing data

Descriptive Analysis

Summary statistics for selected conditioning variables for households, the household head, and the caregiver are presented in Table 3.2. The table provides a short description of the variable, as well as the summary statistic for the full sample. Disaggregating by F&V production category, we present mean values for F&V producers and nonproducers in columns 2 and 3 and report the test for the equality of means in column 4.

The majority of households are headed by males aged about 36 years, who have attained fewer than seven years of formal education. Caregivers are comparably younger and less educated, on average, than household heads; caregivers in F&V-producing households are significantly older than those in nonproducing households. Sampled households comprise, on average, about six members, with half of these being male. We observe F&V producers having a slightly higher share of males than nonproducers.

Table 3.2─Descriptive statistics of sampled households and comparisons by producer category

Variable	Variable definition	Full sample (1)	Producers (2)	Nonproducers (3)	*t*-value (4)
Age, household head	Age of the household head in completed years	36.15 (12.24)	35.69 (12.67)	36.35 (12.05)	–1.49
Sex, household head	Sex of the household head (1 if male)	0.91 (0.29)	0.92 (0.27)	0.90 (0.29)	1.59
Education, head	Number of completed formal years of education for the household head	6.25 (3.38)	6.25 (3.49)	6.25 (3.33)	0.05
Age, caregiver	Age of the caregiver in completed years	30.77 (8.56)	31.63 (9.01)***	30.38 (8.32)	4.04
Education, caregiver	Number of completed formal years of education for the caregiver	4.03 (3.13)	3.95 (3.23)	4.07 (3.08)	–1.04
Household size	Number of occupants in the household	5.97 (2.62)	5.98 (2.81)	5.96 (2.52)	0.24
Male share	The household's share of male members	0.49 (0.21)	0.50 (0.22)**	0.49 (0.20)	2.14
Farm size	Total land owned in acres	3.41 (6.90)	3.73 (10.56)*	3.27 (4.40)	1.84
Housing index	Derived indicator for housing condition (structure of floor, roof, wall, toilet facilities)	0.00 (0.96)	-0.09 (1.03)***	0.04 (0.93)	–3.74
Livestock value	Value of all livestock units (million UGX)	0.95 (4.67)	1.04 (7.91)	0.91 (1.95)	0.80
No latrine	Household has no pit latrine (1 if yes)	0.16 (0.37)	0.19 (0.40)***	0.15 (0.35)	3.55
Water source	Distance to water source in km	0.94 (1.25)	0.82 (1.10)***	0.99 (1.31)	–3.78
Garbage pit	Household has a garbage pit (1 if yes)	0.45 (0.50)	0.49 (0.50)***	0.44 (0.50)	2.64
Household owns:					
– Radio	Household owns a radio (1 if yes)	0.63 (0.48)	0.65 (0.48)*	0.62 (0.48)	1.69
– Telephone	Household owns a telephone (1 if yes)	0.51 (0.50)	0.53 (0.50)	0.50 (0.50)	1.51
– Motorcycle	Household owns a motorcycle (1 if yes)	0.04 (0.20)	0.04 (0.19)	0.04 (0.21)	–0.97
Annual income	Household income per capita (millions UGX)	0.60 (1.42)	0.55 (0.87)	0.62 (1.61)	–1.45
Off-farm income	Household has an off-farm income (1 if yes)	0.75 (0.43)	0.82 (0.38)***	0.72 (0.45)	6.51
Affiliation to social groups					
– Caregiver	Caregiver is affiliated (1 if yes)	0.70 (0.46)	0.72 (0.45)*	0.69 (0.46)	1.65
– Household head	Household head is affiliated (1 if yes)	0.59 (0.49)	0.62 (0.49)**	0.58 (0.49)	2.23
– Other members	Any other household member is affiliated (1 if yes)	0.06 (0.24)	0.08 (0.28)***	0.05 (0.22)	3.58
Household receives agricultural information from:					
– Posters	Posters/flyers/leaflets (1 if yes)	0.01 (0.09)	0.01 (0.12)**	0.01 (0.07)	2.47
– Stockists	Farm input suppliers (1 if yes)	0.04 (0.21)	0.06 (0.23)**	0.04 (0.20)	2.15
– Social facility	Social or religious facility (1 if yes)	0.11 (0.32)	0.16 (0.36)***	0.09 (0.29)	5.58

Variable	Variable definition	Full sample (1)	Producers (2)	Nonproducers (3)	*t*-value (4)
– Extension	Extension services, including NAADS, NGOs, and so forth (1 if yes)	0.32 (0.47)	0.34 (0.47)*	0.31 (0.46)	1.82
– Others	Other sources, including farmers, relatives, friends, and neighbors (1 if yes)	0.22 (0.42)	0.27 (0.45)***	0.20 (0.40)	4.72
Household receives nutrition information from:					
– Posters		0.01 (0.10)	0.01 (0.12)*	0.01 (0.08)	1.85
– Health facilities	Public or private health facilities (1 if yes)	0.37 (0.48)	0.43 (0.49)***	0.34 (0.47)	4.91
– Social facility	Social or religious facility (1 if yes)	0.07 (0.26)	0.11 (0.31)***	0.06 (0.23)	5.92
– Health extension	Health extension agents, such as VHTs (1 if yes)	0.27 (0.44)	0.30 (0.46)***	0.26 (0.44)	2.61
– Others	Other sources, including relatives, friends, and neighbors (1 if yes)	0.16 (0.36)	0.20 (0.40)***	0.14 (0.35)	4.74
Cash crops	Household grows nontraditional cash crops (1 if yes)	0.17 (0.38)	0.26 (0.44)***	0.14 (0.34)	8.89
Intercropping	Household practices intercropping (1 if yes)	0.70 (0.46)	0.81 (0.40)***	0.65 (0.48)	9.65

Source: Authors calculations based on survey data, 2012

Notes: Figures in parentheses are standard deviations. ***, **, and * denote that the difference is statistically significant at the 1%, 5% and 10% levels, respectively. UGX = Uganda shillings, NAADS = National Agricultural Advisory Services, NGO = nongovernmental organization, VHT = village health team.

The average landholding for sampled households is about 3.5 acres, with F&V producers owning significantly more land than nonproducers. This implies that land constraints may be key in the decision of whether to grow F&V crops. Based on the housing index (a factor of the floor material, roofing material, walls, and type of toilet facility), we observe that F&V producers are living in relatively poorer housing conditions than nonproducers. Proper fecal disposal remains a big sanitary problem in Uganda, with 16 percent of sampled households lacking pit latrines. The share of households without pit latrines is 4 percent higher for F&V producers as compared with nonproducers. Sampled households travel an average of about 1 kilometer to get to the nearest water source. F&V producers would have to travel 170 meters less for water than their counterparts; this factor could be vital in F&V production, because most F&V crops are fragile and would require supplemental water, especially during the dry season.

The proportion of households with pits for safe disposal of household garbage is significantly higher for F&V producers as compared with nonproducers. Garbage pits sometimes also serve as compost pits for organic manures and are potentially usable for improved productivity of F&V crops. In terms of physical assets and income, there are no striking differences between F&V producers and nonproducers, except that more F&V producers own radios and are more engaged in off-farm activities than nonproducers. Off-farm income includes agricultural and nonagricultural wages, profits from self-employed activities, transfers, and food aid and has been shown, in other studies, to influence welfare in several ways, including procuring new seed, labor, and household food and health needs (e.g. Babatunde and Qaim, 2010; Owusu et al., 2011). It is thus possible that households with off-farm income will most likely also possess the liquidity to procure seed and pay for labor and other supplies required for F&V production.

Affiliation of households and individuals to social groups and access to agriculture and nutrition information can strongly influence households' decisions to adopt new production methods, including the decision to start producing F&V crops. These same attributes may also be key in influencing consumption behavior and, consequently, nutritional outcomes. The lower half of Table 3.2 shows that within sampled households, caregivers are more likely to be affiliated with social groups than with household heads or other members, such as workers. However, across categories, the level of social group participation is significantly higher for F&V producers than for nonproducers. The share of households with access to agricultural information sources (extension, social groups, neighbors, and so on) is significantly higher for F&V producers. The most common source of agricultural information is the extension; however, also important are other informal sources, such as fellow farmers and social group organizations.[2] Similarly, the share of households with access to nutrition information sources is significantly higher for F&V producers, with the most common sources of nutrition information for all sampled households being health facilities (private and public clinics and hospitals) and health extension agents (in particular, the village health teams); other vital sources are relatives, friends, and neighbors.

Finally, it is interesting to analyze production behaviors of other crops in relation to F&V crops. The bottommost part of Table 3.2 shows that 17 percent of sampled households grow crops classified as nontraditional cash crops (such as maize, rice, and vanilla). The occurrences of these are almost twofold more common for F&V producers as compared with nonproducers. Moreover, 70 percent of sampled households practice intercropping, with significantly higher percentages observed among F&V producers. Due to the small landholdings observed earlier and other resource constraints,

[2] The shares presented in Table 3.2 for agricultural information do not total to 100 percent. Note that some information channel sources (such as radio and television) have deliberately been excluded because they do not satisfy the balancing property required for PSM matching, as will be seen later.

intercropping is a viable production practice for these farming systems. As shown in Section 2, there are indications from Table 3.2 that most F&V crops are intercropped in other crop mixes for nutrition security and diversity.

4. Measuring Food Insecurity

The Household Food Insecurity Access Scale

We follow methods suggested by Kabunga, Dubois, and Qaim (2014) to quantify household food insecurity using a qualitative tool, the HFIAS, instead of explicit quantitative approaches, such as dietary recalls, anthropometric measures, or health data (see: Haddad et al., 1998; Babatunde and Qaim, 2010; Rusike et al., 2010; Qaim and Kouser, 2013). Quantitative approaches are criticized for being data intensive, complex, and costly to implement appropriately, in addition to being insensitive to shocks and seasonality (De Haen et al., 2011; Headey and Ecker, 2013). HFIAS measures a household's own perception of its access to food and is thus relatively easy and less cost intensive to implement (Coates et al., 2007). Moreover, the HFIAS tool has been validated in several developing countries and applied to quantitative impact assessment (see, for instance, Kabunga et al., 2014).

Following guidelines by Coates, Swindale, and Bilinsky (2007), we developed nine questions related to food-insecurity access and incorporated them in the survey questionnaire discussed earlier. These nine questions constitute subdomains, which are clustered in three domains (Table 4.1). Domain I, with only one subdomain, represents anxiety and uncertainty about household food supply. Domain II, with three subdomains, represents food quality, and Domain III, which comprises five subdomains, represents food quantity intakes related to the physical availability at the household level. Respondents answered each question using a score from 0 to 3, depending on whether the particular problem described occurred never (0), rarely (1–2 times), sometimes (3–10 times), or often (more than 10 times) over the past 30 days. Hence, higher scores depict greater perceived household food insecurity. For each household, the HFIAS score corresponds to the sum of the individual scores and ranges between 0 (maximum food security) and 27 (maximum food insecurity).

Interpreting sample HFIAS statistics is founded on observing the proportion of households that responded "never" to all subdomains (Coates, Swindale, and Bilinsky 2007). For instance, the proportion of households that responded "never" to the first subdomain is 41 percent (Table 4.1), implying that 59 percent of sampled households were worried about fulfilling their food needs. Similarly, 72 percent have insufficient food quality (the unweighted mean of three subdomains in Domain II), and 28 percent have insufficient food quantity intake due to physical unavailability (Domain III). These statistics indicate that food insecurity incidences are high in these study areas.

Table 4.1—Domains and subdomains of the HFIAS, with sample statistics

Domain	Percentage response on occurrences over past 30 days: Never (0 times)	Rarely (1–2 times)	Sometimes (3–10 times)	Often (> 10 times)
I. Anxiety and uncertainty about household food supply				
1. Did you worry that your household would not have enough food? (FIQ1)	41.48	19.03	26.59	12.91
II. Insufficient quality (includes food variety and preferences)				
2. Were you or any household member not able to eat the kind of foods you preferred because of lack of resources? (FIQ2)	25.48	22.38	37.09	15.04
3. Did you or any household member eat just a few kinds of food day after day due to lack of resources? (FIQ3)	27.21	21.68	35.58	15.53
4. Did you or any household member eat food that you preferred not to eat because of a lack of resources to obtain other types of food? (FIQ4)	30.54	23.15	33.19	13.12
III. Insufficient food intake and physical consequences				
5. Did you or any household member eat a smaller meal than you felt you needed because there was not enough food? (FIQ5)	48.31	20.09	24.42	7.18
6. Did you or any household member eat fewer meals in a day because there was not enough food? (FIQ6)	55.83	17.37	19.67	7.12
7. Did you or any household member go to sleep at night hungry because there was not enough food? (FIQ7)	79.07	9.45	8.76	2.72
8. Did you or any household member go a whole day without eating anything because there was not enough food? (FIQ8)	85.54	8.53	4.93	1.00
9. Was there ever no food at all in your household because there were no resources to get more? (FIQ9)	92.97	4.54	2.05	0.44

Source: Author calculations based on survey data, 2012

Identifying Food-Secure Households Using Principal Factor Analysis

Initial tests confirmed that the relationships between the data given for the nine indicators in Table 4.1 can be adequately analyzed by principal factor analysis.[3] It thus follows that we can find within our data, subdomains that factor well together, have high correlation among each other, and have notable loading magnitudes to produce a lower number of latent variables that fit and describe common patterns (Kabunga et al., 2014). To obtain a clear pattern that tries to maximize variance and achieve the best suitable pattern that describes the data, we implemented oblique (nonorthogonal) rotations. Similar to Kabunga, Dubois, and Qaim (2014), the quartimin oblique rotation criteria, which minimize the sum of inner products of squared loadings, fit our data. Moreover, we find a two-factor solution with extracted variance of up to 107 percent, based on the eigenvalue and the scree plot criteria (Table 4.2 and Figure 4.1). The cumulative proportion slightly exceeds 100 percent because of the negative eigenvalues observed in other factors beyond these two.

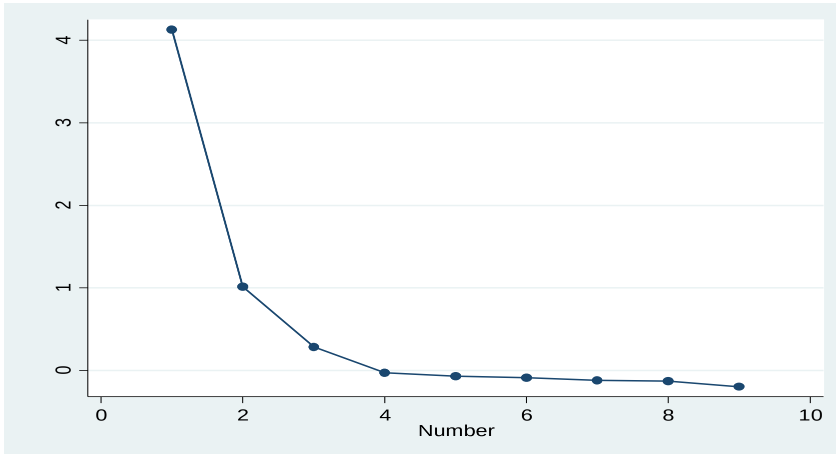
Table 4.2─Summary of the principal factor analysis results (N = 3,581)

Variable (subdomains)	Factor 1 Food insecurity	Factor 2 Severe food insecurity	Uniqueness (1 = communality)
FIQ1	**0.634**	0.154	0.485
FIQ2	**0.850**	–0.078	0.332
FIQ3	**0.850**	–0.067	0.326
FIQ4	**0.771**	0.010	0.399
FIQ5	**0.550**	0.347	0.402
FIQ7	0.144	**0.613**	0.523
FIQ8	–0.001	**0.745**	0.446
FIQ9	–0.127	**0.731**	0.534
Eigenvalues	*4.128*	*1.015*	
Percent variance explained (1.073)	*0.861*	*0.212*	

Source: Author calculations based on survey data, 2012
Note: Boldface loadings are greater than 0.50.

[3] The Kaiser-Meyer-Olkin criterion yields a value of 0.87, which designates the relationships as "meritorious"; the Bartlett test yielded a *p*-value of 0. Both tests signify the data's adequacy for factor analysis Worthington, R.L. and T.A. Whittaker "Scale development research: A Content Analysis and Recommendations for Best Practices." *The Counseling Psychologist*, Vol. **34**, (2006) pp. 806-838..

Figure 4.1—Scree plot of eigenvalues after factor analysis



Source: Author's calculations based on survey data, 2012

Table 4.2 shows a clear factor structure. All nine subdomains (FIQ1–FIQ9) loaded heavily on the two extracted factors, signifying high correlations. Even after rotation, however, subdomain six (FIQ6) persistently exhibited cross-loadings along the two factors and was thus dropped from the analysis. Nonetheless, dropping FIQ6 does not affect internal consistency as measured by Cronbach's alpha index, α, which only reduces from 0.88 to 0.86. Unsurprisingly, our results are similar to those of Kabunga, Dubois, and Qaim (2014), who used a similar method on a different dataset.

The subdomains represent perceptions of food insecurity, with increasing levels of severity as one moves from FIQ1 to FIQ9 (Table 4.2). With this in mind, we observe that subdomains FIQ1–FIQ5 have high loadings on Factor 1, whereas subdomains FIQ7–FIQ9 have high loadings on Factor 2. Moreover, all the loadings of significance (in boldface in Table 4.2) have positive signs, confirming that food-insecurity severity increases with higher reported subdomain values. Against this background and following Kabunga, Dubois, and Qaim (2014), we refer to Factor 1 as a general food insecurity measure, whereas Factor 2 is a measure of severe food insecurity.

Using principal factor analysis, we further score and construct household-specific indices for the identified factors within the sample. Accordingly, for the two factors extracted above, we calculate the food insecurity index (FII) and the severe food insecurity index (SFII) for each household through linear combinations between observed variable values and factor loadings. These indices are normally distributed across the sample with mean zero and standard deviation of one. Like the HFIAS score, higher positive index values indicate higher levels of food insecurity. Noteworthy is that these indices represent relative food insecurity within the sample and are best used when comparing the extent to which one household differs from another within the same sample.

We take advantage of this principle to compare the two constructed indices across F&V producers and nonproducers within our sample. Figure 4.2 shows that F&V producers have lower mean index values than nonproducers, suggesting that F&V producers are relatively more food secure. Alternatively, we can categorize a full sample into quartiles using FII, rendering food-secure, mildly food-insecure, moderately food-insecure, and severely food-insecure households. The percentage of F&V producers and nonproducers falling under each food-security category can then be compared. Figure 4.3 shows that the proportion of food-secure and mildly food-insecure households is higher among F&V producers, whereas the proportion of severely and moderately food-insecure households is higher among nonproducers.

Figure 4.2—Mean relative food-insecurity scores by fruit and vegetable production status

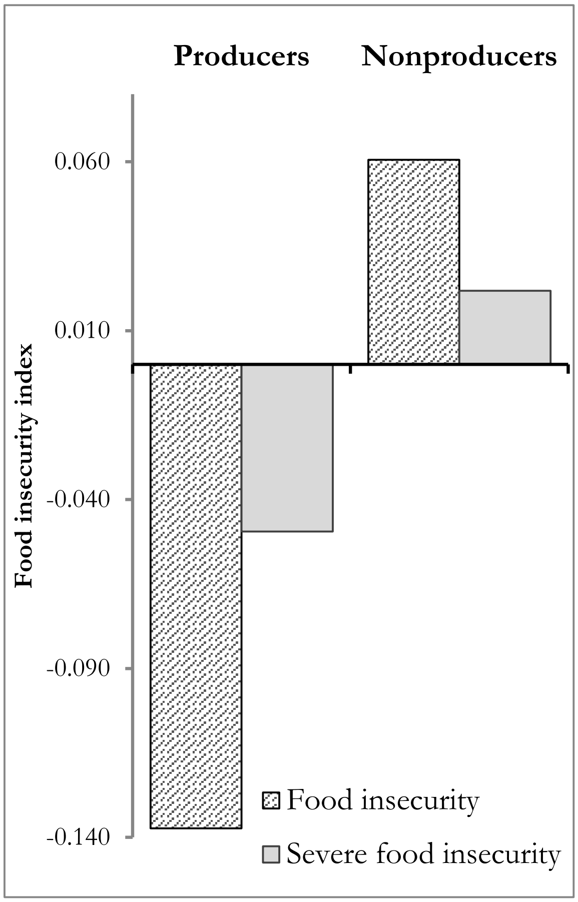
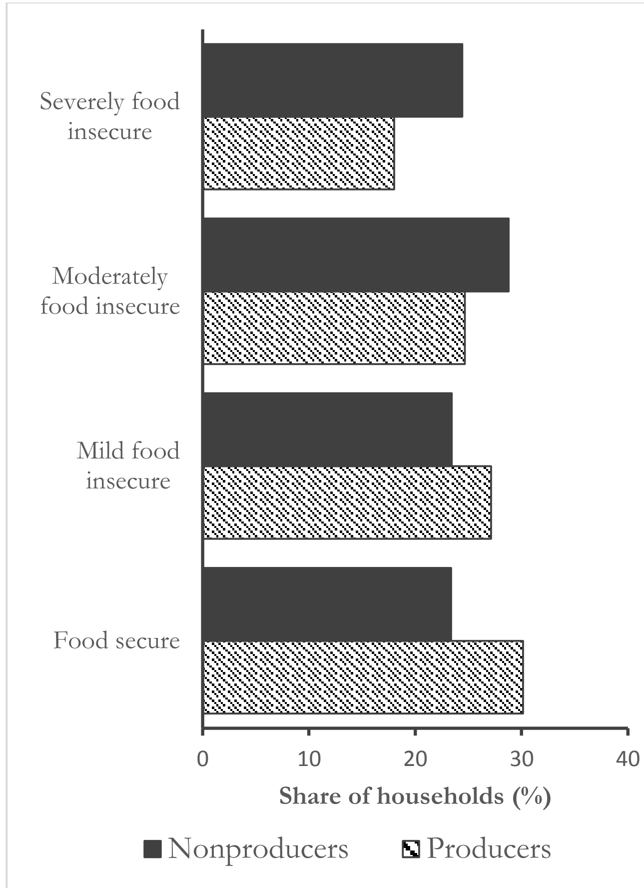


Figure 4.3—Proportion of food-insecure households by fruit and vegetable production status



Source: Authors' calculation based on survey data, 2012

Instructive as these comparisons are, we cannot confidently claim at this point that F&V production causes a positive effect on household food security. This is because of potential selectivity bias. In the next section, we explain how we account for the bias and use the derived FII and SFII indices as outcome indicators.

5. Establishing Casual Linkages of F&V Production

Comparison of Sample Outcomes

Table 5.1 presents the description and comparison of several outcome indicators of interest in F&V producers and nonproducers. The derivation of these indicators was detailed in the previous sections. Comparisons show that caregivers living in F&V-producing households consume significantly more F&Vs as compared with their counterparts in nonproducing households. As also observed earlier, F&V producers are relatively more food secure than are nonproducers. Consequently, these findings are likely to affect the hemoglobin count levels and anemia incidence in women caregivers living in F&V-producing households[4] (4 percentage points higher among nonproducers) as also illustrated in Figure 5.1.

Table 5.1—Comparison of outcome indicators across fruit and vegetable producer categories

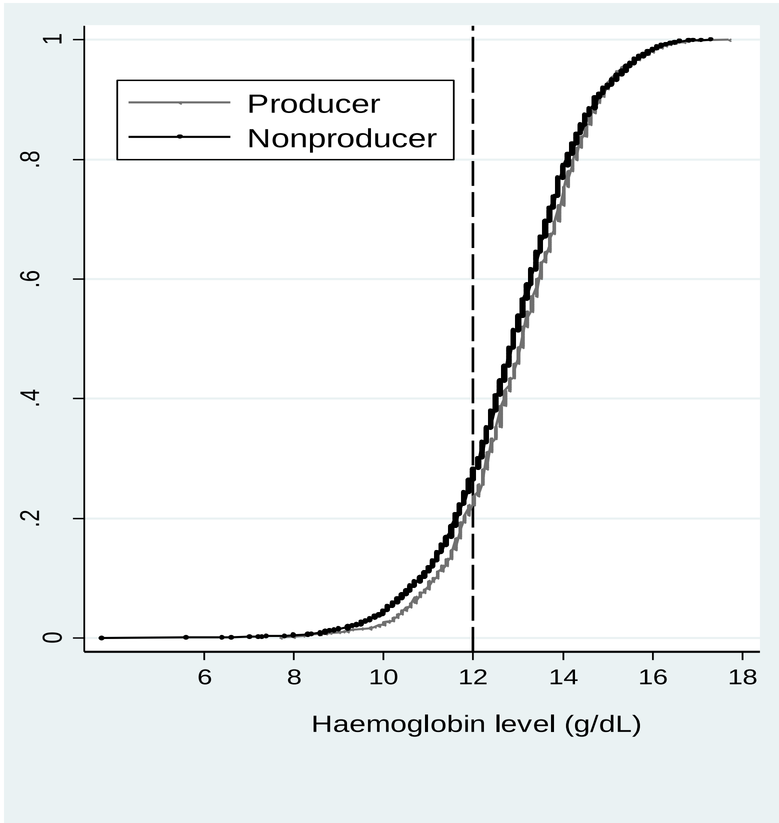
Outcome	Variable description	Producers	Nonproducers	*t*-value
Consumption	Dummy: 1 if caregiver ate a fruit or vegetable in previous 24 hours; 0 otherwise	0.77 (0.42)	0.60 (0.49)	10.20***
Food insecurity index (FII)	Continuous: derived as food insecurity scores based on loadings on Factor 1	–0.14 (0.93)	0.06 (0.93)	–5.88***
Severe food insecurity index (SFII)	Continuous: derived as food insecurity scores based on loadings on Factor 2	–0.05 (0.81)	0.02 (0.89)	–2.28**
Hemoglobin	Continuous: hemoglobin count of women aged 15–49 years in grams per deciliter, adjusted for altitude and malaria	13.03 (1.47)	12.84 (1.58)	3.34***
Anemia (%)	Dummy: 1 if hemoglobin level for woman caregiver is below 12; 0 otherwise	21.37 (41.01)	25.47 (43.57)	–2.65***
Mild anemia (%)	Dummy: 1 for hemoglobin levels above 10 and below 12; 0 otherwise	7.75 (26.76)	10.26 (30.34)	–2.37**
Moderate anemia (%)	Dummy: 1, for hemoglobin levels above 7 and below 10; 0 otherwise	13.53 (34.22)	14.85 (35.57)	–1.04
Severe anemia (%)	Dummy: 1 for hemoglobin levels below 7; 0 otherwise	0.10 (3.00)	0.36 (5.98)	–1.42

Source: Authors' calculations based on survey data, 2012

Note: Figures in parentheses are standard deviations. *** and ** denote that the difference is statistically significant at the 1% and 5% levels, respectively.

[4] Note that anemia incidences and hemoglobin counts in the women caregivers were adjusted for altitude, pregnancy, and malaria.

Figure 5.1─ Hemoglobin levels of women caregivers living in producers and nonproducers households



Source: Authors' calculation based on survey data, 2012

Notes: Hemoglobin counts adjusted for altitude, malaria and pregnancy; individuals with hemoglobin levels below 12g/dL are considered anemic.

Again, due to potential selectivity, we cannot conclusively claim causality based on this descriptive analysis. In the next section, we introduce and explain how we account for the selectivity bias in an econometric framework.

Analytical Framework

We use PSM methods to estimate the causal effects of F&V production on household food security, F&V intake, and women caregivers' anemia levels in a cross-sectional sample without random placement. PSM balances the distributions of observed covariates between a treatment and a control group based on similarity of their predicted probabilities of being selected (that is, their propensity scores). The method does not require a parametric model linking placement to outcomes; thus, it allows estimation of mean net effects without arbitrary assumptions about functional forms and error distributions. We exploit this flexibility to eliminate bias and test for the presence of potentially complex interaction effects.

Two groups are identified: those households that produce F&V crops on their farms, wild or cultivated (denoted $D_i = 1$ for household *i*) and those that do not ($D_i = 0$). Household units with F&V crops (the treated group) are matched to households without (the control group) on the basis of the propensity score,

$$\Pr(D_i = 1 | x_i) \equiv \mathrm{p}(x_i), \qquad [0 < \mathrm{p}(x_i) < 1], \tag{1}$$

where x_i is a vector of observed control variables that determine selection into F&V production.

In our estimations, we use predicted values from standard probit models to estimate the propensity score for each observation in the treated and control group samples (Caliendo and Kopeinig 2008). Using the estimated propensity scores, matched pairs are constructed on the basis of how close the scores are across the two samples. Observations without appropriate matches are dropped from further analysis.

Several matching methods are proposed in the literature (Caliendo and Kopeinig 2008). We use the nearest neighbor matching (NNM) with replacement and kernel-based matching (KBM) methods. The NNM consists of matching each adopter with a nonadopter that has the closest propensity score. We use the nearest five neighbors, which takes the average outcome measure of the closest five matched control observations as the counterfactual for each treated observation. For KBM, all treated observations are matched with a weighted average of all control observations, using weights that are inversely proportional to the distance between the propensity scores of treated and control observations.

Using matched observations, we calculate the average treatment effect on the treated (ATT) as the mean difference in outcome, y_i, of treated and control observations that are matched and balanced on the propensity scores:

$$ATT^{psm} = \mathrm{E}[y_{1i}|D_i = 1, p(x_i)] - \mathrm{E}[y_{0i}|D_i = 0, p(x_i)]. \quad (2)$$

Equation (2) requires that the assumption of common support condition, which requires substantial overlap in covariates between treated and control group, is satisfied, so that observations being compared have a common probability of both belonging to the treated and control category.

Moreover, it is important to check whether the matching procedure balances the distribution of the relevant variables in the treated and control groups by comparing the situation before and after matching and then checking whether any differences remain after conditioning on the propensity score (Caliendo and Kopeinig, 2008). Pseudo-R^2, which indicates how well the covariates x_i explain the adoption probability, should be fairly low after matching, because there should be no systematic differences in the distribution of covariates between both groups (Sianesi, 2004). We do this and report further below.

PSM cannot control for bias due to unobservables. For this reason, we test the robustness of our results by using different matching algorithms (described earlier). Moreover, we test whether unobservables might affect our estimates using the bounding sensitivity tests (Rosenbaum, 2002). We are confident of the feasibility of the approach in getting us as close as possible to statistical identification of the net effects of F&V production on nutrition outcomes. Failure to control for heterogeneity in individual, household, and locational characteristics, as would be done in ordinary least squares regressions, severely biases the estimates.

The Probit Model

The probability of participation in an intervention is vital in estimating its net effects. F&V producers and nonproducers differ in several dimensions that could be relevant to household-level F&V production decisions. It also has policy implications within the context of the promotion of F&V production. In this section, we estimate a probit regression to predict the probability of a household being an F&V producer. Our selection of variables for potential determinants of F&V production (Table 3.2) is guided by theory, literature, and intuition. Accordingly, F&V production is determined by a range of covariates comprised of individual, household, and farm characteristics, including demographics, education of household head and caregiver, assets holding, housing conditions, affiliation to social organizations, and sources of agricultural and nutrition information. We include district dummies to account for district fixed effects. Table 5.2 reports the estimates of the probit regression where the binary outcome takes a value of 1 if the household grows F&V crops and 0 otherwise. The model achieves a relatively good fit with pseudo-R^2 of 14 percent.

Table 5.2—Probit (selection) model

Dependent variable: *F&V production 1/0*	Coefficient (SE)	*z*-value
Age, household head	–0.01 (0.01)	–0.85
Age, household *squared*	0.00 (0.00)	0.52
Sex, household head	–0.03 (0.10)	–0.27
Education, household head	–0.01(0.01)	–0.68
Age, caregiver	0.00 (0.02)	0.18
Age, caregiver *squared*	0.00 (0.00)	0.20
Education, caregiver	0.01 (0.01)	1.55
Household size	0.03 (0.01)**	2.40
Male share	0.19 (0.12)	1.62
Farm size	0.00 (0.00)	0.91
Housing index	0.15 (0.15)	0.95
Livestock value	0.01 (0.01)	1.23
No latrine	0.41 (0.39)	1.05
Water source	–0.09 (0.02)***	–3.92
Garbage pit	0.13 (0.05)***	2.65
Household owns:		
– Radio	0.11 (0.06)*	1.94
– Telephone	0.10 (0.06)*	1.84
– Motorcycle	–0.14 (0.13)	–1.08
Annual income	–0.01 (0.02)	–0.53
Off-farm income	0.16 (0.06)***	2.62
Affiliation to social groups:		
– Caregiver	0.02 (0.06)	0.36
– Household head	0.17 (0.06)***	2.93
– Other members	0.21(0.10)**	2.14
Household receives agricultural information from:		
– Posters	0.80 (0.28)***	2.83
– Stockists	–0.02 (0.12)	–0.19
– Social facility	0.10 (0.08)	1.22
– Extension	–0.04 (0.06)	–0.63
– Others	0.03 (0.07)	0.43
Household receives nutrition information from:		
– Posters	0.05 (0.25)	0.18
– Health facilities	–0.04 (0.06)	–0.72
– Social facility	0.35 (0.10)***	3.62
– Health extension	0.03 (0.06)	0.45
– Others	0.09 (0.08)	1.11
Cash crops	0.20 (0.07)***	2.74
Intercropping	0.30 (0.06)***	4.92
District fixed effects included	*Yes*	
Constant	–1.49 (0.32)***	–4.64
N	*3,452*	
LR	*612.5****	
Pseudo-R^2	*0.14*	
Log likelihood	*–1,812.85*	

Source: Authors' calculations based on survey data, 2012

Notes: Figures in parentheses are standard errors. ***, ** and * denote that the coefficient is significant at the 1%, 5% and 10% levels, respectively. SE=standard errors

Although the objective of such a model is not to explain F&V production decisions, per se, a few results are noteworthy. Household size has a positive and significant effect on the probability of F&V production: larger households will certainly require more food and may therefore tend to cultivate a greater variety of food items, including F&V, for food self-sufficiency and income generation. Households closer to water sources are more likely to grow F&V crops, which is plausible, because most vegetables require more care than other traditional food crops, often including additional irrigation. A household's possession of a garbage pit, radio, telephone, or off-farm income is positively associated with F&V production. This emphasizes the role of information in influencing cropping decisions and may demonstrate that an extra source of income is vital to procuring more inputs, such as seed, fertilizers, and labor required for F&V production. Affiliation to social groups is significant and positively associated with F&V production; however, this is only relevant when the household head and other household members (and not the caregiver) are affiliated. Agricultural information on posters, fliers, and leaflets is positively associated with F&V production, and nutrition information acquired from social and religious facilities, such as churches, increases the probability of F&V production.

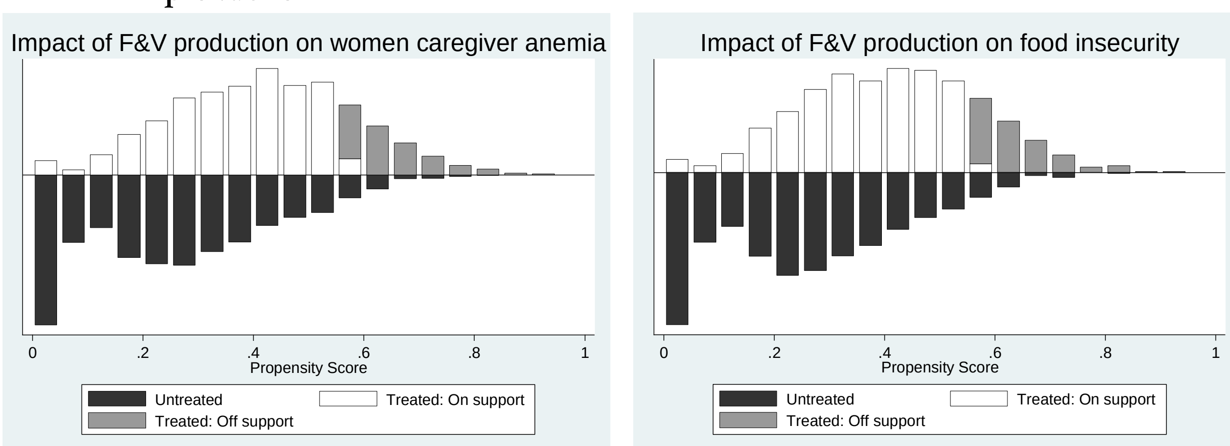
Finally, households that grow nontraditional cash crops and those that practice intercropping are more likely to also produce F&V crops. This particularly makes sense because households are able to integrate F&V crops within other crop mixes, especially when land and resource constraints exist (as shown earlier).

Matching and Balancing Tests

Using the propensity scores estimated from the probit regression, we can match F&V producers to nonproducers. We employ the NNM method with five neighbors to improve the chances of getting better matches. To compare our estimates, we also use the KBM method.[5] In both matching methods, we impose common support and try trimming extreme 20 percent of treatment observations to improve model specification and common support (Stuart 2010). Moreover, as will be explained later, we performed sensitivity analyses to test the stability of our ATT estimates.

Figure 5.1 shows the histograms of propensity scores for F&V producers and nonproducers. The condition of common support is fulfilled, because there is substantial overlap of propensity score distributions. The overlap also shows that the majority of F&V producers are comparable to the majority of the nonproducers in several aspects.

Figure 5.2─Propensity score distribution and common support for the impact of F&V production



Source: Authors' calculations based on survey data, 2012
Note: F&V = fruits and vegetables

Diagnostics are a crucial element of using propensity score methods. In particular, one has to ensure that observed covariate distributions of treated and control groups are balanced after matching to facilitate comparability (for details, see Caliendo and Kopeinig, 2008; Stuart, 2010). We therefore performed covariate-balancing tests after matching. Tables 5.3 and 5.4 show the quality of the match. Table 5.3 reports the means of all covariates for F&V producers and nonproducers before and after

[5] For robustness checks, we also use radius matching methods, which yield results similar to those from NNM and KBM. These results are available upon request.

matching. Notable changes worth mentioning: The average age of the household head is reduced for nonproducers after matching, whereas the average age of caregivers reduces for producers and slightly increases for nonproducers when observations not used as matches are dropped. Average land owned reduces for F&V producers and increases for nonproducers after matching. Similar trends can be observed for other covariates, such as sex of the household head, share of male members, housing index, ownership of a pit latrine, distance to water source, ownership of a motorcycle, affiliation of other household members to social groups, and access to agricultural and nutrition information. In the final analysis, no significant differences remain in covariates after matching.

Table 5.4 presents the results of the overall matching quality for different outcome indicators before and after propensity score estimation based on the NNM and KBM algorithms. The relatively low pseudo-R^2 and the *p*-values of the likelihood ratio test of joint significance of regressors confirm that, after matching, there are no systematic differences in the distribution of covariates between F&V producers and nonproducers. Moreover, standardized mean bias, which before matching is in the range of 13.5–13.8 percent, heavily reduces to a range of 1.7–2.2 percent after matching. Again, this rules out any chances of having a poor-quality match.

Table 5.3—Covariate balance tests

Covariate:	Unmatched sample: F&V producers	Unmatched sample: Nonproducers	Unmatched sample: *p*-value	Nearest neighbor matching: F&V producers	Nearest neighbor matching: Nonproducers	Nearest neighbor matching: *p*-value	% Bias reduction	Kernel-based matching: F&V producers	Kernel-based matching: Nonproducers	Kernel-based matching: *p*-value	% Bias reduction
Age, household head	35.37	36.35	0.03	35.50	34.97	0.38	46.50	35.50	35.23	0.65	72.90
Age, *squared*	1409.1	1467.9	0.14	1410.6	1376.7	0.51	42.40	1410.6	1386.8	0.63	59.40
Sex, household head	0.92	0.90	0.09	0.91	0.92	0.51	51.70	0.91	0.91	0.96	96.20
Education, house head	6.31	6.28	0.83	6.20	6.26	0.73	–119.50	6.20	6.24	0.81	–52.70
Age, caregiver	31.54	30.42	0.00	31.00	30.66	0.42	69.30	31.00	30.73	0.52	75.70
Age, caregiver *squared*	1074.2	994.8	0.00	1037.9	1013.5	0.42	69.20	1037.9	1018.2	0.51	75.20
Education, caregiver	3.97	4.08	0.31	3.93	3.93	0.99	98.80	3.93	3.94	0.96	92.50
Household size	6.03	6.02	0.84	5.90	5.77	0.30	–577.90	5.90	5.86	0.77	–89.50
Male share	0.50	0.49	0.05	0.50	0.50	1.00	99.60	0.50	0.49	0.67	70.10
Farm size	3.78	3.24	0.03	3.43	3.45	0.96	97.40	3.43	3.42	0.95	97.00
Housing index	–0.09	0.04	0.00	–0.09	–0.05	0.46	72.50	–0.09	–0.06	0.60	80.50
Livestock value	1.07	0.92	0.39	0.77	0.82	0.54	67.40	0.77	0.85	0.34	45.70
No latrine	0.20	0.15	0.00	0.20	0.18	0.49	72.90	0.20	0.19	0.63	81.30
Water source	0.80	0.99	0.00	0.86	0.86	0.98	99.40	0.86	0.87	0.87	95.70
Garbage pit	0.49	0.44	0.02	0.45	0.43	0.52	65.60	0.45	0.44	0.72	80.40
Household owns											
– Radio	0.65	0.62	0.15	0.62	0.63	0.89	87.10	0.62	0.63	0.93	92.30
– Telephone	0.53	0.51	0.16	0.51	0.51	0.74	68.90	0.51	0.51	0.82	78.10
– Motorcycle	0.04	0.04	0.30	0.04	0.03	0.50	19.60	0.04	0.04	0.90	84.70
Annual income	0.54	0.62	0.15	0.59	0.62	0.58	57.70	0.59	0.60	0.87	88.30
Off-farm income	0.82	0.72	0.00	0.80	0.79	0.74	93.70	0.80	0.79	0.52	87.50
Affiliation to social groups for:											
– Caregiver	0.72	0.69	0.17	0.69	0.71	0.51	37.00	0.69	0.71	0.54	41.40
– Household head	0.62	0.58	0.03	0.59	0.59	0.97	97.60	0.59	0.59	0.95	95.90
– Others	0.08	0.05	0.00	0.06	0.05	0.35	65.10	0.06	0.06	0.69	84.40
Household receives agricultural information from:											
– Posters	0.01	0.00	0.01	0.00	0.00	0.65	85.80	0.00	0.00	0.67	86.40

Covariate:	Unmatched sample F&V producers	Nonproducers	*p*-value	Nearest neighbor matching F&V producers	Nonproducers	*p*-value	% Bias reduction	Kernel-based matching F&V producers	Nonproducers	*p*-value	% Bias reduction
– Stockists	0.05	0.04	0.06	0.04	0.04	0.59	63.40	0.04	0.04	0.87	88.80
– Social facility	0.15	0.09	0.00	0.10	0.11	0.61	88.10	0.10	0.10	0.67	90.30
– Extension	0.34	0.31	0.11	0.34	0.31	0.35	22.10	0.34	0.32	0.55	49.10
– Others	0.27	0.20	0.00	0.25	0.25	0.96	98.40	0.25	0.25	0.88	95.60
Household receives nutrition information from:											
– Posters	0.01	0.01	0.07	0.01	0.01	0.71	73.50	0.01	0.01	0.86	87.20
– Health facilities	0.43	0.34	0.00	0.41	0.40	0.71	89.70	0.41	0.40	0.57	84.10
– Social facility	0.11	0.05	0.00	0.07	0.07	0.64	89.30	0.07	0.07	0.69	90.80
– Health extension	0.29	0.26	0.02	0.29	0.28	0.70	77.30	0.29	0.28	0.73	79.60
– Others	0.20	0.13	0.00	0.18	0.18	0.91	96.70	0.18	0.18	0.91	96.60
Cash crops	0.25	0.13	0.00	0.18	0.19	0.68	93.50	0.18	0.18	0.71	94.30
Intercropping	0.80	0.65	0.00	0.77	0.77	0.96	99.40	0.77	0.75	0.38	88.00

Source: Authors' calculations based on survey data, 2012
Note: District fixed effects are included in all models. F&V = fruits and vegetables.

Table 5.4—Propensity score matching quality indicators before and after matching

Outcome:	Method	Pseudo-R^2 before matching	Pseudo-R^2 after matching	$p>\chi2$ before matching	$p>\chi2$ after matching	Mean bias before matching	Mean bias after matching	Mean bias reduction (%)
Consumption	NNM	0.15	0.01	0.00	1.00	13.50	2.00	85.19
	KBM	0.15	0.00	0.00	1.00	13.50	1.70	87.40
FII	NNM	0.15	0.01	0.00	1.00	13.60	2.20	83.82
	KBM	0.15	0.00	0.00	1.00	13.60	1.70	87.50
SFII	NNM	0.15	0.01	0.00	1.00	13.60	2.20	83.82
	KBM	0.15	0.00	0.00	1.00	13.60	1.70	87.50
Hemoglobin	NNM	0.15	0.01	0.00	1.00	13.80	2.20	84.06
	KBM	0.15	0.00	0.00	1.00	13.80	1.70	87.68
Anemia in caregivers	NNM	0.15	0.01	0.00	1.00	13.50	2.00	85.19
	KBM	0.15	0.00	0.00	1.00	13.50	1.70	87.41
Mild anemia	NNM	0.15	0.01	0.00	1.00	13.50	2.00	85.19
	KBM	0.15	0.00	0.00	1.00	13.50	1.70	87.41
Moderate anemia	NNM	0.15	0.01	0.00	1.00	13.50	2.00	85.19
	KBM	0.15	0.00	0.00	1.00	13.50	1.70	87.41
Severe anemia	NNM	0.15	0.01	0.00	1.00	13.50	2.00	85.19
	KBM	0.15	0.00	0.00	1.00	13.50	1.70	87.41

Source: Authors' calculations based on survey data, 2012

Notes: KBM = kernel-based matching, NNM = nearest neighbor matching, FII = food insecurity index, SFII = severe food insecurity index.

Causal Estimates

Table 5.5 presents the key results of this paper—that is, the ATT of F&V production on F&V intake, household food security, and anemia in the primary female caregiver. The results reflect the differences in food-security outcomes between households that are F&V producers compared with the situation of those households not producing F&V crops. Similarly, the results reflect anemia outcomes between caregivers living in F&V-producing households compared with the situation of those women living in nonproducer households. We find three interesting results.

First, woman caregivers who are aged 15–49 years and living in F&V-producing households consume F&Vs more often than those living in nonproducer households. The difference of 12 percentage points is highly significant and consistent across both matching algorithms, confirming that F&V availability crucially affects F&V intake for individuals—in particular for women living in producer households. The result concurs with other studies: Bodor et al. (2008) found positive relationships between F&V availability and intake in residents of New Orleans, Louisiana. Neumark-Sztainer et al. (2003) showed that irrespective of F&V tastes and preferences, intake increased among adolescents of Minnesota if F&Vs were available at home. Peltzer and Pengpid (2012) further found that in Southeast Asia, Thai and Sri Lankan adolescents consume more F&Vs than Indonesian, Indian, and Myanmarian adolescents, mainly because of availability. High-consumption patterns in Thailand are further attributed to the fact that the Thai government had a countrywide program for school initiatives to promote increased F&V intake. It is therefore plausible to think that initiatives to promote and intensify F&V production in Uganda would have positive effects on F&V intake of women caregivers and certainly of other household members.

Table 5.5─Average treatment effects and sensitivity analysis

Outcome:	Algorithm	Mean Treated	Mean Control	ATT	*t*-value	Observations Treated	Observations Control	Critical level of hidden bias
Consumption	NNM	0.76	0.64	0.12 (0.02) ***	5.72	839	2,404	1.60–1.70
	KBM	0.76	0.64	0.12 (0.02)***	6.49	839	2,404	1.20–1.30
FII	NNM	-0.03	0.05	–0.09 (0.04)**	–2.02	830	2,386	1.20–1.30
	KBM	-0.03	0.04	–0.08 (0.04)*	–1.95	830	2,386	1.20–1.30
SFII	NNM	-0.02	0.08	–0.10 (0.04)**	–2.40	830	2,386	1.70–1.80
	KBM	-0.02	0.08	–0.10 (0.04)***	–2.82	830	2,386	2.00–2.10
Hemoglobin	NNM	13.07	12.92	0.15 (0.07)**	2.07	814	2,334	1.30–1.40
	KBM	13.07	12.94	0.14 (0.07)**	2.10	814	2,334	1.30–1.40
Anemia in caregivers (%)	NNM	20.97	24.29	-3.31(1.95)*	-1.70	839	2,404	1.50–1.60
	KBM	20.98	24.12	-3.14 (1.79)*	-1.76	839	2,404	1.40–1.50
Mild anemia (%)	NNM	13.95	14.40	-0.45 (1.64)	-0.28	839	2,404	—
	KBM	13.95	14.80	-0.85 (1.50)	-0.57	839	2,404	—
Moderate anemia (%)	NNM	7.03	9.54	-2.50 (1.27)**	-1.97	839	2,404	3.40–3.50
	KBM	7.03	8.97	-1.94 (1.17)*	-1.66	839	2,404	5.40–5.50
Severe anemia (%)	NNM	0.00	0.36	0.36 (0.16)**	-2.19	839	2,404	9.10–9.20
	KBM	0.00	0.35	0.35 (0.15)**	-2.27	839	2,404	> 10

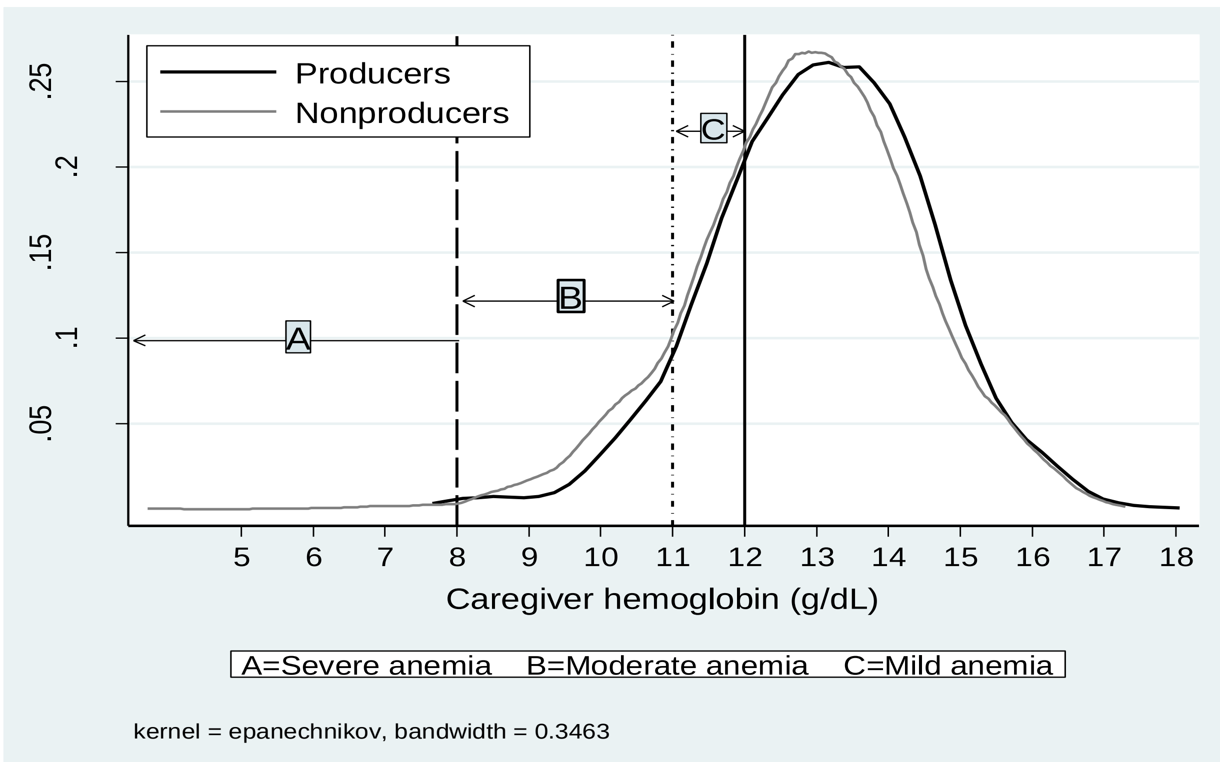
Source: Authors' calculations based on survey data, 2012

Notes: ***, **, and * denote that ATT is significant at the 1%, 5% and 10% levels, respectively. ATT = average treatment effect on the treated, KBM = kernel-based matching, NNM = nearest neighbor matching, FII = food insecurity index, SFII = severe food insecurity index.

Second, Table 5.5 also shows that F&V production significantly and positively contributes to a reduction in household food insecurity. It should be kept in mind that higher values for both FII and SFII indicate higher levels of food insecurity. Negative coefficient estimates connote improvements—reductions in relative food insecurity—and vice versa. Thus, the results in Table 5.5 suggest that F&V producers significantly reduce relative food insecurity by 0.09 index points, which is consistent across both matching methods. F&V producers significantly reduce severe food insecurity by 0.10 index points, suggesting that F&V production is more vital to the more food-insecure households. This result confirms findings reported in other contexts: the contribution of F&V toward household food security has been reported in Uganda (Rubaihayo, 2002; Musinguzi et al., 2006); Kenya (Ogoye-Ndegwa, 2003); Zimbabwe (Mithofer and Waibel, 2003); and South Africa (Mavengahama et al., 2013).

Third, the F&V intake and household food-security effects discussed earlier have direct positive effects on the micronutrient security of individuals. Table 5.5 shows that the hemoglobin levels of women living in F&V-producing households are 0.14–0.15 grams per deciliter higher than they would be had these women lived in nonproducer households. We also observe a slight shift of the curve to the right for women caregivers living in producer households when matched observations are plotted (Figure 5.3). By any means, this is a modest, but highly significant and robust, result from data that have no specific focus on nutrient-dense F&Vs under any deliberate initiative. Yet, even with these modest effects, we find that F&V production is significantly associated with lower prevalence of anemia in women caregivers—by more than 3 percent among women living in F&V-producing households, as compared with the counterfactual scenario. Literary, this translates into more than 12% reduction in anemia using sample mean values as the reference. Notably, the benefits of F&V production accrue most to those women who are severely or moderately anemic, as also further illustrated by matched comparisons in Figure 5.3: The shift to the right for the curve of women caregivers living in producer households is more pronounced in the region of moderate anemia (B) and a long tail to the left in the region of severe anemia is only visible for women caregivers living in nonproducer households. These results are not implausible. F&Vs (including those gathered from the wild) are important sources of micronutrients when consumed to supplement high-caloric staples, but they also act as alternative food sources to households and individuals that face poverty and famine in most African communities.

Figure 5.3—Kernel density curves for hemoglobin levels of caregivers living in matched producer and nonproducer households



Source: Authors' calculations based on survey data, 2012

6. Conclusions

This paper has analyzed the potential causal relationship among F&V production, F&V intake, household food security, and anemia outcomes of individual women caregivers in rural smallholder farming communities of Uganda. Making a direct argument for the intensification of smallholder F&V

production, we contribute empirically to the rare literature evaluating and drawing pathway linkages among agricultural production, nutrition, and health outcomes.

Methodologically, we contribute to literature by using a qualitative tool, the HFIAS, to measure household food security quantitatively in a comparative and impact-assessment framework. The HFIAS is composed of relatively simple and easy-to-implement survey questions that capture multidimensional concepts of household food security. The tool also captures subjectively perceived risks of food insecurity, which is not the case for alternative approaches, such as dietary recalls or anthropometric indicators. With a stronger and larger dataset collected from a different context, we obtain robust and consistent results with the HFIAS tool, as also reported by Kabunga, Dubois, and Qaim (2014). We thus are able to recommend its wider use in other studies of this nature.

Empirically, we find that women caregivers aged 15–49 years and living in F&V-producing households consume more F&Vs than those living in nonproducer households. Econometric estimations using propensity score matching reveal that own F&V production increases F&V intake for caregivers by 12 percent. Compared with other studies in other contexts, we confirm that household-level F&V availability crucially influences the F&V intake of those households, irrespective of tastes and preferences.

Using indices derived from the HFIAS factor analysis, descriptive statistics show that the share of food-secure households is comparatively higher among F&V producers than among nonproducers. Econometric estimations later show that F&V production contributes positively to household food security, with F&V producers seen to reduce food insecurity by 0.09 index points and severe food insecurity by an even higher rate of 0.10 index points. This positive association is attributed to high F&V intake among those individuals living in F&V-producing households and the fact that F&V are an important part of the food mix and diversity, especially for the poor (as also reported from other literature).

We further show that F&V intake and household food-security effects, as a direct result of F&V production, have positive effects on anemia levels for women living in F&V-producer households. Hemoglobin levels of women living in F&V-producer households are seen to increase by 0.14–0.15 grams per deciliter, which is a rather modest but highly significant contribution, with implications for anemia in women of reproductive age. The prevalence of anemia is reduced significantly among women living in F&V-producer households with potential to reduce anemia by more than 12 percent. Importantly, the benefits of F&V production accrue most to those women who severely or moderately face higher anemia levels.

Our results suggest that F&V production is beneficial for food security and ultimately anemia status of individuals—in particular, women of childbearing age. These results are obtained from rural communities where no known interventions to promote F&V consumption or to intensify smallholder F&V production systems exist. The results would certainly be larger if these interventions were deliberately initiated. With the evidence presented here, we are somewhat convinced that smallholder F&V intensification, as one of the food-based strategies to reduce malnutrition, should be initiated in rural Ugandan communities and other countries in similar contexts. The potential benefits of F&V intensification certainly go beyond household welfare benefits to local economywide wage and employment effects, poverty alleviation, and integration in high-value markets if market and other institutions bottlenecks are addressed. Further research is needed to particularly understand these economywide effects.

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