FARM HOUSEHOLDS' AGRICULTURAL COMMERCIALISATION, AND FOOD AND NUTRITION SECURITY IN GHANA

BY

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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DOCTOR OF PHILOSOPHY IN APPLIED AGRICULTURAL ECONOMICS AND POLICY DEGREE

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DECLARATION

I, Benjamin Musah Abu, do hereby declare that except for the references cited, which have been duly acknowledged, this work, "**Farm Households' Agricultural Commercialisation, and Food and Nutrition Security in Ghana**", is a product of my own research undertaken in the Department of Agricultural Economics and Agribusiness, School of Agriculture, College of Basic and Applied Sciences, University of Ghana. I declare that it has never been submitted in whole or in part for any other degree in this University or elsewhere.

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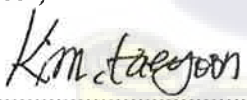

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DEDICATION

This work is dedicated to my wife (Margaret Nasonaa Mahamudu) for her inspiration and unflinching support, my daughter (AnnMarie Deishina Abu), my parents (Mr. and Mrs. Musah Emmanuel Abu), my sister (Lily Musah Abu), my late brother (Asher Musah Abu), and all my family.

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ABSTRACT

Previous studies have provided valuable evidence to guide and shape policies to improve agricultural commercialisation. However, there are still lingering challenges globally with respect to the scope and measurement of agricultural commercialisation, as well as its impact on food and nutrition security. The purpose of this thesis is to contribute new evidence by developing and estimating the determinants of an extended metric of agricultural commercialisation that captures crop and livestock dimensions of commercialisation (named household crop-livestock commercialisation index). It also estimated the impact of this extended metric on various food and nutrition security outcomes and developed and estimated a quadruple-hurdle model of commercialisation as an extension of the triple-hurdle model. Secondary data involving 14,009 households from the Ghana Living Standards Survey round 7 (GLSS7) collected by the Ghana Statistical Service were used to achieve the objectives of this study. To validate findings, primary data were collected from 858 farm households in northern Ghana. The extended metric, household crop and household livestock commercialisation indices were used to estimate the level of commercialisation. Fractional regression was applied to estimate the determinants of the extended metric of commercialisation. In estimating the impact of commercialisation on food and nutrition security outcomes, instrumental variable (IV) approaches were used to account for endogeneity and selectivity of commercialisation, while conditional mixed process was applied to estimate the quadruple-hurdle model. The estimate of the level of commercialisation indicates surplus-oriented agriculture for the crop-livestock metric (26.44%) and crop metric (35.20%), but subsistent-oriented agriculture for the livestock metric (10.94%). The main determinants of the extended metric of agricultural commercialisation are ownership of nonfarm enterprise, bank and agricultural cooperative in community, number of crops cultivated, agricultural land endowment, presence of community market, navigable road to community and access to public transport. Therefore, infrastructure, institutional and production scale variables are vital in boosting agricultural commercialisation in Ghana. Evidence of the impact of commercialisation shows that higher crop-livestock commercialisation improves food and nutrition security of farm households in Ghana. This observation is robust to the use of alternative econometric approaches. In estimating the factors that influence four hurdles of agricultural commercialisation, namely production, sale, market choice and intensity of sale, the key factors that simultaneously determine these four hurdles are presence of bank and market in community, crop production diversity, navigable road to community, availability of public transport, agricultural cooperative in community and household size. Investments that boost infrastructure in agricultural producing areas and promote the effectiveness and efficiency of farmer institutions is critical to induce a shift from subsistent focused to commercially oriented production. Creating specific alternative livestock production and marketing-centred strategies by the Ministry of Food and Agriculture (MoFA) is imperative. The link between commercialisation and food and nutrition security suggests that it is important for Ghana to develop well-functioning food systems through enhancing effective institutional collaborations and cooperations (especially among the Ministry of Health, Ministry of Trade and Industry and MoFA) and strengthening policy that creates an enabling environment within the food value chain.

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LIST OF ABBREVIATIONS

AfDB	African Development Bank
CAPI	Computer-Assisted Personal Interviews
CIMPS	Crop Input Market Participation Share
CMP	Conditional Mixed Process
FAO	Food and Agriculture Organisation
FASDEP	Food and Agriculture Sector Development Policy
FBO	Farmer Based Organisation
FCS	Food Consumption Score
FIES	Food Insecurity Experience Scale
FOC	First Order Condition
GCAP	Ghana Commercial Agriculture Project
GCX	Ghana Commodity Exchange
GDP	Gross Domestic Product
GHS	Ghana Cedi
GLSS	Ghana Living Standards Survey
GMM	Generalised Method of Moment
GPRS	Growth and Poverty Reduction Strategy
GSGDA	Ghana Shared Growth and Development Agenda
GSS	Ghana Statistical Service
Ha	Hectare
HAZ	Height-for-Age Z-score
HCCI	Household Crop Commercialisation Index
HCLCI	Household Crop-Livestock Commercialisation Index
HDDS	Household Dietary Diversity Score
HFIAS	Household Food Insecurity Access Scale
HHS	Household Hunger Scale
HLCI	Household Livestock Commercialisation Index
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IMR	Inverse Mills Ratio
IV	Instrumental Variable
LM	Langrange Multiplier
METASIP	Medium-Term Agriculture Sector Investment Plan
MICS	Multiple Indicators Cluster Survey
MLE	Maximum Likelihood Estimation
MoFA	Ministry of Food and Agriculture
MOI	Market Orientation Index
MT	Metric tonnes
NNP	National Nutrition Policy
OLS	Ordinary Least Squares
PFAG	Peasant Farmers Association of Ghana
RING	Resiliency in Northern Ghana
SAP	Structural Adjustment Programme
SDGs	Sustainable Development Goals
SPRING	Strengthening Partnerships, Results, and Innovations in Nutrition Globally
SRID	Statistics, Research and Information Directorate
UN	United Nations
UNICEF	United Nations Children's Fund

USAID	United States Agency for International Development
WAZ	Weight-for-Age Z-score
WDI	World Development Indicators
WFP	World Food Programme
WHO	World Health Organisation
WHZ	Weight-for-Height Z-score

CHAPTER ONE

INTRODUCTION

1.1 Background

Agriculture plays an important role in the socioeconomic development of Africa. It employed an average of 41.99% of the total labour force on the continent in 2022, contributed to an average of 18.44% to the continent's gross domestic product (GDP) in 2023 and recorded an average annual growth rate of 1.69% in 2023 (World Bank, 2024).[1] Generally, agriculture leads the process of economic growth at the macro level, as evidenced in its contribution to GDP, and poverty reduction of farm households at the micro level in most African economies (Diallo & Wouterse, 2023; Dorosh & Thurlow, 2018). Thus, agriculture holds the key to achieving some of the Sustainable Development Goals (such as no poverty [SDG 1], zero hunger [SDG 2], and decent work and economic growth [SDG 8]).

Agriculture faces numerous challenges that impede its potential to exert the needed socioeconomic development of the continent. The major challenges of agriculture enumerated by various agricultural policy documents, researchers and stakeholders are low mechanisation, and adoption of modern and efficient technologies (e.g., Bambio et al., 2022; Matita et al., 2022; Sheahan & Barrett, 2017; Vandercasteelen et al., 2020), low investments in the sector, especially in growth-inducing infrastructural facilities such as roads, irrigation, electricity, storage and telecommunication (e.g., Villacis et al., 2022), poor access to input and output markets (e.g., Sibhatu et al., 2022; Villacis et al., 2022), inadequate supply of finance and credit to the sector due to risk considerations by the financial sector, poor

[1] These data are from 53, 49 and 49 African countries respectively for employment, GDP and GDP growth.

management of land and water resources due to unsustainable and traditional farming methods (African Development Bank, 2016), and land tenure and fragmentation challenges (e.g., Azadi et al., 2021; Chitonge & Harvey, 2022; Robinson & Flintan, 2022). These challenges are exacerbated by climate change and variability (Gowda et al., 2018; Ziska et al., 2016).

Beyond the challenges enumerated above, one important characteristic of African agriculture that demands attention is the dominance of smallholder farmers, who represent more than 60% of all farmers in Africa (Goedde et al., 2019). This set of farmers represents one of the development challenges of agriculture on the continent, as they are more constrained relative to large-scale farmers (Balana & Oyeyemi, 2022; Touch et al., 2024). Based on the dominance of smallholders, Abu et al. (2014) indicate that without recourse to these smallholders, policies to aid in the development of agriculture will not yield the desired results. The development of African agriculture that is particularly responsive to the nature of smallholder dominance is instituting strategies to promote and enhance productive and commercial agriculture (Sibhatu et al., 2022).

Perhaps, the focus on the area of commercialisation of farm households basically traces its roots to its ability to facilitate the use of improved inputs through increased input market participation, reduce poverty and improve food and nutrition security. For example, commercial agriculture increases productivity (Abdul-Rahaman & Abdulai, 2020; Barrett, 2008; Barrett et al., 2017; Ogutu et al., 2020), aids in tackling food and nutrition insecurity (Gebremedhin et al., 2009; Haggblade et al., 2007; Southgate et al., 2007), increases farm incomes (Aku et al., 2018; Barrett et al., 2017; Carletto et al., 2017; Gebremedhin et al., 2009; Haji, 2022; Kilimani et al., 2022; Mmbando et al., 2015; Montalbano et al., 2018;

Muriithi & Matz, 2015; Ochieng et al., 2019; Ogutu et al., 2020), reduces poverty (Ogutu & Qaim, 2019), reduces food prices emanating from lower costs and competition (Jayne et al., 1996), holds great potential for rural development (Kuijpers, 2018), and stimulates economic growth and development (Carletto et al., 2017; Ogutu et al., 2020; Rashid et al., 2010; von Braun, 1995).

The potential role of commercial agriculture in stimulating food and nutrition security is recognised in the literature (e.g., Koppmair et al., 2017; Nkegbe & Abdul Mumin, 2022; Ochieng et al., 2015, 2019; Seng, 2016; Sibhatu et al., 2022; Usman & Haile, 2022). Achieving food and nutrition security is a global development challenge. Food and nutrition security have been recognised as a fundamental human right (UN, 2010) and have potential for achieving economic, social and human development. In general terms, Africa faces more food and nutrition insecurity relative to other continents. UNICEF et al. (2020) note that two-fifths of all stunted children, a quarter of all overweight children and more than a quarter of all wasted children under 5 worldwide reside in Africa. The consequences of nutritional deficiencies (e.g., malnutrition) include infant mortality (Behrman et al., 2004), adverse effects on school attendance and performance, and cognitive capacity (Maluccio et al., 2009), low labour productivity, wages, and economic growth (Horton & Ross, 2003).

Issahaku and Abu (2024) indicate that the food security and nutritional challenges in Africa is paradoxical since food production is a primary business on the continent. They further note that this paradox motivates the increased calls for adopting food security and nutrition-sensitive agricultural policies and interventions. For example, interventions in promoting agricultural commercialisation hope that these interventions will improve food and nutrition security (Anderman et al., 2014; Carletto et al., 2017; Linderhof et al., 2019). From both

policy and empirical perspectives, farm households' agricultural marketing, and food and nutrition security are key issues in the agricultural development landscape. Thus, this study's purpose is to explore farm households' agricultural commercialisation and its impact on food and nutrition security.

While agricultural commercialisation does not have a unique definition, it is generally defined as a sustained shift from subsistent-dependent and consumption-focused production to a market-focused production (see e.g., Abafita et al., 2016; Omiti et al., 2009; Pradhan et al., 2010). Agricultural commercialisation occurs when farm households engage in markets to either sell their crop produce and livestock and/or buy produce and inputs (Barrett, 2008). There is consensus on the basic tenets of agricultural commercialisation in the literature. These are: (i) farmers participating in the markets to sell their crop produce or buy crop produce, referred to as their participation in the crop output market; (ii) farmers participating in the markets to sell their livestock produce, referred to as their participation in the livestock output market; and (iii) farmers participating in the markets to buy essential inputs for production, referred to as their participation in the input market (Alene et al., 2008).

Therefore, agricultural commercialisation involves farm households participating in two markets; (i) the output market, where crops and livestock produce are sold or bought and, (ii) the input market, where inputs are sourced for production. This dualistic market setting provides one of the bases for the varied definitions of agricultural commercialisation in the literature. Previous studies (Govereh et al., 1999; Rios et al., 2008; Strasberg et al., 1999) defined agricultural commercialisation to reflect farmers' crop output market participation. In this case agricultural commercialisation is defined as the proportion or fraction of farmers' total crop production that is sold. Most of the empirical literature has conceptualised

agricultural commercialisation following this definition (e.g., Abu et al., 2016; Alhassan et al., 2020; Boughton et al., 2007; Burke et al., 2015; Chegere & Kauky, 2022; Haji, 2022; Kilimani et al., 2022; Olwande & Mathenge, 2012; Omiti et al., 2009; Reyes et al., 2012).

Interestingly, the livestock output market and the input market dimensions of commercialisation have not received considerable attention as compared to the crop output commercialisation, they have been emphasised in the literature and argued to be very significant in defining commercialisation. For example, Pingali (1997) and Jaleta et al. (2009) have emphasised that agricultural commercialisation entails far more than just selling produce in the market and is achieved when the principles of profit maximisation guide farmers' decisions on product choice and input use. Alemu et al. (2006) and Jaleta et al. (2009) share similar views on incorporating other dynamics beyond crop marketing in defining commercialisation. In support of this, recent studies (e.g., Belay et al., 2021; van Asselt & Useche, 2022) have emphasised the importance of the livestock sub-sector to commercialisation.

Based on these arguments, this study adopts a concept of agricultural commercialisation that encapsulates a two-fold dimension of crop output market participation and livestock output market participation. With this conceptualisation, this study defines agricultural commercialisation as farmers' continuous shift from subsistent production into profitable market-oriented production through engagement in markets to sell crops and livestock. The input dimension of commercialisation has not been pursued because of the apparent complexity in adding it to the crop and livestock dimension. For example, government input subsidies to farmers are a potential confounding issue because farmers who receive such subsidized inputs do not report them. Thus, the possibility of undervaluing input use and

expenditure is apparent. Further, underlying relationship between input use and crop production is a key impediment.

Ghana has a rich history of national and agricultural policies and strategies aimed at developing the agriculture sector. After independence in the late 1950s, modernisation of agriculture was the main objective of agricultural development (Asuming-Brempong & Kuwornu, 2013; Seini, 2002). Agricultural policy focused on state-led mass participation in mechanised agriculture and industrialisation-led production. Specific agricultural policies were subsidisation of agricultural inputs and credit, price controls, government participation in agricultural production (through state farms), distribution and marketing. These strategies ignored smallholder farming in favour of large-scale job-oriented agriculture. However, the state-led large-scale intervention did not yield the desired results (Asuming-Brempong & Kuwornu, 2013; Seini, 2002).

From the late 1960s, agricultural policy shifted to capitalist-oriented agricultural development. Large-scale farms were privatised due to the increased emphasis on private ownership. Smallholder farmers received support through the establishment of singe commodity development boards, extension delivery and rural development (Asuming-Brempong & Kuwornu, 2013; Seini, 2002). Agricultural programmes such as the 'Operation Feed Yourself' and 'Operation Feed Your Industries' promoted smallholder agricultural productivity growth to boost food and raw material production. Due to severe economic challenges and the deterioration of the economy in the early 1960s to the 1970s, Economic Recovery Programme (ERP) and Structural Adjustment Programme (SAP) were initiated in the 1980s.

After the ERP and SAP in the 1980s, the Medium-Term Agricultural Development Programme was launched to boost the agricultural sector in 1988. This was succeeded by Ghana Vision 2020 in 1995 and then the Accelerated Agricultural Growth and Development Strategy implemented in 2001 as a supportive policy to the Vision 2020. By 2002, Vision 2020 was truncated and replaced by the Ghana Poverty Reduction Strategy (GPRS). To complement the GPRS with respect to the agricultural sector, the Food and Agriculture Sector Development Policy (FASDEP) was launched in 2002 and later upgraded to the FASDEP II in 2007. An implementation plan to achieve FASDEP II's objectives was drawn and implemented in 2011 as the Medium-Term Agriculture Sector Investment Plan (METASIP). Currently, the country has rolled out METASIP II which started in 2014.

1.2 Problem statement

Ghana's agricultural policies and strategies aimed at the development of agriculture share a common objective of improving farmer integration into domestic and international markets. Fundamentally, these policies acknowledge that the development of the sector and those involved in it is grounded on the need for farmers to integrate with the market to boost their incomes. Despite these policy initiatives and strategies, agricultural commercialisation is characterised as low and generally surplus-oriented in Ghana. Data from the Ghana Living Standards Survey Round 6 (GLSS6) and Round 7 (GLSS7) indicate the aggregate level of crop commercialisation to be 41.77% and 42.38%, respectively for some selected crops (Table 1.1).

The analyses in Table 1.1 shows that cereals have the lowest level of commercialisation. Further, it is observed in Table 1.1 that the level of commercialisation fluctuates. While

legumes and cereals experienced an increase in commercialisation between the two datasets, roots and tubers slightly declined.

Table 1.1: Crop harvest, sales and commercial intensity

Crop	GLSS6				GLSS7			
	Harvest value (in million GHS)	Sale value (in million GHS)	Sale intensity (%)	Crop type sale intensity (%)	Harvest value (in million GHS)	Sale value (in million GHS)	Sale intensity (%)	Crop type sale intensity (%)
Maize[a]	1,712.08	597.71	34.91		1,325.80	550.60	41.53	
Millet[a]	111.25	15.93	14.32		98.87	26.93	27.24	
Sorghum[a]	59.95	11.41	19.03	36.54	75.41	15.65	20.75	38.86
Rice[a]	258.82	157.67	60.92		269.70	94.63	35.09	
Groundnut[b]	358.63	173.98	48.51		585.45	410.84	70.18	
Beans[b]	130.92	59.47	45.42	47.69	147.44	53.53	36.31	63.36
Cassava[c]	1,553.79	525.64	33.83		1,369.82	483.69	35.31	
Cocoyam[c]	207.36	44.72	21.57		282.09	72.77	25.80	
Yam[c]	1,615.92	966.14	59.79	43.71	1,327.54	550.20	41.45	40.02
Plantain[c]	908.15	336.71	37.08		912.15	450.76	49.42	
Total/mean	6,916.86	2,889.38	41.77*	-	6,394.26	2,709.61	42.38*	-

Note(s): a, b and c represent cereals, legumes, and roots and tubers, respectively; * denotes average not total. Source: Analysis by author from the GLSS6 and GLSS7 data.

Overall, there was a marginal increase in the level of commercialisation between the two periods. Another observation that points to the challenge of stimulating agricultural commercialisation in Ghana is the number of households that decide to sell their produce (Figure 1.1).

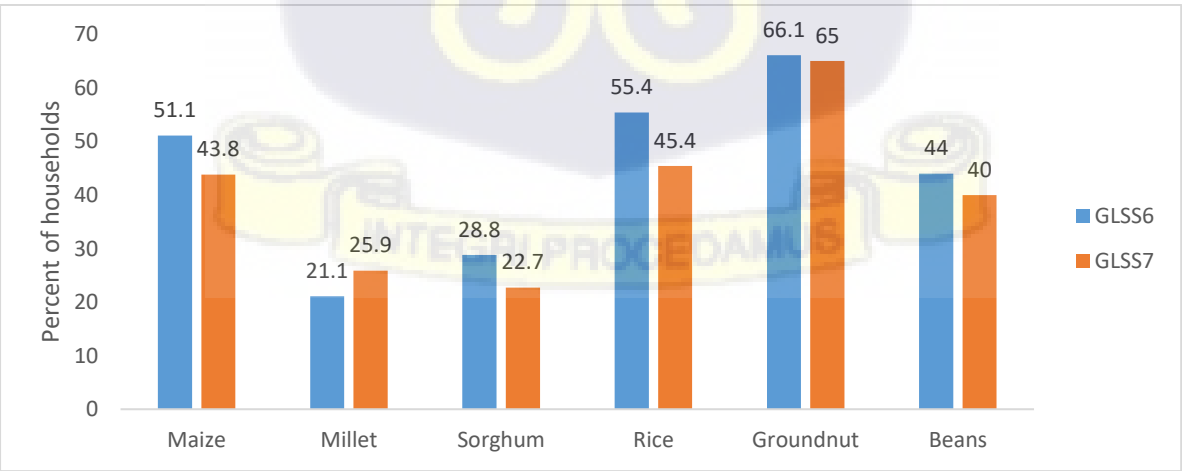


Figure 1.1: Proportion of households selling their crop produce
Source: Produced by author using GLSS6 and GLSS7 data

It is observed that only groundnut has more than 50 percent of producing households selling their produce in the two periods. Livestock commercialisation is also low and characterised as subsistent-oriented. Table 1.2 presents livestock production and sale data from the GLSS6 and GLSS7.

Table 1.2: Livestock production, sales and commercial intensity

	GLSS6			GLSS7		
Livestock	Livestock value (in million GHS)	Sale value (in million GHS)	Sale intensity (%)	Livestock value (in million GHS)	Sale value (in million GHS)	Sale intensity (%)
Cattle	2,255.93	165.16	7.32	2,695.77	173.09	6.42
Sheep	728.46	55.51	7.62	741.61	71.77	9.68
Goat	619.21	66.44	10.73	824.72	72.58	8.80
Pig	170.17	37.68	22.14	339.79	40.32	11.87
Rabbit	4.37	0.66	15.10	6.77	0.61	9.01
Chicken	562.69	102.33	18.19	442.57	39.04	8.82
Guinea fowl	62.18	10.84	17.43	43.41	11.52	26.54
Turkey	9.01	3.16	35.07	10.75	0.75	6.98
Duck	18.93	2.82	14.90	21.04	1.67	7.94
Total/mean	4,430.95	444.60	10.03*	5126.43	411.35	8.02*

Note(s): * denotes average not total. Source: Analysis by author from the GLSS6 and GLSS7 data.

The evidence shows that the levels of livestock commercialisation were respectively 10 percent and 8 percent in the GLSS6 and the GLSS7. Cattle have the lowest level of livestock commercialisation in both data. Commercialisation of all livestock declined in the GLSS7 data relative to the GLSS6 data, except sheep and guinea fowl commercialisation.

In recognition of the low agricultural commercialisation, the government of Ghana established the Ghana Commodity Exchange (GCX) to enhance commercial agriculture through the formalisation of market proceedings.[2] Traditional markets possess fundamental constraints that prevent smallholders from maximising their gains. Among these constraints is

[2] Please refer to: https://gcx.com.gh/who_we_are/ for more information on the purpose of the GCX.

the presence of high transaction costs of produce marketing and high risks emanating from price volatility (e.g., Pingali et al., 2019). Commodity exchanges reduce transaction costs, short-term price variability and spatial price dispersion, and provide better commodity risk management, adequate price information and market transparency (Rashid et al., 2010). In addition, commodity exchanges help in increasing the efficiency of market transactions (Thurow & Kilman, 2009) and boost market returns (Rashid et al., 2010). However, data show that there is low patronage of farmers in the GCX proceedings. For example, in 2022 data from the Statistics, Research and Information Directorate (SRID) of MoFA showed that out of a total production of 2,000,020 metric tonnes of maize, only 936.31 metric tonnes were traded on the GCX in 2019 (representing about 0.05%). For soyabeans, out of a total production of 213,300 metric tonnes, only 50.63 metric tonnes were traded (representing about 0.02%). One key implication of these data is that the traditional market system is still a dominant channel for smallholders to sell their produce.

Fundamentally, the low commercialisation problem can be best tackled by the government and relevant stakeholders through evidence-based policies. Therefore, one key input into policy processes requires a comprehensive understanding and evidence of commercialisation. Previous studies (Abu et al., 2016; Barrett, 2008; Bellemare & Barrett, 2006; Burke et al., 2015; Fafchamps & Hill, 2005; Goetz, 1992) have provided valuable evidence to guide and shape policies to improve agricultural commercialisation. However, there are still lingering challenges concerning: (i) the scope of agricultural commercialisation; (ii) the measurement of agricultural commercialisation; and (iii) the impact of agricultural commercialisation on food and nutrition security.

Regarding the scope of agricultural commercialisation, the development of the empirical commercialisation literature started on a foundation that commercialisation has two interlinked decisions (Bellemare & Barrett, 2006; Goetz, 1992). Before a farm household sells a specified quantity of farm produce, a first decision must be made to sell. This fundamental view of commercialisation dominated the literature until Burke et al. (2015) identified lack of comprehensiveness as its main weakness. As a result, they suggested an augmentation to the two-step view by introducing a three-step decision process: decision to produce a crop, decision to participate in the market to sell and the intensity of participation, arguing that this three-step view of commercialisation is relevant as it overcomes the limitation of previous models and provides new insights to policy formulation.

While the contribution of Burke et al. (2015) is remarkable, it failed to provide comprehensiveness to commercialisation because, commercialisation really embodies a four-step decision process, including, (i) the decision of a farmer to produce a crop in the first place; (ii) conditioned on producing the crop, the second decision to sell the crop, (iii) a third decision to decide the selling channel, and (iv) a final decision on the quantity to sell through the identified selling channel.[3] These four decision processes provide the comprehensiveness of commercialisation. Thus, the augmentation that was provided by Burke et al. (2015) overlooked the selling choices of farm households. The recognition, therefore, of a four-tiered decision process that provides comprehensiveness to commercialisation opens a methodological gap and to an extent, a policy gap that demands attention, because an empirical framework that acknowledges a four-tiered decision process would not only

[3] Apart from the first decision of production, the other decision processes depend heavily on the quantity produced.

contribute evidence to inform policy formulation, but also contribute to extending the literature.

The measurement of agricultural commercialisation has primarily focused on farmers' crop marketable surpluses, measured by the household crop commercialisation index (HCCI). Meanwhile, the definition of agricultural commercialisation embodies crop and livestock marketable surpluses (e.g., Gebreselassie & Sharp, 2007; Jaleta et al., 2009). The weakness of the HCCI in capturing the livestock dimension of commercialisation provides an important empirical niche to contribute to the literature by developing an extended metric of agricultural commercialisation, which encapsulates crop and livestock market engagements of farm households.

The link between agricultural commercialisation and farm households' food and nutrition security is expanding. However, it is generally observed that the link is not clear due to a combination of scanty, mixed, and inconclusive results (Carletto et al., 2017; Kuijpers, 2018; Kuma et al., 2019; Linderhof et al., 2019; Radchenko & Corral, 2018). The influence of country nuances in investigating the link cannot be overemphasised. For example, in Africa, there is marked heterogeneity across regional, sub-regional and country-level (Beck et al., 2015). There are nuances pertaining to economic and financial structures, colonial and political ideology, and socio-cultural characteristics. Therefore, evidential conclusions from country-level studies across the world and especially in Africa may be inappropriate to impose on other countries. This observation calls for more country-level studies across the developing world.

In Ghana, the examination of the commercialisation-food and nutrition security links is thin, though most agricultural policy documents and strategies aim to address these. The study of Ecker (2018) focused on the effect of agricultural transformation (measured by farm production diversity) on food and nutrition security. A notable study that directly tackled this link is that of Abdul Mumin and Abdulai (2022), who specifically estimated the impact of smallholder market participation on food and nutrition security. However, this contribution is limited by its concentration in northern Ghana instead of the whole country. Meanwhile, there are sharp differences between the country's northern and southern divide in terms of agro-ecological characteristics and resource endowments. Thus, it may be problematic to generalise conclusions to the entire country.

Another weakness of the study is its general limited metrics for food and nutrition security, measuring these by constructing the consumption score of nutrient-rich foods. A more nuanced analysis that employs various measures would be more helpful, especially in determining the robustness of estimates. Further, a study by Nkegbe and Abdul Mumin (2022) examined the impact of community development initiatives and access to community markets on household food security and nutrition in Ghana. Whiles this study considered a variety of food and nutrition security measures (including household dietary diversity score, food consumption score, and consumption of protein, iron, and vitamin A), the concentration is on the impact of community market access, which is only a proxy for agricultural commercialisation.

Based on the foregoing issues, this study aims to fill the measurement and scope gaps, and expand the literature on the impact of agricultural commercialisation by providing responses to the following key questions:

1. What is the level of an extended metric of agricultural commercialisation in Ghana?
2. What are the determinants of the extended metric of agricultural commercialisation in Ghana?
3. What is the impact of the extended metric of agricultural commercialisation on household food and nutrition security outcomes in Ghana?
4. What factors simultaneously influence production, selling decision, market choice and intensity of agricultural commercialisation in Ghana?

These questions are imperative and providing responses to them are key ingredients in the agricultural policy processes in Ghana on the one hand and contributing to the literature on the other hand.

1.3 Objectives of the study

The overall objective of this study is to examine the determinants and the impact of agricultural commercialisation on household food and nutrition security in Ghana. The specific objectives are:

1. To develop and analyse the level of an extended metric of agricultural commercialisation in Ghana.
2. To estimate the determinants of the extended metric of agricultural commercialisation in Ghana.
3. To estimate the impact of agricultural commercialisation on household food and nutrition security in Ghana.
4. To simultaneously estimate the determinants of the decision to produce, the decision to sell, the choice of market and the intensity of agricultural commercialisation in Ghana.

1.4 Hypotheses of the study

Based on the specific objectives, the hypotheses guiding this study are:

1. An extended metric of agricultural commercialisation suggests the importance of the livestock subsector to agricultural commercialisation behaviour of farm households.
2. Key determinants of an extended metric of agricultural commercialisation are infrastructure variables (e.g., road, market, availability of transport), institutional variables (agricultural cooperatives), and farm characteristics (e.g., land endowment and crop diversity).
3. The extended metric of agricultural commercialization reflects the impact of agricultural commercialization on food and nutrition security better than the widely used crop commercialisation index.
4. A quadruple-hurdle model of agricultural commercialisation is a better modelling approach of commercialisation behaviour of farm households than the triple-hurdle approach.

1.5 Relevance of the study

Agricultural transformation and modernisation have been at the forefront of agricultural development goals in Ghana and are recognised in most agricultural policy documents and national development strategies. For example, the FASDEP I, the FASDEP II and the GPRS II all envisage an agricultural development framework that promotes agricultural modernisation to catalyse the economy's rural and structural transformation. Key to this transformation is a shift from subsistent-oriented agriculture to a productive and commercial agriculture. The FASDEP II for example, has two main agricultural policy objectives that stress this assertion – improved growth in incomes and increased competitiveness and

enhanced integration into domestic and international markets. Considering the increased focus on evidence-based policy making by governments and development partners, examining the underlying factors that influence production and commercialisation provides the necessary evidence relevant to policy making by the Ministry of Food and Agriculture and other stakeholders to devise effective and efficient policies that would lead to the achievement of these policy objectives.

The lack of consensus on the causal impact of commercialisation on food and nutrition security in the literature can confound commercialisation interventions that seek to improve food and nutrition security. The evidence on the impact of commercialisation and the subsequent test of the transmission mechanism can inform policy making. For example, a positive effect of commercialisation would be accompanied with the underlying transmission mechanism that would inform policy makers on the critical variable to tackle in policy formulation. Likewise, an adverse or no effect would reveal the mechanisms for such results that would help in policy.

Finally, this study expands the frontier of knowledge in the literature by introducing the quadruple-hurdle model of commercialisation and an extended metric of agricultural commercialisation. As discussed earlier, the triple-hurdle model is the current level of knowledge in the commercialisation literature (see Abu et al., 2016; Burke et al., 2015). This proposed contribution extends the commercialisation literature and stimulates further discussions on appropriate techniques for assessing the commercialisation behaviour of farmers. The development and subsequent application of the extended metric of agricultural commercialisation that considers both crop and livestock output market engagement in this study contribute to literature.

1.6 Organisation of the study

The first chapter of this study presented an introduction, which included background, problem statement, objectives, hypotheses and relevance of the study. The rest of the study is organised as follows. Chapter two, which reviews relevant literature, immediately follows this chapter. The literature review presents Ghanaian context of agriculture, and food and nutrition security, evidence on pertinent issues related to this study including the measurement of agricultural commercialisation and the effect of commercialisation on food and nutrition security. Chapter three follows the literature review chapter and provides the methodology of the study including data used, theoretical framework, and methods of analysis. Chapter four presents the results of the study based on the various objectives and their corresponding discussions. Finally, chapter five summarises the findings of this study, provides conclusion and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

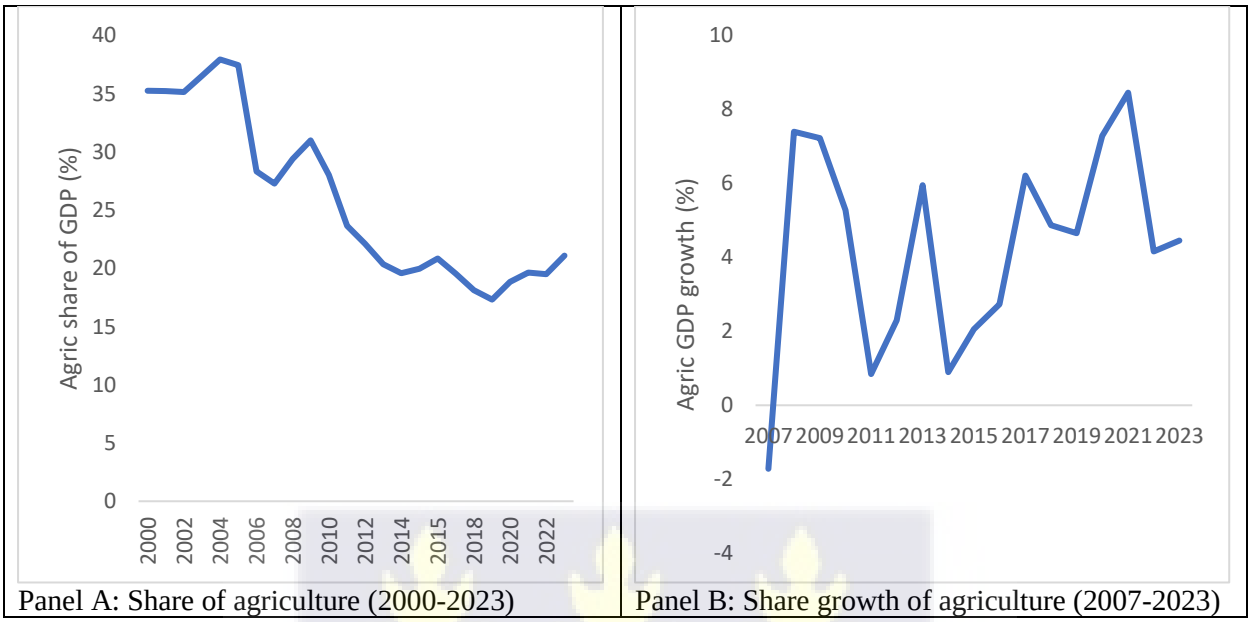
This chapter presents the context of agriculture and food and nutrition security in Ghana and examines previous studies on agricultural commercialisation that are particularly relevant to understanding the specific objectives of this study. The specific areas of previous studies covered are the measurements of agricultural commercialisation, markets and agricultural commercialisation in developing economies, empirical modelling of agricultural commercialisation in the literature, and the effects of agricultural commercialisation on food and nutrition security. This chapter is relevant as it provides the empirical issues of agricultural commercialisation, places this study within the context of what has been done already, and provides the basis for the approaches to be adopted by this study.

2.2 Context: agriculture, and food and nutrition security in Ghana

2.2.1 Agriculture in Ghana

Ghana's economy is basically agrarian. Data from the WDI show that the share of agriculture in Ghana's GDP has been declining since 1990. Figure 2.1 presents the performance of the agriculture from 2000 to 2023. Despite the continuous decline in agriculture's contribution to GDP (Panel A of Figure 2.1) and the fact that in recent times the agriculture sector has ceded its supremacy to the services sector in terms of its contribution to the GDP (i.e., 42.46% of GDP for services in 2023) majority of people and the Ghanaian economy depend on the sector. From the WDI data, in 2023, agriculture's contribution to GDP was 21.10 percent,

amounting to about US$ 14.97 billion (constant 2015 US$) and grew by 4.45 percent in 2023. Panel B in Figure 2.1 shows that agriculture's growth has been dwindling.



Panel A: Share of agriculture (2000-2023) Panel B: Share growth of agriculture (2007-2023)

Figure 2.1: Trend of agricultural share and growth in GDP of Ghana (2000-2023)
Source: World Bank's WDI

Between 1990 and 2023, agriculture averagely contributed 29.93 percent to GDP, and between 2007 and 2023, the average growth rate was 4.30 percent. In terms of employment, the sector employed 39.74 percent of the economically active population in 2022, averaging 49.73 percent from 1991 to 2022.

Agricultural geography in Ghana is classified into seven main agro-ecological zones, which are distinguished based on climate, vegetation, and soil types. They include, Deciduous Forest, Transitional, Coastal Savannah, Guinea Savannah, Sudan Savannah, Moist Evergreen and Wet Evergreen. The agriculture sector is basically partitioned into five subsectors, including crops, cocoa, livestock, fishing and forestry and logging. However, the food crops subsector is predominant in terms of the number of participants, size of production and contribution to agriculture GDP, where it accounts for around 70 percent in 2017 (Ministry of

Food and Agriculture, 2017). The bulk of agricultural production is undertaken in rural areas and the most predominant scale of production is a subsistent-based smallholder farming, where these types of farmers cultivate under two hectares in a typical production season and account for around 90 percent of all producers (Ministry of Food and Agriculture, 2017). These smallholders basically produce various food crops through intercropping, which accounts for around 80 percent of the national agricultural output in 2017 (Ministry of Food and Agriculture, 2017).

Few farmers engage in large and medium scale commercial production, and this is often concentrated on the cultivation of plantations and cash crops (such as rubber, oil palm, pineapples, and coconut) (Ministry of Food and Agriculture, 2021). For smallholders, production technology is characterised by use of traditional and unmechanised farm machinery such as hoes, cutlasses, and bullock. The country produces cereal and root tuber staples (such as maize, rice, millet, sorghum, cassava, cocoyam, yam, plantain), cash crops (such as cocoa, oil palm, coconut, coffee, cotton, kola, rubber), and fruits and vegetables (pineapple, citrus, banana, pawpaw, mangoes, tomato, pepper, okro, eggplant, and onion). Another important characteristic of production is the heavy dependence on rain-fed agriculture. There is low investment in irrigated agriculture, as the share of irrigated land is only 0.28 percent of total arable land according to data from WDI.

Agricultural workers have persistently been among the poorest in Ghana, with poverty incidence of self-employed farmers increasing from 39.2 percent in 2012/13 to 42.7 percent in 2016/17 (Ghana Statistical Service, 2018). The many challenges that impede agricultural growth is the principal factor contributing to the high poverty incidence of farmers. Agriculture is still characterised by very low land and labour productivity. For example, the

land productivity of cereals estimated at 1.7MT/ha falls short of the country's attainable level of 5MT/ha and the sub-regional average level of 2MT/ha (World Bank, 2017). Other challenges pertain to declining fertility of farmlands, inadequate provision of finance and credit, poor production, market and information infrastructure, postharvest losses, weak extension delivery services, low adoption of improved farm technology, climate change and variability, and pests and diseases (Ministry of Food and Agriculture, 2017).

Despite these challenges, the potential of agriculture in contributing to numerous development outcomes (such as poverty reduction and economic growth) has provided the platform for various governments to develop the agriculture sector. Though there are various development policy interventions, the overarching objective of these interventions border on boosting productivity and transforming farmers from subsistent smallholders to commercial ones with the view of boosting incomes, reducing poverty, and making the sector the engine of growth. For example, Ministry of Food and Agriculture (2009) indicated that the transformation of the agricultural sector is premised on commitments to improve and boost access to markets. In addition, Ghana's MoFA initiated the Ghana Commercial Agriculture Project (GCAP) with a prime focus of tackling barriers that impede the movement from a sector dominated by subsistence-based smallholders to a sector based on a stronger market-based orientation. Based on the crucial role of commercial agriculture, undertaking an empirical study to examine its determinants and its impact on key development outcomes such as food and nutrition of farm households is imperative.

2.2.2 Food and nutrition security in Ghana

Ghana has made significant progress in reducing food insecurity and nutritional challenges. For example, from the early 1990s to 2015, the number of malnourished people fell from 7

million to under 1 million (Steiner-Asiedu et al., 2017). The most important driver of such progress has been the efforts in reducing poverty. In fact, before the 2015 official deadline for achieving the then Millennium Development Goal 1 of halving extreme poverty, Ghana was one of the few countries in Africa to achieve the feat (Ecker & van Asselt, 2017), including halving the prevalence of underweight among children between 1990 and 2015.

However, food insecurity and nutritional deficiencies are still challenges, as these cankers, manifesting especially in the form of malnutrition and/or micronutrient deficiencies, persist (Ecker & van Asselt, 2017; Steiner-Asiedu et al., 2017). Steiner-Asiedu et al. (2017) note that Ghana faces a "triple burden of malnutrition", that is, underweight, overweight and micronutrient malnutrition. Table 2.1 presents the statistics of food and nutrition security measures. These recent statistics clearly indicate that there is progress made in the prevalence of undernourishment in the total population (a reduction of 7.1 percentage points between the 3-year averages of 2004/2006 and 2019/2021). Progress is also made in the prevalence of anaemia among women of reproductive age (15-49 years) (a reduction of 8.8 percentage points between 2012 and 2019) and the prevalence of stunting in children under 5 years (a reduction of 8.0 percentage points between 2012 and 2020). The prevalence of low birthweight reduced by 0.3 percentage points between 2012 and 2015.

Despite the progress, current levels of food insecurity and nutritional constraints are still national development challenges, especially that the human and economic costs are massive (IFPRI, 2015). About 4 percent of the total population is undernourished while 5.1 percent are food insecure. About 14.2 percent of children under 5 are stunted, which is more pervasive in the Northern region (28.8%) and less prevalent in the Greater Accra region

(12.6%) (GSS, 2018). There are still very large proportions of the population who cannot afford nutrient adequate diet (26.5%) and healthy diet (61.2%).

Table 2.1: Food and nutrition security statistics in Ghana

Indicator and year	Percent (%)
FAO et al. (2022):	
Prevalence of undernourishment in total population	
2004-2006	11.2
2019-2021	4.1
Prevalence of severe food insecurity in total population	
2014-2016	5.1
2019-2021	5.6
Prevalence of moderate and severe food insecurity in total population	
2014-2016	38.3
2019-2021	36.6
Prevalence of obesity in adult population	
2012	9.4
2016	10.9
Prevalence of anaemia among women of reproductive age (15-49 years)	
2012	44.2
2019	35.4
Prevalence of wasting in children under 5 years (2020)	6.8
Prevalence of stunting in children under 5 years	
2012	22.2
2020	14.2
Prevalence of overweight in children under 5 years	
2012	2.2
2020	2.9
Prevalence of low birthweight	
2012	14.5
2015	14.2
Proportion of people who cannot afford energy sufficient diet (2019)	5.3
Proportion of people who cannot afford nutrient adequate diet (2019)	26.5
Proportion of people who cannot afford healthy diet (2020)	61.2
GSS (2018):	
Prevalence of underweight (2018)	12.6

Source: FAO et al. (2022); GSS (2018)

In addition, for nutritional challenges such as the prevalence of food insecurity, obesity, and overweight in children, the situation is not improving. The proportion of overweight children increased by 0.7 percentage points from 2012 to 2020. Between 2012 and 2016, the proportion of people who were obese increased by 1.5 percentage points, while the prevalence of severe food insecurity increased by 0.5 percentage points. In fact, obesity has been particularly observed to be a new threat to public health challenges in Ghana (Ecker &

van Asselt, 2017). They explain that structural transformation of the economy moves people away from physically demanding agricultural activities to more sedentary work coupled with lifestyle changes involving time for leisure and a move away from consumption of own produced food to purchase foods that are dense in calories and fats. These all culminate into obesity, overweight and related health conditions.

Despite the countrywide challenge, food insecurity and nutritional challenges tend to exhibit disproportionate concentrations across geographic locations. This pattern tends to mimic the nature and character of economic conditions, living standards, agro-ecological conditions, and differences in local delicacies (Ecker & Fang, 2016; Ecker & van Asselt, 2017). Data from the Multiple Indicators Cluster Survey (MICS) for 2017/2018 show that the prevalence of severe underweight, stunting and wasting are higher in rural than urban areas (GSS, 2018). For example, while the prevalence of severe stunting and underweight in children under 5 years are 3.5 percent and 2.1 percent, respectively in urban areas, they are 5.7 percent and 2.6 percent in rural areas. It is only the prevalence of severe overweight where the urban statistics are higher than the rural statistics. Further, there are marked differences across the north-south divide, with the northern parts severely affected (Steiner-Asiedu et al., 2017). For example, the prevalence of underweight, stunting and wasting are respectively 2.52, 3.34 and 1.18 percentage points more in northern Ghana than in southern Ghana[4] (GSS, 2018).

Recognising the challenges posed by food insecurity and nutritional deficiencies made various governments to invest in interventions to contain the situation. Earlier, the Ghana Vision 2020 and the Ghana Shared Growth and Development Agenda (GSGDA) viewed the

[4] Northern Ghana comprises Northern, Savannah, North-East, Upper East, Upper West and Brong Ahafo regions, and southern Ghana comprises Greater Accra, Ashanti, Eastern, Western, Central and Volta regions.

promotion of food and nutrition security as important foundations for enhancing human development. The development of the National Health Policy and the Child Health Policy in 2007 prioritised interventions for boosting food and nutrition security outcomes. To further prioritise investments and actions towards nutrition, the country developed and launched the National Nutrition Policy (NNP) in 2013. The main objective of the policy was to provide a platform for targeting nutrition-sensitive interventions to improve the nutrition and health of people.

Agricultural policies such as FASDEP I and FASDEP II also outlined food and nutrition security interventions. For example, FASDEP II identified food security and emergency preparedness as a key policy objective and outlined strategies such as irrigation development, the introduction of high-yielding crop varieties, managing post-harvest losses, improving accessibility and distribution of food, macro and micronutrients and food fortification, coordination of nutritional programmes, among others as key strategies. To complement government's policy efforts, some donor partners rolled out interventions to boost food and nutrition security, including USAID's Systems for Health, Resiliency in Northern Ghana (RING) and Strengthening Partnerships, Results, and Innovations in Nutrition Globally (SPRING).

2.3 Measurements of agricultural commercialisation

Central to the measurements of agricultural commercialisation is the definition of the concept itself. In general, agricultural commercialisation is viewed as a sustained shift from subsistent-dependent, consumption-focused production to a marketed-focused production (see e.g., Abafita et al., 2016; Goletti, 2005; Omiti et al., 2009; Pradhan et al., 2010). Agricultural commercialisation involves a structural transformation of agricultural production

from a consumption-led orientation to a market-orientation (von Braun, 1995). This transformation does not necessarily imply a transition from the production of food crops to cash crops. This implies that commercialisation is achieved when farm production decisions are undertaken based on incentives and motivation from the market. Govereh et al. (1999) view agricultural commercialisation as a continuum from zero (i.e., complete subsistence-oriented production) to unity (i.e., complete commercial production), each representing the proportion of output that is marketed. Jayne et al. (2011:1) proposed a concept of agricultural commercialisation as "*a virtuous cycle in which farmers intensify their use of productivity-enhancing technologies on their farms, achieve greater output per unit of land and labour, produce greater farm surpluses (or transition from deficit to surplus producers), expand their participation in markets, and ultimately raise their incomes and living standards*".

A market-incentive production implies that it is not only output that drives farm households to participate in the market but also participation is stimulated by the need to organise appropriate productive inputs (e.g., agro-chemicals and labour). This dimension of commercialisation, though often ignored, is emphasised by Pingali and Rosegrant (1995), Pingali (1997), Alemu et al. (2006), and Jaleta et al. (2009). They assert that agricultural commercialisation, in addition to crop and livestock output market participation, involves the degree to which farm households engage the market to purchase farm inputs. In the context of agricultural development, these two dimensions of agricultural commercialisation (i.e., crop/livestock output and input commercialisation) are complements – input commercialisation stimulates production and productivity which then increases marketable surplus and crop/livestock output commercialisation provides the liquidity to procure inputs.

In the empirical measurement of agricultural commercialisation, while Jaleta et al. (2009) point to the lack of common base for measurement, the literature seems to be unanimously and fixatedly settled on the HCCI defined generally as the value of the proportion of total crop output sold relative to the value of total crop output produced. This is mathematically defined following the works of Strasberg et al. (1999) and Govereh et al. (1999) as:

$$\boldsymbol{HCCI_{ij}} = \left[\frac{\boldsymbol{Gross\ value\ of\ crop\ sale_{hhi,year\ j}}}{\boldsymbol{Gross\ value\ of\ all\ crop\ production_{hhi,year\ j}}}\right] * \mathbf{100} \qquad (2.1)$$

where the estimated value of $HCCI_{ij}$ in each household ranges between 0 and 100 (i.e., $0 \leq HCCI_i \leq 100$), which implies that all the crops produced can be sold or none may be sold. For situations where $HCCI_i = 0$, such households are described as totally subsistence-oriented households or autarchic, and households described as commercial have higher values of $HCCI_i$. A fully commercialised household is one with $HCCI_i = 100$. While the HCCI is a composite measure of all crops produced and marketed by a household, most empirical studies adapt it to measure the commercialisation of single crops by individuals (see e.g., Abu & Issahaku, 2017; Burke et al., 2015; Sekyi et al., 2017, 2020).

In more recent studies (e.g., Abdul Mumin & Abdulai, 2022; Linderhof et al., 2019), the HCCI is simply restated as:

$$\boldsymbol{HCCI_i} = \frac{\sum_{k=1}^{K} \bar{\boldsymbol{P}}_k \boldsymbol{S_{ik}}}{\sum_{k=1}^{K} \bar{\boldsymbol{P}}_k \boldsymbol{Q_{ik}}} \qquad (2.2)$$

where S_{ik} is farm household i's market sales quantity of crops k valued at the community average price $\bar{P}_k$, Q_{ik} is the quantity of all crops K produced also evaluated as the average

community-level price $\bar{P}_k$. When all crop production is sold, $S_{ik} = Q_{ik}$ and $HCCI_i = 1$, and when none is sold $S_{ik} = 0$ and $HCCI_i = 0$.

Numerous studies (e.g., Abdul Mumin & Abdulai, 2022; Bolarinwa et al., 2021; Carletto et al., 2017; Cazzuffi et al., 2020; Linderhof et al., 2019; Muriithi & Matz, 2015; Ogutu et al., 2020) apply this common measure of commercialisation. The studies that apply the HCCI measure ascribe to the definition of commercialisation provided by Govereh et al. (1999) as a continuum from zero to unity. Interestingly, the wide application of the HCCI does not imply that it is a perfect measure of commercialisation. Several authors (e.g., Gebreselassie & Sharp, 2007; Jaleta et al., 2009) stress that the HCCI does not incorporate the commercialisation of livestock and is very prone to yielding misleading indices. The HCCI is utterly inadequate in satisfying the overall definition of commercialisation. Therefore, the continuous side-lining of livestock commercialisation is a fundamental lacuna in the literature. Most studies just mention its relevance in passing and do not launch approaches to capturing it.

However, some studies have begun looking at empirical measures of input commercialisation. One recent contribution is the work of Linderhof et al. (2019). In their study on the effect of agricultural commercialisation on food security in Vietnam, they defined a measure of input commercialisation referred to as the crop input market participation share (CIMPS) derived from fertiliser use. Realizing the weaknesses of the HCCI – inability to live up to the entire food-system – they added the CIMPS, defined as "the share of purchased inputs value to the total value of inputs used for production", and stated mathematically as:

$$\boldsymbol{CIMPS_i} = \frac{\sum_{r=1}^{R} \overline{W}_r X_{ir}}{\sum_{r=1}^{R} \overline{W}_r I_{ir}} \quad (2.3)$$

where X_{ir} is farm household i's purchased amount of input r valued at the average input price $\overline{W}_r$, I_{ir} is the total value of input r used by the household in production, R is a vector of all inputs, and r represents the input index.

Despite the introduction of the CIMPS as part of the commercialisation metrics, the problem remains that a composite measure that combines the output (crop and livestock) commercialisation is still missing in the literature, a realisation that justifies this study.

2.4 Markets and agricultural commercialisation in developing economies

The market is an important institution in economics, and this is manifested in the numerous theoretical works on market organisation and structures. Markets provide an opportunity for specialisation, make available a wide range of choices to consumers and provide opportunities for capital accumulation. The stylised theory of a market that promotes an efficient allocation of resources is the perfectly competitive market. However, a widely espoused characteristic of markets in developing economies is market failure, a situation where the market is incapacitated to provide efficient resource allocation.

In the context of the relationship between markets and the agricultural commercialisation of farm households in developing economies, the literature demonstrates that the fundamental cause of market failure is the presence of transaction costs. This was first observed by Coase (1937), who defied the long-standing view of classical economists of costless exchange, noting that participation in market proceedings by economic agents imposes some costs such that these agents arrange exchanges to lessen these costs. Based on Coase's postulation, the

commercialisation literature has developed primarily along the tangent of examining the role of transaction costs and market failure in the marketing behaviour of farmers (Goetz, 1992; Key et al., 2000).

The work of Furlong and Slotsve (1983) on pickup and delivery pricing exposes an important impact of transaction costs in the development of the market centre and farmgate commercialisation decisions. Transaction costs force farmers to decide to either sell at the farmgate or travel to a market centre to sell. Farmers who decide to avoid transaction costs offer to sell at the farmgate, choosing a pickup price, which is basically an offer of discounts in the form of lower prices, while farmers who decide to incur transaction costs travel to market centres and offer delivery prices in the form of higher prices. By implication, Furlong and Slotsve (1983) demonstrate that transaction costs account for the difference between farmgate and market centre prices.

Several classifications of transaction costs have been proposed in the literature. Hobbs (1997) provided three classifications, including information, negotiation, and monitoring costs. Another classification divides transaction costs into tangible costs (e.g., cost of transportation and communication) and intangible costs (e.g., moral hazard and uncertainty), where the former are those that can be easily observed or identified and the latter are more difficult to observe (e.g., Holloway et al., 2000). Pingali et al. (2005) opine that intangible transaction costs results from informational asymmetries and challenges in enforcing contracts. The most popular classification is the fixed and proportional classification. Fixed transaction costs are typical sunk costs that do not vary with the marketable surplus available for sale. This type encapsulates the information and negotiation classifications provided by Hobbs (1997), which are incurred *ex-ante* of the actual sale and the monitoring classification, which is *ex-*

post of the sale. For example, costs associated with identifying a potential market or buyer, negotiating, bargaining, and enforcing market contracts are fixed transaction costs because, the level of marketable surplus does not influence the amount of these costs. Available evidence (see Burke et al., 2015; Goetz, 1992; Key et al., 2000) indicates that fixed transaction costs do not impact the quantity of marketable surplus available for sale but are a critical factor in determining the probability of participating in the market. However, it is important to note that given the quantity constraints of smallholders, higher fixed costs may easily prevent them from selling. Proportional transaction costs are costs of marketing which are variant with the volume of marketable surplus, such that higher quantities attract higher costs and vice versa. The cost of transporting quantities to a market centre is a typical example of proportional transaction costs. Unlike the fixed transaction costs, Key et al. (2000) show that proportional transaction costs can determine both the probability of participating and the volume of sale.

Another essential discussion of transaction costs was extended by Pingali et al. (2005) on specific sources they emanate from. In this discussion, transaction costs can be farm-specific, location-specific (where farmers in urban or developed areas face lower costs relative to those in rural or remote areas due primarily to differences in infrastructure such as access to roads, communication, markets and productive inputs), crop-specific (where high-value produce face more transaction costs relative to staples), household-specific (where risk aversion, uncertainty, household composition and characteristics, and social networks impose costs).

Though transaction costs have been very much discussed in the literature, one elusive thing about them is their measurement. A way to directly measure transaction costs has still not

been found, since they are generally classified as unobservable. However, because they are important and unavoidable in empirical studies of markets, transaction costs are usually measured through observable characteristics used as relevant proxies. For example, in the context of agricultural commercialisation, transaction costs of selling can be measured using proxies such as actual transportation costs in reaching the markets, availability of navigable roads and their condition (good versus bad), access to public means of transport, ownership of private means of transport, and access to market information and information enhancing equipment (e.g., mobile phones and radios).

Being one of the most important thematic issues in the commercialisation literature, several studies have explored the effect of transaction costs on the commercialisation behaviour of farm households. The World Bank (2008) noted that high transaction costs are still a key determinant of sub-Saharan Africa's imperfect input and output markets. Further, transaction costs are responsible for missing labour, credit, and output markets (Pingali et al., 2005). Goetz (1992) established that fixed transaction costs are a key barrier to the marketing of grains in Senegal. Alene et al. (2008) observed that higher transaction costs constrained the marketing of maize in Kenya. Several other studies (e.g., Abdul-Rahaman & Abdulai, 2020; Abdulai & Birachi, 2009; Fafchamps, 1992; Shilpi & Umali-deininger, 2007) have highlighted the role of transaction costs in limiting the market participation of farmers. The literature has demonstrated that farmers in rural areas who are far from established markets and who have infrastructural constraints face higher transaction costs in reaching markets (see e.g., Endalew et al., 2020; Kyaw et al., 2018; Megerssa et al., 2020; Stifel et al., 2016; Stifel & Minten, 2017).

The general recommendation for solving the bane of transaction costs is improving infrastructure and information access for remote farmers. The development of navigable roads, provision of means of transport, establishing market infrastructure and improvement in communication facilities are observed to reduce transaction costs in marketing agricultural produce. For example, advances in the mobile telecommunication space in developing economies have reduced information asymmetry and provided access to better market information to farmers (see e.g., Aker, 2010; Courtois & Subervie, 2015; Fafchamps & Minten, 2012). In addition, the availability of public markets has been observed to boost agricultural commercialisation (Andaregie et al., 2021; Andaregie & Astatkie, 2020; Key et al., 2000; Manda et al., 2021) and stimulate income growth (Aku et al., 2018).

Beyond the transaction cost effect on agricultural commercialisation, several determinants have been identified in the literature. Socioeconomic characteristics are key commercialisation determinants. Generally, especially for studies that observe a significant effect of gender, male farmers or male-headed farm households commercialise more than female farmers (e.g., Abu et al., 2016; Aku et al., 2018; Andaregie et al., 2021; Awotide et al., 2016; Nxumalo et al., 2019; Sekyi et al., 2020). These studies attribute the gender disparity in commercialisation behaviour to resource disparity, where females are more resource constrained. However, the evidence on age is not generally straightforward. While some evidence indicates that older farmers are more commercialised (e.g., (Abdullah et al., 2019; Nxumalo et al., 2019; Tafesse et al., 2020) – attributing the difference to the farming experience and knowledge on market networks and selling dynamics – others report younger farmers are more commercialised (e.g., Abu et al., 2016; Alhassan et al., 2020; Andaregie et al., 2021; Nkegbe et al., 2022; Sekyi et al., 2020) – explaining that younger farmers are

relatively productive and more risk-averse while older farmers tend to prioritise food security.

Another household characteristic that seems to have a generally unanimous effect on commercialisation is household size, which has been observed to harm commercialisation (Abu et al., 2016; Alhassan et al., 2020; Kyaw et al., 2018; Megerssa et al., 2020; Sekyi et al., 2020). This is usually explained from the angle of larger family sizes reducing marketable surpluses due to high consumption demands on produce. The educational level of farmers is also identified as a positive correlate of commercialisation (Andaregie et al., 2021; Endalew et al., 2020; Kyaw et al., 2018; Manda et al., 2021; Megerssa et al., 2020; Nxumalo et al., 2019; Tafesse et al., 2020), with the explanation that more educated farmers have more understanding and awareness in adopting technology and farm practices, and more experience and knowledge in marketing dynamics. Market information stimulates commercialisation by providing timeous information on key issues such as market prices and places with high demand. Therefore, several studies have found market information to positively influence commercialisation (Abu, 2015; Abu et al., 2014, 2016; Aku et al., 2018; Kyaw et al., 2018; Megerssa et al., 2020). Further, farmer organisations (i.e., cooperatives) also stimulate commercialisation (Abu et al., 2014; Abu & Issahaku, 2017; Kyaw et al., 2018; Ochieng et al., 2019).

Farm characteristics are also key determinants of commercialisation. In the commercialisation literature, farm size or landholding is generally a positive correlate (Aku et al., 2018; Chegere & Kauky, 2022; Endalew et al., 2020; Hagos et al., 2020; Hailua et al., 2015; Manda et al., 2021; Mariyono, 2018; Nkegbe et al., 2022; Olwande et al., 2015; Sekyi et al., 2020; Tafesse et al., 2020), suggesting that increased output is necessary for

households to raise marketable surpluses. Further, agricultural technology adoption is observed to stimulate commercialisation through increased productivity (e.g., Abu & Issahaku, 2017; Andaregie et al., 2021; Manda et al., 2021). In addition, agricultural credit exhibits a generally positive effect on commercialisation (see Abu et al., 2014, 2016; Abu & Issahaku, 2017; Manda et al., 2021; Nkegbe et al., 2022; Sekyi et al., 2020). Agricultural extension is also an important correlate of commercialisation (Abu & Issahaku, 2017; Andaregie et al., 2021; Endalew et al., 2020; Kyaw et al., 2018; Nkegbe et al., 2022).

The next set of determinants is the influence of community-specific or geographic-specific characteristics, where the literature has generally shown that communities with motorable roads or availability of public and markets have higher commercialisation ratios (e.g., Abu & Issahaku, 2017; Alhassan et al., 2020; Kyaw et al., 2018; Manda et al., 2021; Nkegbe et al., 2022).

2.5 Modelling agricultural commercialisation of farm households

From the conceptual paper of Barrett (2008), agricultural commercialisation carries a dichotomous nature: farm households enter the market as either sellers or buyers, with these two mutually exclusive decision processes underpinned by optimisation theory. The optimizing behaviour of farm households dictates utility maximisation subject to budgetary constraints. Based on this, the literature (see Bellemare & Barrett, 2006; Goetz, 1992; Holloway et al., 2005) treats market participation as a two-stage phenomenon: (i) farm households choose three mutually exclusive events: decide to be net buyers, net sellers, or autarchic and (ii) net buyers and net sellers decide how intensive they would engage the market.

The literature presents and tests two competing assumptions about whether farm households simultaneously or sequentially make these two decisions. Without any formal test, Key et al. (2000) assume that Mexican corn producing households take simultaneous decisions, meaning that they determine beforehand the volume of marketable surplus before acquiring relevant information on their choices. Bellemare and Barrett (2006) note that decision taken simultaneously renders farm households in Kenya and Ethiopia vulnerable to exploitation by traders. Abu et al. (2016) provide a likelihood ratio empirical test and find that farm households participating in the maize and groundnut markets in Ghana make simultaneous decisions. Also, without a formal testing, Goetz (1992) and Holloway et al. (2005) assume that farm households in sub-Sahara Africa and Ethiopia, respectively, make sequential decisions, meaning that, taking relevant information on the market precedes decisions about the transactions. In this case, farm households hold significant market power over traders. In an empirical test, Bellemare and Barrett (2006) find that farm households in Kenya and Ethiopia adhere to sequential decision-making. Other studies (see Akpan et al., 2012; Dehinenet et al., 2014; Fischer & Qaim, 2014; Muamba, 2011; Ricker-Gilbert & Jayne, 2009) also assume or find evidence for sequential decision-making. However, in a recent study, Burke (2019) notes that using typical two-tiered models (e.g., double-hurdle model) to test for sequential or simultaneous decision-making is misleading because imposing restrictions on such models to judge the nature of decision-making is problematic.

The empirical literature concentrates on two types of studies: first, modelling determinants and intensity of participation (see Abu et al., 2014; Andaregie et al., 2021; Kyaw et al., 2018) and second, modelling participation and choice of market (see Abu et al., 2016). In a landmark contribution, Burke et al. (2015) developed the triple-hurdle model, applied to dairy marketing in Kenya, which augments the two-stage processes by adding an initial first-stage

decision to produce. On the econometric modelling front, commercialisation studies are three: one-step, two-step and three-step models. Studies such as Tafesse et al. (2020) in Ethiopia, Omiti et al. (2009) in Kenya, Holloway et al. (2001) in Ethiopia, Martey et al. (2012) in Ghana and Abu (2015) in Ghana modelled determinants of commercial intensity in a single step or as a standalone model. In the process, Tobit and truncated regression models are widely used. However, these studies fall short with an underlying assumption that factors determining participation and intensity are the same and with the same directional effects. This assumption has been found to be restrictive and erroneous (Ricker-Gilbert et al., 2011; Wooldridge, 2002) and unable to deal with the problem of selection bias arising from ignoring the first decision process of participation.

To overcome the one-step approach's weakness, the two-step approach sequentially or simultaneously models market participation and participation intensity. Several studies employ this econometric approach (see e.g., Abu et al., 2014; Alene et al., 2008; Boughton et al., 2007; Goetz, 1992; Holloway et al., 2005). Widely used econometric models are the Heckman sample selection (see e.g., Abu et al., 2016; Alene et al., 2008; Andaregie et al., 2021; Boughton et al., 2007; Goetz, 1992; Kyaw et al., 2018), the double-hurdle models (see e.g., Abu et al., 2014; Olwande & Mathenge, 2012; Reyes et al., 2012) and the endogenous switching regression (Abu & Issahaku, 2017; Nkegbe et al., 2022; Sekyi et al., 2020; Tesfay, 2020). These models appropriately capture the two-prong nature of commercialisation on the one hand and attempt to overcome the problem of selection bias. Selection bias arises because, in modelling these two decision processes of participation and intensity, a set of observable covariates may jointly determine both participation and intensity, such that ignoring any of them breeds the problem. Second, unobservable factors may also jointly

determine these two processes leading to correlated error terms such that standalone estimations would yield biased and inconsistent parameter estimates.

Though the Heckman selection and the double-hurdle models are widely used, their estimation structures and assumptions differ. In terms of structure, the Heckman sample selection model first estimates the participation stage with a probit model, intrinsically derives a parameter referred to as the inverse mills ratio (IMR) and then estimates the second stage with an OLS after including among the covariates the IMR to correct selection bias. The Heckman model assumes that in the second stage, the intensity of commercialisation of farmers who have not participated in the first stage (i.e., zero) is unobserved or omitted (Ricker-Gilbert et al., 2011; Wooldridge, 2002). However, in terms of structure, the double-hurdle first estimates the participation stage with a probit model and then estimates the intensity stage with a truncated regression model. The double-hurdle assumes that the intensity of commercialisation of farmers who have not participated (i.e., zero) is their optimal choice rather than a missing or unobserved outcome (Reyes et al., 2012). The basic difference between the switching regression models and the Heckman and double-hurdle is its disaggregated modelling of the second stage model of commercialisation between the two groups of people in the first stage binary model (usually financial inclusion/credit access, adoption of technology, and nonfarm engagement).

Despite the contributions of the two-step approaches in solving the weaknesses of the one-step approaches, they are observed to also possess a fundamental weakness by Burke et al. (2015). They argue that in a random sample of farm households, it is always likely that some households may not produce the crop of interest. This possibility adds another important decision-making process in commercialisation: the decision to produce a particular crop of

interest. However, the two-step approaches generally ignore this decision process, except for the study of Muamba (2011). Following this weakness, Burke et al. (2015) developed the triple-hurdle model which augments the two-stage processes by adding an initial first-stage decision to produce. Thus, the triple-hurdle model proposes the introduction of a first-stage decision to produce model to precede the participation and intensity stages.

Even though the triple-hurdle model is theoretically and empirically better than the previous approaches, it also has a fundamental weakness. It completely ignores an important dimension of market participation – choice of market by farm households. Meanwhile, this decision process is very important especially to ensure that the market becomes remunerative. Thus, the triple-hurdle model is a means to an end. In this case, the end is building a complete model of commercialisation that represents all the thematic areas of commercialisation: production, participation, choice of market and intensity. This realisation makes this methodological contribution relevant, as the development of the quadruple-hurdle model significantly departs from previous studies and represents a platform to provide all-rounded evidence for priority setting in policy formulation meant to boost commercialisation.

Abu et al. (2016) have noted that though Bayesian and frequentist econometric approaches have been applied in agricultural commercialisation studies, the balance of application is much tilted towards applying the latter. Despite this, Bayesian econometric approaches have made notable contributions (see Holloway et al., 2001, 2004, 2005, 2008). One significant contribution is a shift from the use of zero censoring threshold of data in frequentist approaches to the use of random or unknown censoring threshold. Unlike zero censoring studies, random censoring provides the empirical capacity for estimating the specific marketable surplus required for non-participation farmers to participate in markets.

2.6 Effect of agricultural commercialisation on food and nutrition security

2.6.1 Common measures of food and nutrition security in commercialisation studies

A review of commercialisation impact studies (i.e., all the studies cited in this thesis) reveals that six food and nutrition security indicators/metrics are generally used, namely, (i) dietary diversity, (ii) anthropometric measures, (iii) intake of nutrients, (iv) consumption expenditures, (v) self-assessed food insecurity status, and (vi) food coping score/index. Two basic variants of dietary diversity metrics are used, including household dietary diversity score (HDDS) (e.g., Anderman et al., 2014; Chegere & Kauky, 2022; Koppmair et al., 2017; Nkegbe & Abdul Mumin, 2022; Ochieng et al., 2015; Seng, 2016; Sibhatu et al., 2022; Usman & Haile, 2022) and food consumption score (FCS) (e.g., Abdul Mumin & Abdulai, 2022; Anderman et al., 2014; Chegere & Kauky, 2022; Linderhof et al., 2019; Nkegbe & Abdul Mumin, 2022; Sibhatu et al., 2022; Usman & Haile, 2022). The HDDS is generally calculated as the number of food groups a household consumes within a given reference period. Kennedy et al. (2011) outlined 12 food groups, namely, (i) cereals, (ii) roots and tubers, (iii) vegetables, (iv) fruits, (v) meats, (vi) eggs, (vii) fish and seafood, (viii) pulses, nuts, and seeds, (ix) milk and milk products, (x) oils and fats, (xi) sweets, and (xii) spices, condiments, and beverages. The FCS is an extension of the HDDS by considering two extra pieces of information: (i) a household's frequency of consuming these food groups, and (ii) applying standard weights to the considered food groups.

Children's anthropometric measures of stunting, wasting, and underweight (e.g., Anderman et al., 2014; Carletto et al., 2017; Chegere & Kauky, 2022; Haji, 2022) are the basic anthropometric measures used in the literature. Stunting, wasting and underweight are respectively proxied by the Height-for-Age z-score, Weight-for-Height z-score and Weight-

for-Age z-score. Considering the intake of nutrients, the prominent measures used are consumption of calories (e.g., Linderhof et al., 2019; Ogutu et al., 2020), protein (e.g., Abdul Mumin & Abdulai, 2022; Kilimani et al., 2022; Nkegbe & Abdul Mumin, 2022), calcium (e.g., Kilimani et al., 2022), iron (e.g., Abdul Mumin & Abdulai, 2022; Kilimani et al., 2022; Nkegbe & Abdul Mumin, 2022; Ogutu et al., 2020), zinc (e.g., Kilimani et al., 2022; Ogutu et al., 2020), and vitamin A (e.g., Abdul Mumin & Abdulai, 2022; Kilimani et al., 2022; Nkegbe & Abdul Mumin, 2022; Ogutu et al., 2020). Some studies use consumption expenditures to proxy food and nutrition security. Three variants of consumption expenditures are used, including household consumption expenditure (e.g., Carletto et al., 2017; Usman & Haile, 2022), household food consumption expenditure (e.g., Cazzuffi et al., 2020; Usman & Haile, 2022), and household food purchase share (e.g., Usman & Haile, 2022).

Further, self-assessed food security or insecurity measures are also employed in the literature. For example, a self-assessed binary indicator of whether a household is food insecure or not has been applied (e.g., Usman & Haile, 2022). In addition to this, Kuma et al. (2019) in a study in Ethiopia constructed food insecurity z-score as a proxy of food security, while Sibhatu et al. (2022) in a study in Zambia and Anderman et al. (2014) in a study in Ghana used months of household adequate food provisioning/supply as a proxy of food security. Related to this, Anderman et al. (2014) and Ochieng et al. (2015) constructed a food coping score/index as a proxy for food security.

2.6.2 Effects of commercialisation on food and nutrition outcomes

Most pioneering studies (e.g., Dewey, 1981; Fleuret & Fleuret, 1983; Gross & Underwood, 1971; Hernandez et al., 1974) of the impact of agricultural commercialisation on nutritional

outcomes were unable to place a clear handle on whether there was any significant effect or even the direction of effect. However, these were noted to have failed to appreciate the usefulness of adopting an appropriate conceptual framework or empirical causal relationship to specify potential transmission channels linking commercialisation to nutrition, among other problems (Carletto et al., 2017; Ochieng et al., 2015).

The debate on the direction of commercialisation effect may not be settled if we consider the evidence on a study-by-study basis because studies tend to use different metrics such that it is difficult to sweepingly indicate the direction of impact when commercialisation exerts heterogenous impacts. However, if we consider a metric-by-metric basis, the dissection of the direction of the impact of agricultural commercialisation may be manageable because we can see where the commonalities are.

Out of the nine studies that used HDDS as an outcome and reviewed in this study, only Anderman et al. (2014) found no significant effect of commercialisation on HDDS in Ghana. The rest of the eight studies (i.e., Chegere & Kauky, 2022; Koppmair et al., 2017; Nkegbe & Abdul Mumin, 2022; Ochieng et al., 2015, 2019; Seng, 2016; Sibhatu et al., 2022; Usman & Haile, 2022) estimated a significantly positive effect of commercialisation on HDDS, and no study found a significant negative effect of commercialisation on HDDS. Therefore, considering the balance of the evidence, agricultural commercialisation positively impacts household dietary diversity. Also, the balance of the evidence suggests that commercialisation positively correlates with food consumption score. From the seven studies that used FCS as an outcome, the study of Anderman et al. (2014) did not find any significant effect, while Linderhof et al. (2019) reported mixed results across geographic space in Vietnam (i.e., positive effects in some places and negative effects in other places). However,

the rest of the five studies (i.e., Abdul Mumin & Abdulai, 2022; Chegere & Kauky, 2022; Nkegbe & Abdul Mumin, 2022; Sibhatu et al., 2022; Usman & Haile, 2022) reported positive effects.

There is sufficient evidence to conclude that commercialisation boosts the consumption of micro and macro nutrients. The three studies reviewed that estimate the impact of commercialisation on protein intake (i.e., Abdul Mumin & Abdulai, 2022; Kilimani et al., 2022; Nkegbe & Abdul Mumin, 2022) all reported a significantly positive impact. Also, the impact on the intake of iron is significantly positive and consistent among the various studies (see Abdul Mumin & Abdulai, 2022; Kilimani et al., 2022; Nkegbe & Abdul Mumin, 2022; Ogutu et al., 2020); impact on zinc is significantly positive (see Kilimani et al., 2022; Ogutu et al., 2020). Apart from Ogutu et al. (2020) that did not find a significant effect on intake of vitamin A for consumption of own produced food but only on consumption on purchased food in Kenya, the rest of the studies (e.g., Abdul Mumin & Abdulai, 2022; Kilimani et al., 2022; Nkegbe & Abdul Mumin, 2022) reported positive effects. In addition, Kilimani et al. (2022) reported a significantly positive effect on calcium intake. For calories, while Ogutu et al. (2020) found a positive effect in Kenya, Linderhof et al. (2019) observed mixed evidence in Vietnam. Evidence from self-assessed food security measures confirm the evidence of impact on the other measures. For example, the evidence of Sibhatu et al. (2022) in Zambia, Usman and Haile (2022) in Ethiopia and Zambia and Kuma et al. (2019) in Ethiopia show that households with higher levels of commercialisation have better food security outcomes.

For all these studies, the positive effects of commercialisation on food and nutrition security are explained through numerous transmissions. Carletto et al. (2017) indicate that at the macro-level, commercialisation boosts trade and efficiency through comparative advantage,

stimulating welfare and economic growth in a study in Malawi, Tanzania and Uganda. The macro-level achievements then translate to micro-level impacts. The most prominent transmission channel in the literature is increased income from commercialisation (see e.g., Aku et al., 2018; Carletto et al., 2017; Haji, 2022; Kilimani et al., 2022; Mmbando et al., 2015; Montalbano et al., 2018; Muriithi & Matz, 2015; Ochieng et al., 2019; Ogutu et al., 2020; von Braun & Kennedy, 1994). Ogutu et al. (2020) empirically tested the hypothesis of whether commercialisation boosts farm incomes and found that indeed an improvement in farm income is an important transmission channel of commercialisation in Kenya. Income gains from commercialisation improve food and nutrition security through the capacity it provides households to purchase food and other essential calories and micro-nutrients (Abdulai & Aubert, 2004; Carletto et al., 2017; Ecker, 2018; Kuijpers, 2018; Kuma et al., 2019; Ogutu et al., 2020; von Braun, 1995). Carletto et al. (2017) indicate that a rise in household income powers a 'virtuous cycle' that stimulates the enhancement of food consumption.

Another transmission channel is the increase in the diversity of own food production and improvement in crop production mix of farm household that provide wide range of produce that have variety of nutritional value (e.g., Chege et al., 2015; Hirvonen & Hoddinott, 2017; Koppmair et al., 2017; Kuijpers, 2018; Kumar et al., 2015; Ochieng et al., 2015). Indeed, commercialisation complements the consumption of own-produced food rather than competing with it (Ogutu et al., 2020). In addition, commercialisation has productivity-boosting potentials, primarily via the opportunity of specialisation which provides the liquidity to procure productivity-enhancing inputs (Barrett, 2008; Minten et al., 2009; Muriithi & Matz, 2015; von Braun & Kennedy, 1994). Rios et al. (2009) corroborate this by estimating a positive correlation between commercialisation and productivity in Vietnam and

Guatemala. Further, commercialisation promotes comparative advantage and encourages economies of scope through crop diversification and thus facilitating the transfer of production experience from staple production to high value crops (Abdulai & CroleRees, 2001; Ecker, 2018; Govereh & Jayne, 2003; Ogutu et al., 2020).

Despite the positive effect of commercialisation, some studies find negative effects, insignificant effects and mixed effects on some food and nutrition measures (e.g., Anderman et al., 2014; Carletto et al., 2017; Cazzuffi et al., 2020; Chegere & Kauky, 2022; Cooper & West, 2017; Linderhof et al., 2019; Ochieng et al., 2015). For example, Linderhof et al. (2019) estimate that the proportions of cash crop production, crop output market participation and fertiliser market participation exhibit heterogeneous effects (in sign [where the a-priori expectation is supposed to positive], magnitude, and significance) on caloric intake and dietary diversity score in Vietnam. The effect of commercialisation on child anthropometric measures of stunting, wasting and underweight is one of the areas with no strong evidence of an effect or simply inconsistent results. For example, Chegere and Kauky (2022) in Tanzania, Carletto et al. (2017) in Malawi, Tanzania and Uganda, and Anderman et al. (2014) in Ghana reported no statistically significant evidence of the effect of commercialisation on stunting. For wasting, apart from Haji (2022), who reported a positive effect in Ethiopia, Chegere and Kauky (2022) and Anderman et al. (2014) reported no significant effect in Tanzania and Ghana, respectively, whiles Carletto et al. (2017) reported a negative effect in Malawi, Tanzania and Uganda. Further, Chegere and Kauky (2022) and Carletto et al. (2017) reported no significant effect on underweight , while Anderman et al. (2014) reported a negative effect in Ghana.

In general, studies that do not find a statistically significant effect of commercialisation on development outcomes or find mixed effect are simply sceptical of the transmission channels suggested by positive effect studies. The scepticism is basically fuelled by the explanation that improvements in household income may not necessarily boost levels of food consumption because households may not have the interest in procuring nutritious food due principally to intra-household factors such as diverse income elasticities or where that translates to the procurement of food, the distribution of that in the household may not be equitable, with male members having the advantage. In some cases, there are imbalances between the marginal propensity to spend on food and the marginal propensity to consume calories or other pressing needs of households, such as water and sanitation, which maybe more prioritised than nutrition (Carletto et al., 2017). It is also possible that commercialisation shifts dietary quality through the increased intake of calories and not micronutrients when own-produced food is substituted for purchased food (Remans et al., 2015).

Another ground of scepticism about commercialisation effect is the tendency for men to exercise more control of production and income (von Braun & Kennedy, 1994). Such control is observed to shift household spending function away from nutritious foods to other areas of household needs (Fischer & Qaim, 2012; Hoddinott & Haddad, 1995). Earlier, Binswanger and von Braun (1991) argued that it is not given that incomes may rise from commercialisation. It is also possible, however, that commercialisation may dictate the disproportionate specialisation in the production of cash crops, and increased sales of food may reduce the availability of own food consumption and thus worsening food insecurity, particularly in a situation where sale incomes are used to purchase food and market prices are not remunerative (Carletto et al., 2017). Underlying missing markets and market failures may

impose high transaction costs, which can disrupt potential opportunities and gains from markets and thus reduce crop sale incomes, purchased diets and consumption (Abdul-Rahaman & Abdulai, 2020; Fafchamps, 1992). Commercialisation reduces the quantity of own-produced food for household use (Ogutu et al., 2020).

2.7 Summary of review

The review shows the agricultural commercialisation literature is replete with empirical evidence that primarily examine how transaction costs influence commercialisation behaviour of farmers. Ricardian trade theory is the basic theoretical underpinning of commercialisation studies. Recent studies have focused on the effect of commercialisation on development outcomes such as poverty, food and nutrition security. The measurement of commercialisation is primarily fixed on the household commercialisation index, which measures the ratio of crop sale value to crop production value. Several econometric modelling models are used, which are primarily based on a two-stage modelling approaches.

The review has provided several elements that have shaped this study. The definition of agricultural commercialisation capturing livestock dimension in the literature provided the motivation for the development of the extended metric of agricultural commercialisation. The contribution of Burke et al. (2015) on the triple-hurdle model has shaped the development and estimation of the quadruple-hurdle model. More importantly, the theoretical development of the quadruple-hurdle's likelihood function has benefited from their contribution. This study has also benefitted from the literature by borrowing the microeconomic theory of utility laid by Key et al. (2000). Further, the use of instruments for agricultural commercialisation in the quest to examine its impact on food and nutrition is fundamentally based on the literature. All the instruments of agricultural commercialisation come from previous studies this study

reviewed. In addition, the control variables selected for estimations and the choice of econometric models are based on the literature.

The literature review has clearly showed that adopting an appropriate conceptual framework or empirical causal relationship has provided a marked difference between current and earlier studies. While commercialisation has not become a panacea for improving food and nutrition security, it is undoubtedly a necessary condition for achieving food and nutrition security.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents the methodology employed to achieve the study's objectives. The specific issues presented are data, conceptual framework, theoretical framework, and methods of analysis.

3.2 Data

This study uses a cross-sectional design and a quantitative research approach involving the use of secondary and primary data. This study pertains to farm households in Ghana. Thus, the study area is the whole country. Ghana is agrarian, with majority of labour, especially in rural areas, involved in agricultural production. This study used household survey data collected by the GSS, named the Ghana Living Standards Survey (GLSS). The GLSS is one of the flagship country-wide data collected by the GSS, dating back to 1987 when the first round (GLSS1) was conducted. Since then, six more series have been collected between 1988 and 2017. The second, third, fourth, fifth and sixth rounds were undertaken respectively in 1988, 1991/92, 1998/99, 2005/2006 and 2012/2013. The specific round used by this study is the seventh (i.e., GLSS7), which is the latest and was collected between October 2016 and October 2017.

The GLSS7 involves a nationally representative and stratified random sample of 14,009 households in 1,000 enumeration areas. It adopted questionnaires from the Living Standards Measurement Survey of the World Bank (Ghana Statistical Service, 2019). The dataset has emerged as one of the most important, and richest in Ghana as it presents comprehensive,

reliable, and up-to-date data. Focusing on the household as the key socioeconomic unit, the GLSS7 comprises data on demographic characteristics of households, education, health, employment, migration and tourism, housing conditions, household agriculture, household expenditure, income and their components and access to financial services, credit, and assets. There is detailed data on agricultural production and marketing of various crops and livestock and various food and nutrition security information that met the objectives of this study.

However, to provide validation of the results from the GLSS7 dataset, primary data were collected in northern Ghana (including Northern, North-East, Savannah, Upper East, and Upper West regions). The main reason for this validation pertains to time. As indicated, the GLSS7 data was collected in 2016/2017. A more recent primary data provides the foundation to judge if determinants and impacts are consistent over time. Data from the GSS show that northern Ghana has the largest proportion of households owning or operating a farm. GSS (2019) reports that the Upper East region leads the rest of the regions in Ghana with a proportion of 83.2 percent, followed by the Upper West region with 80.4 percent and the Northern region with 70.6 percent.[5] Based on this, these five regions from northern Ghana were used as the study area for the primary data collection to validate the results from the GLSS7 dataset.

The specific target population for the primary data collection is farm households in Northern, Upper East, Upper West, Savannah, and North-East regions. Maize production data in the 2021/2022 season was used as basis of selecting a representative sample. Maize was chosen because it is an important staple crop in Ghana (Ministry of Food and Agriculture-

[5] The North-East and the Savannah regions were carved out from the Northern region after the GLSS7 data were collected. The data from these regions are thus within that of the Northern region.

International Food Policy Research Institute, 2020) and has high demand and potential for commercialised farming. In addition, maize is the highest cultivated crop in northern Ghana, cultivated by 266,320 households (representing 78.6% of all households), 122,609 households (representing 64.9% of all households), and 101,640 households (representing 77.7% of all households) in Northern, Upper East and Upper West regions, respectively (Ghana Statistical Service, 2019).

This study intended to derive a representative sample and thus, aimed at determining an appropriate sample size. From Ghana Statistical Service (2019), 338,651 households, 188,850 households and 130,775 households respectively in Northern[6], Upper East and Upper West regions were involved in agriculture in 2016/2017 production season, with a total in all these regions of 658,275 households. Applying this on the sample determination formular proposed by Yamane (1967) and assuming a precision level of 0.05, a total sample of 400 was obtained[7]. However, considering the objective of estimating a quadruple-hurdle model that demands a relatively large sample, this estimated sample size was increased (i.e., oversampling) to 858 farm households, representing the final sample size.

This study applied a multi-stage sampling procedure involving three stages to identify respondents. The first stage was the selection of districts in each region in consultation with the regional offices of MoFA based on the objective criterion of those that had higher production of maize in the 2020/2021 production season. The study purposefully determined to sample 10 districts across the five regions. Thus, the number of districts sampled in each

[6] Northern region at the time of collecting the data used here contained Savannah and North-East regions. Thus, the data for these two regions are in the northern region.

[7] For large population (i.e., 50,000+), the formula is given as $n = \frac{N}{1+N(e)^2}$, where N is the population, and e is the level of precision allowed (i.e., 0.05 or ±0.05).

region was proportional to the size of the number of districts in the region. Table 3.1 presents the sampled districts, communities, and sample size whiles Figure 3.1 presents a map of the sampled regions and districts. Based on the proportional apportionment of districts, three districts each were sampled from the Northern and Upper East regions, two districts from Upper West region, one each from Savannah and North-East regions. These sampled districts were identified as the topmost maize-producing districts.

Table 3.1: Sampled districts, communities and sample size

Region	No. of districts	Sampled district	Sampled community	Sample size
Northern	16	Gushiegu	Galwei	29
			Kpatinga	26
			Zinindo	31
		Savelugu	Diare	28
			Nakpanzoo	26
			Pigu	28
		Nanumba South	Kukuo	29
			Nakpayili	27
			Wulensi	33
Upper East	15	Talensi	Nungo	26
			Pwalugu	30
			Winkogo	30
		Tempane	Basyonde	26
			Tubong	24
			Woriyanga	24
		Garu	Farfar-Denugu	24
			Kugri-Songo	25
			Worikambo-Zaare	25
Upper West	11	Sissala East	Dasima	27
			Jeffisi	30
			Sorbelle	27
		Sissala West	Bujan	30
			Sakai	31
			Wellembelle	28
Savannah	7	Sawla-Tuna-Kalba	Kakiasi	36
			Nakwabi	34
			Nyange	34
North-East	6	West Mamprusi	Kparigu	31
			Nabari	30
			Shenvonyan	29
Total	55	10	30	858

Source: Author's compilation, 2022

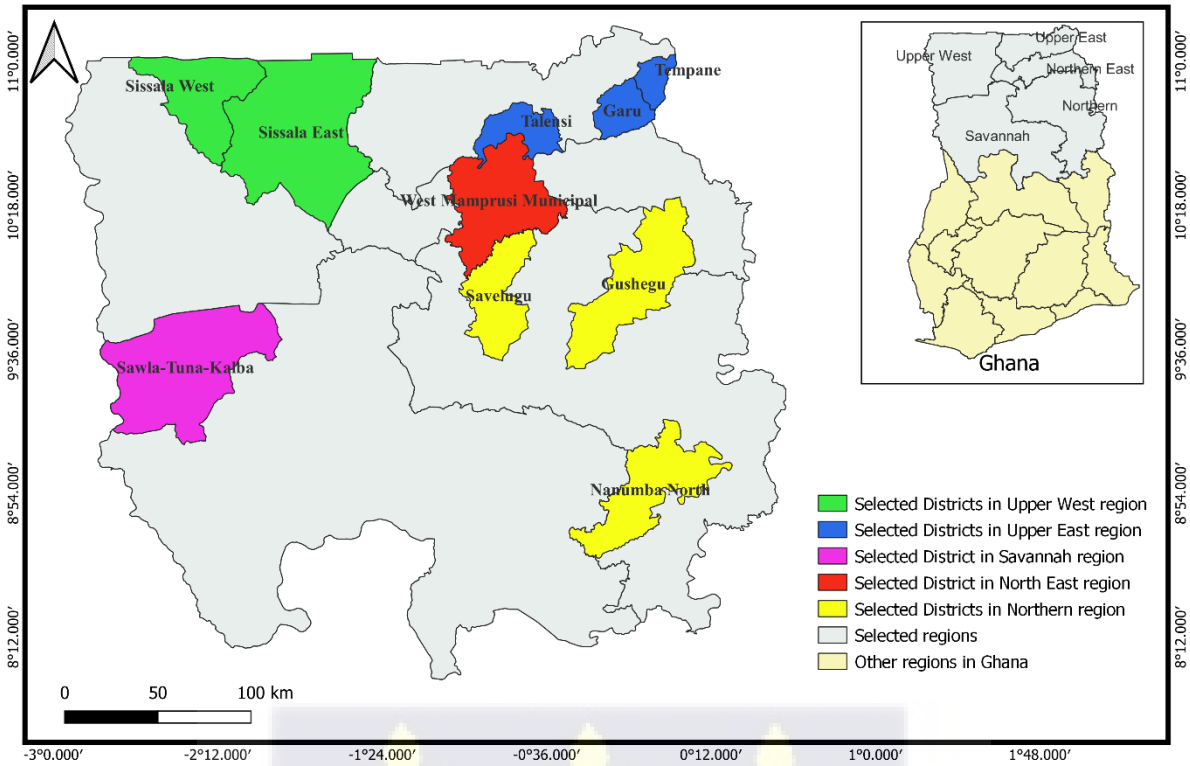


Figure 3.1: Map of study area for primary data

Source: Produced by the Remote Sensing/GIS Laboratory, Department of Geography, University of Ghana, 2022 on author's request

The second stage was an objective selection of three communities in each sampled district based on maize production level (i.e., the three topmost maize-producing communities). Thus, thirty communities were sampled (see Table 3.1). The final stage was the random sampling of farm households in the selected communities, distributed proportionally across regions. Northern region received the largest sample size because of its largest number of districts while North-East received the smallest because of its smallest number of districts. Apart from Savannah and North-East regions, which have one district each, the regional sample sizes were distributed near equally for the districts in Northern, Upper East and Upper West regions.

Further, community sample sizes were distributed near equally based on the sample sizes of the districts. Since the sampled communities did not have predefined list of farm households,

a list of all farm households in each community was compiled by enumerators assigned to the respective regions. Microsoft Excel's "RAND()" function was used to draw the random sample from the respective lists. Focused group discussions involving key informants were also conducted in each community to obtain community-level data such as market, bank, extension, road, availability of public transport and agricultural cooperatives. These variables are used in econometric models. Structured questionnaires (for the purpose of speeding the data collection process and analysis and ensuring consistency across the regions) were developed and programmed through computer-assisted personal interview (CAPI) in Enketo KoboToolbox platform.

3.3 Conceptual framework of the study

Based on the research questions and objectives, the conceptual framework that underpins this study is presented in Figure 3.2. The framework recognises that household resource endowments (e.g., land, farm equipment, wealth, and experience), household characteristics (e.g., size, composition and gender distribution) and enabling factors (e.g., favourable policy environment, favourable climatic and biophysical environment) influence the operations of crop and livestock production. On a crop or livestock-specific basis, a household may decide to produce a crop or livestock or both in a production season. This decision is what has been introduced by Burke et al. (2015) in the commercialisation literature as the first hurdle of their triple-hurdle model. Once the decision is made to produce, farmers have two decisions regarding their crop and livestock produce – either they decide to sell or otherwise. This is the first decision in the earlier two-step commercialisation literature but the second in the triple-hurdle approach. Those who decide not to sell are said to not participate in the market, otherwise referred to as autarchic households (see Bellemare & Barrett, 2006).

On the other hand, those who decide to sell are faced with two decisions regarding their participation in the market – either selling at the farmgate or the market centre.

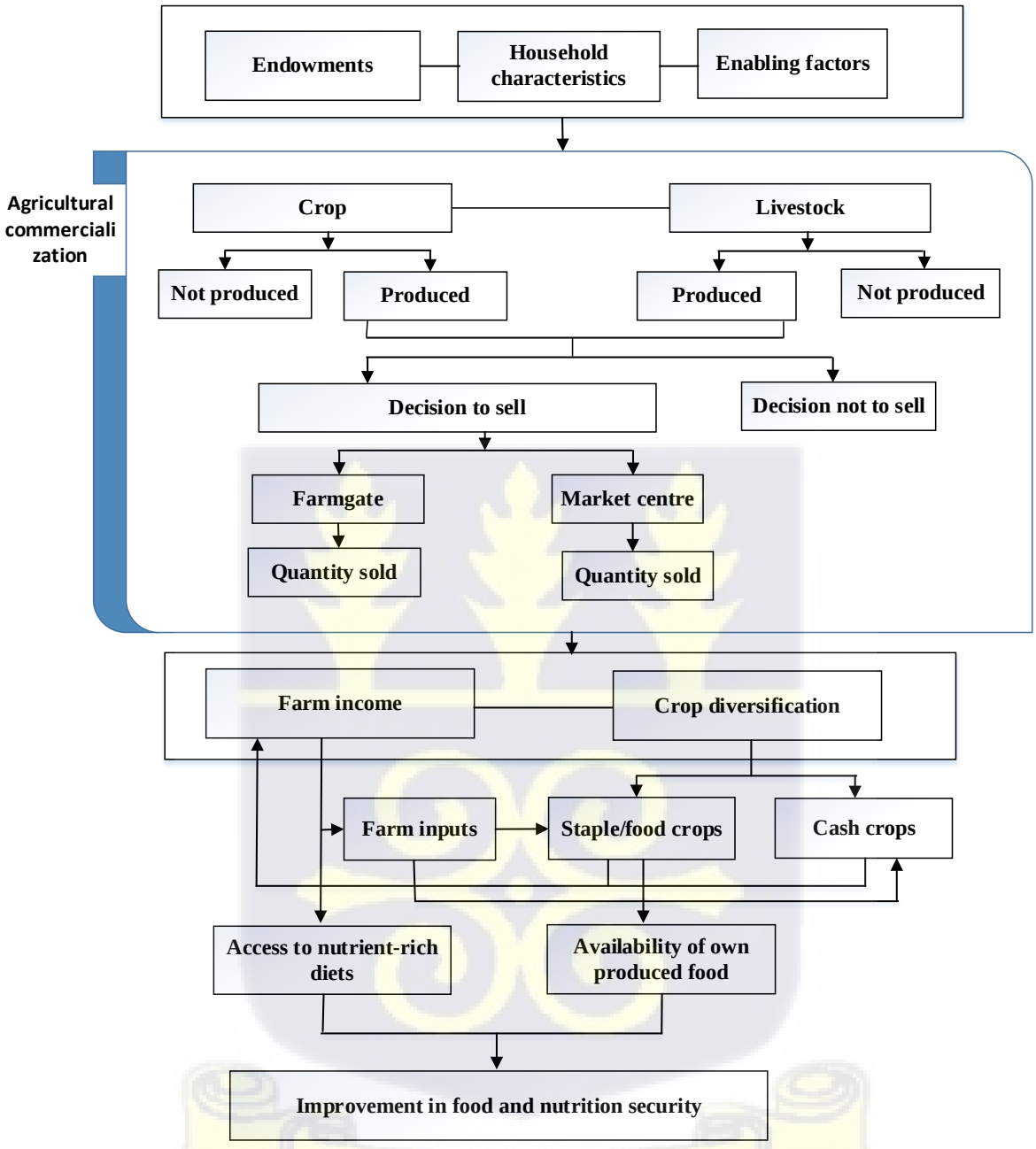


Figure 3.2: Conceptual framework
Source: Author's construct

Several studies (e.g., Abu et al., 2016; Fafchamps & Hill, 2005; Muamba, 2011) have explored the underlying factors that determine the choice of market. The two-step or triple-

hurdle modelling approaches do not capture this decision process. Finally, farm households decide the various quantities to sell at the chosen market. The decision to sell and the quantities sold define the two-step dimension of agricultural commercialisation, while the decision to produce, the decision to sell and the quantity sold underlie the triple-hurdle model. The production of crops and livestock provides the platform to conceptualise and measure agricultural commercialisation, which is influenced by household resource endowments, household characteristics and enabling factors (i.e., provides the opportunity to develop an extended metric of agricultural commercialisation (objective 1), and examine the determinants of the extended metric (objective 2)). Furthermore, the four decisions (i.e., production, sale, market choice, and sale quantity) provide the opportunity to estimate a quadruple-hurdle model of commercialisation (objective 4).

Agricultural commercialisation is then observed to boost farm incomes (see Binswanger & von Braun, 1991; Carletto et al., 2017; Kuma et al., 2019; Ogutu et al., 2020; von Braun, 1995; von Braun & Kennedy, 1994), and encourage crop diversification through economies of scope (see (Abdulai & CroleRees, 2001; Ecker, 2018; Govereh & Jayne, 2003). Farm income allows farmers to purchase productivity-enhancing farm inputs (i.e., fertilisers, improved seeds, pesticides and insecticides), which increases production and productivity of staple and cash crops. Increased production of staple food increases the availability of own-produced food, while increased production of cash crops increases farm income, which enhances the financial capacity of households to purchase nutrient-rich food they do not produce from markets. The availability of own-produced food and purchased food through increased income will ultimately lead to improved household food and nutrition security, which is the focus of objective 3.

3.4 Theoretical framework

Two competing household models attributed to Singh et al. (1986) applied to agricultural commercialisation are the separable and the non-separable models. The separable model operates under a well-functioning input and output market and posits that farm households make independent production and consumption decisions under a utility maximisation framework, whiles the non-separable model posits that farm households make production and consumption decisions simultaneously because of missing or imperfect input and output markets (Benjamin, 1992; Henning & Henningsen, 2007; Omamo, 1998).

In general, the commercialisation literature is theoretically underpinned by the theory of trade proposed by Ricardo (1817). Inference from the Ricardian trade theory indicates that farm households engage in markets to benefit from numerous consumption bundles to derive welfare gains by specializing in producing goods for which they have comparative advantage, and exchange for those they have no comparative advantage. However, the macro nature of the trade theory makes it weak to explain micro-level developments of farmer market engagements. This shortcoming led to the development of alternative theoretical foundations for agricultural commercialisation.

Micro-level theoretical basis for this study is derived from the theory of utility. Following the initial theoretical foundation first laid by Key et al. (2000), reemphasised by Bellemare and Barrett (2006) and further applied by Burke et al. (2015) and Bolarinwa et al. (2021), a farm household seeks to maximise its utility specified in equation (3.1):[8]

[8] For subscripts: *i* is household, *u* is utility, *j* is good/crop, *p* is proportional, *f* is fixed, *q* is quantity produced; for superscripts: *m* is market, *s* is seller, *b* is buyer, *cc* is community characteristics, *hi* is household input and *us* is unknown shocks.

$$\boldsymbol{max}\ \boldsymbol{u}(\boldsymbol{c_i}; \boldsymbol{z_u}) \quad (3.1)$$

Subject to constraints in equation (3.2) through equation (3.5):

$$\sum_{i=1}^{N} \left[\left(\boldsymbol{p_j^m} - \boldsymbol{t_{pj}^s}(\boldsymbol{z_t^s})\boldsymbol{\delta_j^s}\right) + \left(\boldsymbol{p_j^m} + \boldsymbol{t_{pj}^b}(\boldsymbol{z_t^b})\boldsymbol{\delta_j^b}\right)\right]\boldsymbol{m_j} - \boldsymbol{t_{fj}^s}(\boldsymbol{z_t^s})\boldsymbol{\delta_j^s} - \boldsymbol{t_{fj}^b}(\boldsymbol{z_t^b})\boldsymbol{\delta_j^b} + \boldsymbol{T} = \boldsymbol{0} \quad (3.2)$$

$$\boldsymbol{q_j} - \boldsymbol{n_j} + \boldsymbol{A_j} - \boldsymbol{m_j} - \boldsymbol{c_j} = \boldsymbol{0}, \boldsymbol{j} = \boldsymbol{1}, \ldots, \boldsymbol{J} \quad (3.3)$$

$$\boldsymbol{G}(\boldsymbol{q}, \boldsymbol{n}; \boldsymbol{z_q}) = \boldsymbol{0} \quad (3.4)$$

$$\boldsymbol{c_j}, \boldsymbol{q_j}, \boldsymbol{n_j} \geq \boldsymbol{0} \quad (3.5)$$

Equation (3.1) represents the objective function of the farm household, expressed as the household's utility u as a function of consumption vector c for each good i and z_u defines the exogenous shifters in utility. Equation (3.2) identifies the household's typical budget constraint, acknowledging the presence of proportional and fixed transaction costs. p_j^m is a vector of market prices for the goods produced, t_{pj}^s and t_{fj}^s are, respectively, proportional and fixed transaction costs incurred by sellers while t_{pj}^b and t_{fj}^b are, respectively, proportional and fixed transaction costs incurred by buyers. These transaction costs respectively affect the price received and paid by sellers and buyers, respectively. It is observed that t_{pj}^s and t_{pj}^b are generally unobserved and are accounted for by setting them as functions of observable exogenous factors denoted by z_t^s and z_t^b respectively. δ_j^s is market engagement indicator equal to 1 for sellers of good j and 0 otherwise, and δ_j^b is equal to 1 for buyers of good j and 0 otherwise. m_j is the quantity of good j marketed and T represents exogenous transfers and all other income. Equation (3.3) represents the resource balance, which basically states that for any good j, the amount consumed, c_j, the amount marketed, m_j and the amount of inputs used, n_j, cannot exceed the amount produced, q_j, and the endowment, A_j. Equation (3.4) is the typical production technology used by the household, which relates the output produced,

q_j, to the inputs used, n_j, and other supply shifters, z_q, which is assumed to depend on other exogenous factors. Equation (3.5) represents non-negativity constraints.

From these specifications of objective function and constraints, a typical Lagrangian function that provides the platform to obtain first order conditions (FOCs) of optimal solution is specified as:

$$\mathbf{L} = \boldsymbol{u}(\boldsymbol{c_i}; \boldsymbol{z_u}) + \sum_{j=1}^{N} \boldsymbol{\mu_j}(\boldsymbol{q_j} - \boldsymbol{n_j} + \boldsymbol{A_j} - \boldsymbol{m_j} - \boldsymbol{c_j}) + \boldsymbol{\phi G}(\boldsymbol{q}, \boldsymbol{n}; \boldsymbol{z_q}) + \boldsymbol{\lambda}\left[\sum_{i=1}^{N} \left[(\boldsymbol{p_j^m} - \boldsymbol{t_{pj}^s})\boldsymbol{\delta_j^s} + (\boldsymbol{p_j^m} + \boldsymbol{t_{pj}^b})\boldsymbol{\delta_j^b}\right]\boldsymbol{m_j} - \boldsymbol{t_{fj}^s}\boldsymbol{\delta_j^s} - \boldsymbol{t_{fj}^b}\boldsymbol{\delta_j^b} + \boldsymbol{T}\right] \quad (3.6)$$

Where μ_j, ϕ and λ are the Lagrange multipliers for the respective constraints. The first order condition with respect to the traded quantity, m_j, is expressed as:

$$-\boldsymbol{\mu_j} + \boldsymbol{\lambda}\left[(\boldsymbol{p_j^m} - \boldsymbol{t_{pj}^s})\boldsymbol{\delta_j^s} + (\boldsymbol{p_j^m} - \boldsymbol{t_{pj}^b})\boldsymbol{\delta_j^b}\right] = \mathbf{0}, \qquad \boldsymbol{j} \in \{\boldsymbol{j}|\boldsymbol{m_j} \neq \mathbf{0}\} \quad (3.7)$$

An indirect utility function derived generally from the optimisation problem in equation (3.6) and specifically on the FOC in equation (3.7) yields the traded quantity functions specified as:

$$\boldsymbol{m_s} = (\boldsymbol{q} - \boldsymbol{c}) = \boldsymbol{m_s}(\boldsymbol{z_t^s}, \boldsymbol{z_q}, \boldsymbol{n}, \boldsymbol{p^m}, \boldsymbol{T}, \boldsymbol{A}), \text{ for net sellers, and} \quad (3.8)$$

$$\boldsymbol{m_b} = (\boldsymbol{c} - \boldsymbol{q}) = \boldsymbol{m_b}(\boldsymbol{z_t^b}, \boldsymbol{z_q}, \boldsymbol{n}, \boldsymbol{p^m}, \boldsymbol{T}, \boldsymbol{A}), \text{ for net buyers} \quad (3.9)$$

Equation (3.8) and equation (3.9) are the basic theoretical models that underpin empirical studies of commercialisation in the literature. However, these well-known theoretical

equations have two main weaknesses. First, they do not explicitly provide the platform to model a particular crop's first-stage production decision (Burke et al., 2015). Second, they fail to consider the dichotomy of market participation decisions of selling/buying at farmgate or at a designated market centre.

Burke et al. (2015) solved the first weakness by stating the maximisation of expected utility specified in equation. (3.10), subject to the uncertain objective function for commercialisation equation (3.11):

$$\boldsymbol{max}\ \boldsymbol{E}[\boldsymbol{u}(\boldsymbol{c})] \tag{3.10}$$

$$\boldsymbol{D}[\boldsymbol{m}] = \boldsymbol{D}\left[\boldsymbol{m}\left(\boldsymbol{z_t}, \boldsymbol{z_q}, \boldsymbol{n}, \boldsymbol{p^m}, \boldsymbol{T}, \boldsymbol{A}\right)\right] \tag{3.11}$$

Burke et al. (2015) argue that the determinants of input demand, n, which is essentially analogous to the decision to produce a particular crop, is fundamentally based on the distribution of marketing outcomes under the assumption that the household has information on these marketing engagement determinants before producing a particular crop. For example, factors such as transaction costs, distance to a market, presence of traders around the locality, access to some productive resources and proximity to public agricultural services may be known by farm households before making production decisions. However, factors such as the unknown production shocks z_q^{us} and market prices p^m may be unknown at the time of production. Farm households negotiate their lack of direct knowledge of these factors by taking the expected value of these shocks and market prices in the form of their respective distributions to serve as the basis of making production decisions. Denoting these distributions as $D(z_q^{us})$ and $D(p^m)$ respectively, the rule that establishes the decision to produce a particular crop is specified as:

$$\boldsymbol{n} = \boldsymbol{n}\left[\boldsymbol{z_t}, \boldsymbol{z_q^{cc}}, \boldsymbol{z_q^{hi}}, \boldsymbol{D}\left(\boldsymbol{z_q^{us}}\right), \boldsymbol{D}(\boldsymbol{p^m}), \boldsymbol{T}, \boldsymbol{A}\right] \quad (3.12)$$

$$\boldsymbol{w_1} = \boldsymbol{w_1}\left[\boldsymbol{z_t}, \boldsymbol{z_q^{cc}}, \boldsymbol{z_q^{hi}}, \boldsymbol{D}\left(\boldsymbol{z_q^{us}}\right), \boldsymbol{D}(\boldsymbol{p^m}), \boldsymbol{T}, \boldsymbol{A}\right] \quad (3.13)$$

$$\boldsymbol{w_1} = \boldsymbol{0}, \text{ if } \boldsymbol{n} = \boldsymbol{0} \text{ and } \boldsymbol{w_1} = \boldsymbol{1}, \text{ if } \boldsymbol{n} > \boldsymbol{0} \quad (3.14)$$

where w_1 defines the binary decision of whether a farm household produces a particular crop or otherwise. The inclusion of equation (3.13) (that represents the binary indicator w_1) to the theoretical models in equation (3.8) and equation (3.9) profoundly extends the literature from a double-hurdle case to a triple-hurdle case.

However, the second weakness of failing to account for the dichotomy of market participation decisions regarding farmgate and designated market centre sales remains unresolved. Meanwhile, this hurdle is non-trivial because the choice of market by farm households is a key determinant of the effectiveness of the market system in poverty alleviation (Abu et al., 2016). Also, the generally less remunerative farmgate participation (Fafchamps & Hill, 2005) presents a challenge that needs policy attention.

To solve the dichotomy of market participation decisions, we still exploit the maximisation problem in equation (3.10) and equation (3.11). The study argues that what determines the level of transaction costs, z_t, which is essentially analogous to the decision to sell at the farmgate or at a designated market centre, is fundamentally based on the distribution of both marketing outcomes and infrastructural endowment which are known by the farm households before deciding to sell at the farmgate or at a designated market centre. For example, factors such as market prices (both at farmgate and market centres), transportation costs to the nearest market centres, the volume of marketable surpluses, ownership of private means of

transport, accessibility to public transport, nature of roads to market centres and pre-contractual arrangements are known by farm households before making market choice decisions. However, factors such as the unknown production shocks z_q^{us} and market prices p^m may be unknown at the time of production. Farm households negotiate their lack of direct knowledge of these factors by taking the expected value of these shocks and market prices in the form of their respective distributions to serve as the basis for making market choice decisions. Denoting these distributions as $D(z_q^{us})$ and $D(p^m)$ respectively, the rule that establishes the decision of a market choice of a particular crop is specified as:

$$\boldsymbol{z_t = z_t\left[z_q^{cc}, z_q^{hi}, D\left(z_q^{us}\right), p^m, T, A\right]} \quad (3.15)$$

$$\boldsymbol{w_3 = w_3\left[z_q^{cc}, z_q^{hi}, D\left(z_q^{us}\right), p^m, T, A\right]} \quad (3.16)$$

$$\boldsymbol{w_3 = 0}, \text{ if } \boldsymbol{z_t = 0} \text{ and } \boldsymbol{w_3 = 1}, \text{ if } \boldsymbol{z_t > 0} \quad (3.17)$$

Where w_3 defines the binary decision of whether a farm household sells at the farmgate or at a designated market centre. The inclusion of equation (3.16) (that represents the binary indicator w_3) to the theoretical models in equation (3.8) and equation (3.9) in addition to the first stage decision to produce (equation (3.13)) further presents an extension from Burke et al.'s (2015) triple-hurdle to a quadruple-hurdle. The solution to this weakness provides the fundamental contribution of this study to the theoretical developments of the agricultural commercialisation literature.

Based on the foregoing, the quadruple-hurdle theoretical specification can be represented as:

Production decision: $\boldsymbol{w_1 = w_1\left(z_t, z_q^{cc}, z_q^{hi}, D\left(z_q^{us}\right), D(p^m), T, A\right)}$ (3.18)

Market participation decision: $\boldsymbol{w_2 = w_2\left(z_t^b, z_q, n, p^m, T, A\right)}$ (3.19)

Choice of market decision: $\boldsymbol{w_3 = w_3\left(z_q^{cc}, z_q^{hi}, D\left(z_q^{us}\right), p^m, T, A\right)}$ (3.20)

Intensity of farmgate sellers: $\boldsymbol{q_4 = q_4\left(z_t^b, z_q, n, p^m, T, A\right)}$ (3.21)

Intensity of market centre sellers: $\boldsymbol{q_5 = q_5\left(z_t^b, z_q, n, p^m, T, A\right)}$ (3.22)

where w_2 is a binary indicator showing whether a household participates in the market to sell a crop or otherwise, q_4 is the sales quantity of a farmgate seller, q_5 is the sales quantity of a market centre seller and the rest are as defined before.

3.5 Methods of analysis

The methods of analysis are presented in accordance with the four specific objectives of this study.

3.5.1 Measurement of agricultural commercialisation

Following from the weaknesses of the previous measures of commercialisation in the literature, this study defines a composite measure of agricultural commercialisation, named the Household Crop-Livestock Commercialisation Index (HCLCI) and defined mathematically as:

$$\boldsymbol{HCLCI_i = \frac{\sum_{k=1}^{K} \bar{P}_k S_{ik} + \sum_{l=1}^{L} \bar{A}_l M_{il}}{\sum_{k=1}^{K} \bar{P}_k Q_{ik} + \sum_{l=1}^{L} \bar{A}_l N_{il}}} \quad (3.23)$$

Where S_{ik} is farm household i's market sales quantity of crops k valued at the community average price $\bar{P}_k$, Q_{ik} is the quantity of all crops K produced also evaluated as the average community-level price $\bar{P}_k$ (see equation 2.2). M_{il} is the total number of livestock sold at the average sale price $\bar{A}_l$, N_{il} is the total number of livestock owned and L is a vector of all

livestock. The measure, $\frac{\sum_{l=1}^{L} \bar{A}_l M_{il}}{\sum_{l=1}^{L} \bar{A}_l N_{il}}$ defines a household livestock commercialisation index (HLCI). The HCLCI will also lie between 0 and 1 (i.e., $0 \leq HCLCI_i \leq 1$). If a household does not participate in both crop and livestock markets, $HCLCI = 0$, but if the household participates in one of the markets, it will be $0 < HCLCI_i < 1$. Since it is an average, HCLCI will penalise a household in two ways; first, for not participating in either the livestock or crop market sides of commercialisation, and second, when participation on one side is low. Given that the HCLCI is an amalgam of the HCCI and the HLCI, retrieving the standalone crop and livestock commercialisation indices is very easy. In other words, the HCLCI is decomposable into HCCI and HLCI.

This study argues that HCLCI is more important in measuring farm households' commercialisation than the standalone measures. The HCLCI is relatively more capable to identify farm households which are regarded as subsistent than the HCCI, because, in the case of the latter, a household may participate in the livestock market but not the crop market and still classified as a non-market participant (i.e., have 0 HCCI) but the former will at least capture the livestock participation. It also easily solves the criticism of the HCCI not capturing the livestock dimensions of commercialisation. Again, by including HLCI, it solves the issues of misleading estimates of commercialisation provided by the HCCI.

After estimating the level of commercialisation, farm households are characterised based on their commercialisation levels following the categorisation of FAO (1989) and Pingali and Rosegrant (1995) that: (i) farmers who sell less than 25 percent of their produce (i.e., $sales < 25\%$) are characterised as subsistent-oriented; (ii) farmers who sell at least 25 percent but less than 50 percent of their produce (i.e., $25\% \leq sales < 50\%$) are characterised as

surplus-oriented; and (iii) farmers who sell at least 50 percent of their produce (i.e., $sales \geq 50\%$) are characterised as commercial-oriented.

3.5.2 Determinants of agricultural commercialisation

Given that the HCLCI is a fraction (relating the value of sale to the value of production of crop and livestock) that yields an index from 0 to 1, implying a case where non-market participants are still included in the sample, the appropriate econometric approach to modelling its determinants is the fractional regression model. The fractional regression framework is applied to empirical studies where the outcome of interest is a fraction (i.e., either between 0 and 1 or from 0 to 1) such as proportions and rates. This modelling framework has been applied to several empirical works including, labour market participation rates of employees' retirement plans (Papke & Wooldridge, 1996) and examination pass rates of students (Papke & Wooldridge, 2008).

Basically, the fractional response regression is a quasi-likelihood estimator that fits a model using the mean of the outcome variable conditioned on a vector of covariates using probit, logit, or heteroskedastic probit model. The general log-likelihood function for fractional response models is specified as:

$$\ln L = \sum_{j=1}^{N} w_j \, y_j \ln\{G(x_j'\beta)\} + w_j(1 - y_j) \ln\{1 - G(x_j'\beta)\}$$

Where N represents the observations, y_j denotes the dependent variable, w_j represents the optional weights, $\ln L$ is derived through a maximisation process and $G(x_j'\beta)$ can be modelled following probit or logit. If the functional form underlying $G(x_j'\beta)$ is a cumulative normal

distribution density function, then the probit specification can be specified as $\Phi(x_j'\beta)$. x_j represents a vector of all covariates and Φ represents the standard normal cumulative density function.

The fractional response model is applied to fit the parameters of the following model:

$$\boldsymbol{HCLCI_i = \beta_0 + \beta_1 SEC_i + \beta_2 FC_i + \beta_3 CC_i + \beta_4 LC_i + \epsilon_i} \quad (3.24)$$

Where SEC, FC, CC and LC, respectively, represent vectors of household socioeconomic characteristics, farm characteristics, community characteristics and location characteristics that are hypothesised to influence the level of commercialisation (Table 3.2). The use of these variables is influenced by the theoretical model in equation (3.8) and literature (Abu et al., 2016; Burke et al., 2015; Ogutu et al., 2020; Olwande et al., 2015). Socioeconomic variables such age and education proxy for the managerial and technical capacity of farm households which are key in making farm decisions. Socioeconomic characteristics that indicate household endowment (such as assets, remittances, and nonfarm income) provide essential resources for farm investments, whiles household size is usually a proxy for labour. These variables have implications for commercialisation, and food and nutrition security. Farm characteristics provide useful information on farm investments and maintenance level that are also key for commercialisation.

Further, community characteristics proxy for the level of social networks, community endowments and resource base, which stimulate commercialisation as well as food and nutrition security.

Table 3.2: Explanatory variables and their measurement

Variable	Measurement
Socioeconomic characteristics	
Gender of head	Dummy: 1 = if male; 0 otherwise
Age of head	Number of years
Household size	Number of people in household
Marital status of head	Dummy: 1 = if married; 0 otherwise
Education of head	Number of years attended school
Received cash remittance	Dummy: 1 = if yes; 0 otherwise
Nonfarm engagement	Dummy: 1 = if yes; 0 otherwise
Value of assets	Ghana cedi (GHS)
Stop work due to illness	Number of times in the production season
Farm characteristics	
Number of crops produced	Number produced
Agric land endowment	Hectares (ha)
Expenditure on agrochemicals	Ghana cedi (GHS)/ha
Expenditure on hired labour	Ghana cedi (GHS)/ha
Community characteristics	
Presence of agric extension office	Dummy: 1 = if yes; 0 otherwise
Presence of agric cooperatives	Dummy: 1 = if yes; 0 otherwise
Availability of irrigation fields	Dummy: 1 = if yes; 0 otherwise
Perceived rain pattern	Dummy: 1 = if more rain; 0 otherwise
Availability of navigable road	Dummy: 1 = if yes; 0 otherwise
Availability of public transport	Dummy: 1 = if yes; 0 otherwise
Availability of mobile phone network	Dummy: 1 = if yes; 0 otherwise
Presence of bank	Dummy: 1 = if yes; 0 otherwise
Presence of public market	Dummy: 1 = if yes; 0 otherwise
Location characteristics	
Resides in rural area	Dummy: 1 = if yes; 0 otherwise
Lives in southern Ghana	Dummy: 1 = if yes; 0 otherwise
Lives in coastal zone	Dummy: 1 = if yes; 0 otherwise
Lives in forest zone	Dummy: 1 = if yes; 0 otherwise
Lives in savannah zone	Dummy: 1 = if yes; 0 otherwise
Lives in Greater Accra area	Dummy: 1 = if yes; 0 otherwise
Lives in NR	Dummy: 1 = if yes; 0 otherwise
Lives in UER	Dummy: 1 = if yes; 0 otherwise
Lives in UWR	Dummy: 1 = if yes; 0 otherwise
Lives in SR	Dummy: 1 = if yes; 0 otherwise
Lives in NER	Dummy: 1 = if yes; 0 otherwise

Notes: NR (northern region), UER (upper east region), UWR (upper west region), SR (savannah region) and NER (northeast region) pertain only to the primary data; physical quantities of agrochemicals (comprising fertiliser, insecticides and herbicides) and hired labour are not used because the GLSS7 data only capture amount spent.

For example, presence of agricultural cooperatives in community, agriculture extension office in community and bank in community are used as proxies for membership in agricultural cooperatives, access to extension services and credit/financial inclusion, respectively.

Location characteristics proxy for environmental and biophysical characteristics that affect production.

In the GLSS7 data, two models are estimated, including (i) a model without correcting for selectivity bias and (ii) a model that corrects for selectivity bias. The rationale for accounting for selectivity bias in the GLSS7 but not in the primary data is because, in the former case, out of the 14,009 sample, only 7,332 households produced either crop or livestock or both. Therefore, the HCLCI is constructed for only this subsample which is used for estimations. Therefore, using the subsample out of the total sample (which was randomly selected) presents potential selectivity bias and must be accounted for. However, in the primary data, all the 858 randomly selected households produced either crop or livestock or both, for which HCLCI is constructed for all. The baseline model (i.e., the preferred) is the one where selectivity bias will be accounted for. Selection bias is corrected using a two-part model, which is a type of Heckman selection model where a first stage probit model is estimated with the dependent variable of participating in the market to sell crop and livestock (i.e., 1 for the case where a household sells crop and livestock and 0 otherwise). After estimating the probit model, an inverse mills ratio is estimated and then added to the fractional regression model to simultaneously detect and correct for selectivity bias in the second stage.

3.5.3 Impact of agricultural commercialisation on food and nutrition security

In measuring the impact of the extended metric of agricultural commercialisation (i.e., HCLCI) on food and nutrition security in a household farm setting, we specify the following generic regression model:

$$\boldsymbol{FNS_i = \delta_0 + \delta_1 AC_i + \delta_2 X_{i1} + \varepsilon_{i1}} \quad (3.25)$$

where FNS_i indexes food and nutrition security outcome for household i. Several indicators are used to proxy for food and nutrition security including, food consumption expenditures, child anthropometric measures of stunting, wasting and underweight, and food security access scales. This implies that several models are estimated based on the type of indicator used. AC_i denotes the level of the extended metric of agricultural commercialisation of the household (i.e., HCLCI, which is the proportion of crop and livestock sold), X_{i1} represents all exogenous (control) variables hypothesised to influence food and nutrition security outcomes (see Table 3.2), δ_0, δ_1 and δ_2 are the estimated parameters, and ε_{i1} is the error term. Equation (3.25) is referred to as a generic model because food and nutrition security are measured in several ways. The parameter of interest is δ_1, which captures the effect of commercialisation (AC_i) on food and nutrition security metrics (FNS_i). However, due to the generic nature of the equation, δ_1 is still ambiguous since the measurement of food and nutrition security are different. In addition, the sign of δ_1 may depend on the metric considered. For example, its sign is expected to be positive for outcomes such as food consumption expenditures but negative for measures of stunting, wasting and underweight.

The measures of food and nutrition security used in this study are presented in Table 3.3. Twelve measures are used, distributing into six apiece for food security and nutrition outcomes. Seven measures are common in the GLSS7 and the primary data.[9] HDDS is measured as the number of food groups consumed. Twelve food groups are used including (i) cereals, (ii) roots and tubers, (iii) pulses, legumes, and nuts, (iv) meat and poultry, (v) fish

[9] Though the food consumption expenditure outcome is common in the two datasets, they are measured differently. In the GLSS7, the per capita expenditure is in real value while that of the primary data is in nominal value. In addition to these, an additional measure of per capita adult equivalent food expenditure is used for the GLSS7 data, while total food consumption expenditure is used for the primary data.

and seafood, (vi) vegetables, (vii) milk and milk products, (viii) fruits, (ix) eggs, (x) oil and fats, (xi) sugar and honey, and (xii) miscellaneous (usually condiments and spices).

Table 3.3: Measurements of food and nutrition security outcomes

Variable	Measurement	Data source
Food security outcomes:		
Per capita real annual food consumption expenditure	Continuous: GHS/annum	GLSS7
Per capita annual food consumption expenditure	Continuous: GHS/annum	Primary
Household Dietary Diversity Score (HDDS)	Continuous: number of food groups consumed	GLSS7 and primary
Food Consumption Score (FCS)	Continuous: weighted average of number of food groups consumed	GLSS7 and primary
Food Insecurity Experience Scale (FIES)	Ordered: 0 = Severe food insecurity; 1 = Moderate food insecurity; 2 = Food security to mild food insecurity)	GLSS7 and primary
Household Hunger Scale (HHS)	Ordered: 0 = Severe hunger; 1 = Moderate hunger; 2 = Little to no hunger	Primary
Household Food Insecurity Access Scale (HFIAS)	Ordered: 0 = Severely food insecure; 1 = Moderately food insecure; 2 = Mildly food insecure; 3 = Food secure	Primary
Nutrition outcomes:		
Vitamin A	Continuous: household frequency consumption of vitamin A rich foods over 7 days	GLSS7 and primary
Protein	Continuous: household frequency consumption of protein rich foods over 7 days	GLSS7 and primary
Hem iron	Continuous: household frequency consumption of hem iron rich foods over 7 days	GLSS7 and primary
Stunting	Dummy: 1 = if child is stunted; 0 otherwise	GLSS7
Wasting	Dummy: 1 = if child is wasted; 0 otherwise	GLSS7
Underweight	Dummy: 1 = if child is underweight; 0 otherwise	GLSS7

From these food groups, HDDS is calculated as the sum of the consumption of each food group. Thus, it ranges between 0 (i.e., no consumption of any food group, which is unlikely) and 12 (i.e., consumption of all food groups). The higher the score, the better. The HDDS essentially serves as a proxy for the degree of household nutritional needs being met (Jones et al., 2014; Parappurathu et al., 2015). More calories, intake of vital micronutrients, and good nutritional status are linked to a more varied diet (Azzarri et al., 2015; Kumar et al., 2015;

M'Kaibi et al., 2017; Wagner & Tasciotti, 2018). Hence, dietary diversity is a reliable proxy for access to food and nutrients.

The FCS is similar to the measurement of the HDDS except that weights are applied to the food groups in addition to considering the frequency of consumption of these food groups. In constructing the FCS, the twelve food groups used in computing the HDDS are scaled down to 8 groups, namely (i) main staples, (ii) pulses, (iii) vegetables, (iv) meat and fish, (v) milk and milk products, (vi) fruits, (vii) oil and fats, and (viii) sugar and honey (see e.g., Chegere & Kauky, 2022; WFP, 2008). From this re-categorisation, the FCS is calculated as: FCS = (main starches*2) + (pulses*3) + (vegetables*1) + (fruits*1) + (meat and fish*4) + (milk and milk products*4) + (oil and fats*0.5) + (sugar*0.5), where the values are the weights. The FCS is important because it gives an indication of dietary variety, frequency of food intake, and nutritional value in relative terms (WFP, 2008). The construction of intake of vitamin A-rich food, protein-rich food and hem iron-rich food followed the same procedure of constructing the HDDS, except that sub-food groupings under each food group were used. Thus, sub-food groups that are known to contribute to these nutrients were re-classified. The consumption frequency of these sub-groups over 7 days under each nutrient were summed to construct the outcomes. The sub-food groups for each nutrient are dairy, organ meat, eggs, orange and green vegetables, and orange fruits for vitamin A rich foods; pulses, dairy, flesh meat, organ meat, fish, and eggs for protein rich foods; and flesh meat, organ meat and fish for hem iron rich foods. Double counting for the construction of these nutrients is permitted because they measure inadequacy of these nutrients rather than dietary diversity (see WFP, 2015).

FIES is constructed from several questions, from which various scores from 0 to 8 are obtained for different households. These scores are then used to categorise households into three streams: food secured or mildly food insecure households (FIES score of 0 to 3), moderate food insecure households (FIES score of 4 to 6), and severe food insecure households (FIES score of 7 to 8) (e.g., Wambogo et al., 2018). These categorisations provide an ordered outcome, because food secured or mildly food insecure condition is better than moderate food insecurity condition and severe food insecurity households, and moderate food insecurity condition is better than severe food insecurity condition. Similarly, HHS and HFIAS are constructed from respective questions that yield scores to categorise into their respective ordered outcomes.

Further, the GLSS7 dataset has information to construct child (i.e., 0-59 months) anthropometric measures of stunting, underweight and wasting. Stunting, underweight and wasting indicators are generally conceptualised respectively by Height-for-Age (H/A), Weight-for-Age (W/A) and Weight-for-Height (W/H). The respective z-scores of these indicators are used as the measures of stunting, underweight and wasting. The z-score, Z_{ij}, for the i^{th} indicator for the j^{th} child is estimated as:

$$\boldsymbol{Z_{ij} = \frac{V_{ij} - V_{Mi}}{\sigma_{Mi}}} \qquad (3.26)$$

where V_{ij} denotes the observed value of the i^{th} indicator for the j^{th} child, V_{Mi} and σ_{Mi} respectively denote the median and standard deviation of the i^{th} indicator in the reference population. The WHO Anthro software (WHO, 2011) was used to estimate the z-scores for stunting (i.e., Height-for-Age Z-score (HAZ)), underweight (i.e., Weight-for-Age Z-score (WAZ)) and wasting (i.e., Weight-for-Height Z-score (WHZ)). The HAZ, WAZ and WHZ

estimates were then used to indicate whether a child is stunted, wasted and underweight or otherwise. A child with HAZ, WHZ, and WAZ less than -2 z-scores is identified as stunted, wasted, and underweight. WHO (2011) indicates that some z-scores are outliers and should not be considered for analysis to prevent distortion. Outliers ($-6 > HAZ > 6$; $-5 > WHZ > 5$; $-6 > WAZ > 5$) were dropped from the analysis.

It is important to note that the food and nutrition security measures used in this study do not capture all the dimensions of food security, especially in light of the proposal for a six-dimension of food security (see Clapp et al., 2022). Generally, the measures capture – albeit individually and not cumulatively – availability, access, and utilisation dimensions of food security but not the stability and now agency and sustainability dimensions. HDDS, FCS, stunting, wasting and underweight capture utilisation dimension of food security (Anderman et al., 2014). Vitamin A, protein, hem iron, FIES, HHS and HFIAS are all measures of availability and accessibility. Further, food consumption expenditures, HDDS and FCS capture the accessibility dimension of food security (Kennedy et al., 2011; Lovon & Mathiassen, 2014; WFP, 2008) as they help measure economic access to food.

Agricultural commercialisation is measured using the extended metric – the household crop-livestock commercialisation index (HCLCI). Considering the food and nutrition security measures in Table 3.3, we can re-specify equation (3.25) as:

$$\boldsymbol{FNS_{ij} = \alpha_{0j} + \alpha_{1j}AC_i + \alpha_{2j}X_{i1} + \epsilon_{ij1}} \quad (3.27)$$

$$\boldsymbol{FNS_{ik} = \beta_{0k} + \beta_{1k}AC_i + \beta_{2k}X_{i1} + u_{ik1}} \quad (3.28)$$

$$\boldsymbol{FNS_{il} = \gamma_{0l} + \gamma_{1l}AC_i + \gamma_{2l}X_{i1} + v_{il1}} \quad (3.29)$$

Where j $(j = 1, \ldots, 9)$, k $(k = 1,2,3)$ and l $(l = 1,2,3)$ respectively represent continuous, dummy, and ordered food and nutrition security outcomes in Table 3.3. $\alpha's$, $\beta's$ and $\gamma's$ are respective parameters to be estimated, and ϵ, u and v are respective error terms. Specifically, α_1, β_1, and γ_1 respectively measure the impact of commercialisation on the various measures.

If we can identify and include all variables that determine agricultural commercialisation in the vector of covariates (i.e., X_{i1}) and further assume that there is orthogonality between AC_i the respective error terms, then the unbiased and consistent impact of commercialisation on food and nutrition security can be estimated using OLS, binary probit (or logit), and ordered probit (or logit), respectively, for equation (3.27), equation (3.28) and equation (3.29).

Since we cannot control for all factors in X_{i1} or sustain the assumption of orthogonality, there are potential issues of selectivity bias and endogeneity that constrain OLS, probit and ordered probit estimators to yield unbiased and consistent estimates. Selectivity bias, for example, may arise from observed characteristics (e.g., resource endowment, proximity to markets and infrastructural imbalances among households), which introduce self-selection in commercialisation (see e.g., Abdul Mumin & Abdulai, 2022). Unobserved characteristics (e.g., innate farm management and entrepreneurial abilities) may impose a joint influence on commercialisation and food and nutrition security outcomes, which creates endogeneity bias (Ogutu et al., 2020) and omitted variable problem (Heckman et al., 2018). In addition, the potential of a reverse causality, imposed by a situation where improved food and nutrition security stimulates commercialisation through productivity gains is very likely (Ogutu et al., 2020). One implication of these envisaged econometric problems is to identify econometric modelling frameworks that deal with these confounding challenges.

This study controlled for endogeneity by employing instrumental variable two-stage regression approaches for equation (3.27) and equation (3.28). Specifically for equation (3.27) (i.e., for all the continuous outcomes), a two-step generalised method of moment (GMM) approach is adopted to obtain efficient estimates of the coefficients as well as consistent estimates of the standard errors. Thus, the GMM is preferred to the two-stage least squares (2SLS) because it is more efficient when dealing with a situation where the number of instruments used (i.e., three in this study) is more than the number of endogenous variables (i.e., one in this case) and also robust to heteroskedasticity (Kuma et al., 2019). The first stage of this instrumental variable approach is specified as:

$$\boldsymbol{AC_{ij} = \eta_{0j} + \eta_{1j} X_{i1} + \eta_{2j} M_i + \xi_{ij1}} \quad (3.30)$$

Where M_i is a vector of instruments, $\eta's$ are the parameters to be estimated and ξ is the error term. It is through the instruments that endogeneity is accounted for. Therefore, the main issue about IV approaches is the identification of valid instruments. A valid instrument must satisfy two requirements. The first requirement is instrument relevance, which is defined as an instrument possessing a strong correlation with the variable it is instrumenting for (i.e., AC). Thus, an instrument must be statistically significant in a regression of equation (3.30). The second requirement is instrument exogeneity, which is defined as an instrument being orthogonal (i.e., uncorrelated) with the outcome (i.e., FNS_{ij}) or omitted variables influencing it. Thus, the effect of an instrument on the outcome should only be through AC. Three instruments have been identified. These are market in the community, community average commercialisation index, and community average market orientation index.

Market in the community is a key variable in stimulating commercialisation and has been previously used as an instrument of commercialisation (see e.g., Abdul Mumin & Abdulai, 2022). In addition, several studies (see Abu & Issahaku, 2017; Alhassan et al., 2020; Nkegbe et al., 2022) report that the presence of a market in a community is a significant determinant of commercialisation. Markets stimulate commercialisation by reducing transaction costs (see (Usman & Haile, 2022). Farm households which reside in communities with markets are more likely to sell and sell higher proportions of their produce since transportation costs to sell produce are avoided. Households are even more likely to sell to itinerant buyers who come to trade in their community markets. Therefore, markets can meet the relevance requirement of a valid instrument. For the exogeneity requirement, it is argued that markets do not directly influence food and nutrition security outcomes. The presence of a market does not automatically improve food and nutrition security but does so through some pathways, including providing the opportunity for farm households to raise income from commercialisation. Thus, market is not expected to correlate with household food and nutrition security outcomes. It can be argued that markets also stimulate food and nutrition security through providing the same opportunity for households to buy food, implying that markets are both relevant for commercialisation, and food and nutrition security. However, this possibility is what makes markets a good instrument because households can use the market to improve food and nutrition security through purchases. For purchases to occur, households need income, which can be supplied through income from commercialisation, remittances, and nonfarm activities. Markets first allow households to sell their produce to raise income to buy food. Therefore, the influence of markets on food and nutrition security is through incomes raised from agricultural commercialisation (see Usman & Haile, 2022). These variables should be included as control factors to account for food purchases from remittances and nonfarm activities.

Community average commercialisation index is derived by taking the average of commercialisation indices of all households in the same community (i.e., sum of commercialisation indices of all households in community divided by the number of households in the community). This implies that household-level commercialisation is aggregated at the community level and indicates the community's commercialisation rate. This aggregate index is expected to influence household-level commercialisation. The motivation for this expectation is driven by literature on the influence of social networks and neighbourhood effects on marketing and agricultural technology adoption (see e.g., Andersson et al., 2015; Magnan et al., 2015; Ogutu et al., 2020). When households in a community mimic one another in their commercialisation behaviour, the average commercialisation in the community is likely to be high. The community average commercialisation index is not expected to be correlated with food and nutrition outcomes. Other studies have applied this instrument (e.g., Cazzuffi et al., 2020).

Community average market orientation index is derived by taking the average of market orientation indices of all households in the same community (i.e., a sum of market orientation indices of all households in the community divided by the number of households in the community), where the market orientation index[10], following Gebremedhin and Jaleta (2010), is calculated as:

$$\boldsymbol{MOI_i} = \frac{\sum_{c=1}^{k} \boldsymbol{CSCI_c L_{ci}}}{\boldsymbol{L_i}} \qquad (3.31)$$

[10] The calculation of the market orientation index (MOI) does not include livestock because central to its calculation is farm size but since farm size is not directly applicable to livestock, it is not included in the calculation.

Where MOI_i is market orientation index of household i, $CSCI_c$ is crop-specific commercialisation index of crop c (calculated as value of crop c sold divided value of crop c produced), L_{ci} is cultivated farm size of crop c and L_i is total farm size of all crops. Highly tradable crops will have $CSCI_c$ closer to 1 while low marketable crops will have it closer to 0. Thus, market-oriented farm households will allocate more productive resources (e.g., land, fertilisers, and labour) to more marketable crops. The rationale for using this instrument is that there is no homogeneity in the tradability of crops. For example, produce that are often regarded as cash crops (e.g., cocoa, cotton, cashew, coffee, and rubber) are more tradable than staples (e.g., maize, rice, sorghum, groundnut, and beans). There are even crop-type heterogeneities in tradability (e.g., maize versus millet). Farm households tend to allocate more productive resources to highly tradable or marketable crops (Ouedraogo, 2018). Therefore, market orientation index is expected to be correlated with commercialisation. However, this behaviour of households does not influence food and nutrition security. The arguments for the validity of these instruments are only necessary but not sufficient to justify their use. Formal tests that indicate of validity are applied before these instruments are used.

After estimating equation (3.30) with these potentially valid instruments, the second stage of the IV approach is to estimate:

$$\boldsymbol{FNS_{ij} = \pi_{0j} + \pi_{1j} AC_i + \pi_{2j} X_{i1} + \epsilon_{ij1}} \qquad (3.32)$$

Where all the variables are as defined before, and equation (3.27) and equation (3.32) are similar. However, α_{1j} and π_{1j} are different because the former represents a biased and inconsistent estimate of the impact of commercialisation on food and nutrition security using OLS and the later represents the unbiased and consistent estimate of the impact of

commercialisation from the two-stage IV approach. The IV approach provides formal tests of instrument validity by including statistics to test for under-identification (i.e., test of the relevance of the instruments – correlated with commercialisation), weak identification (i.e., instruments correlated with commercialisation (relevant) but only weakly), overidentification (i.e., overall validity of instruments – uncorrelated with the error term and correctly excluded from the estimated equation) of the instruments. A similar approach is applied to equation (3.28) – except that it is a binary, not a continuous version.

A similar two-step IV estimation approach is applied to equation (3.29), except that this approach accounts for the ordered nature of the outcome. Specifically, an ordered probit regression with an endogenous covariate (otherwise called an extended ordered probit) is applied. The extended ordered probit, as the name implies extends the ordinary probit model by specifying an alternative equation that models the endogenous covariate. Therefore, the extended ordered probit model specifies a simultaneous estimation of equation (3.29) and equation (3.30), where equation (3.30) provides the fundamental difference between the ordinary ordered probit and the extended ordered probit. The extended ordered probit model accounts for endogeneity by including the vector of instruments in equation (3.30) and the simultaneous modelling of the error terms, v_{il1} and ξ_{ij1}, which also overcomes selectivity bias.

To test for the robustness of all these econometric models, alternative econometric specifications are estimated for all outcomes (i.e., continuous, dummy and ordered). For all continuous outcomes, a linear regression model with endogenous covariates (otherwise called an extended regression) is applied. For all dummy outcomes a probit regression with endogenous covariate (otherwise called an extended probit) is applied. The extended

regression and extended probit, like the extended ordered probit, respectively extend OLS and binary probit by also providing an additional equation to model commercialisation (specifically equation (3.30)) with all control variables and instruments to correct for endogeneity. Further, for all ordered outcomes, a control function ordered probit is applied. The control function approach involves estimating a first-stage regression of commercialisation on all the control variables and instruments (as in equation (3.30)) and predicting the residuals. A second stage ordered probit of the ordered food and nutrition security outcomes is then estimated including all control variables and the predicted residual. A significance of the residual indicates the existence of endogeneity and automatically corrects for it (see Navarro, 2010; Wooldridge, 2015).

Following the literature (see e.g., Haji, 2022; Ogutu et al., 2020) on the impact of commercialisation on food and nutrition security outcomes, this study assesses commercialisation impact in the presence of substitutability between own produced food and purchased food. The rationale for this assessment is to examine whether commercialisation decreases diet availability and quality from own produced food. To undertake this, the impact model (i.e., equation (3.32)) is re-estimated, however, with food and nutrition security outcomes constructed from own produced food and purchased foods. Essentially, the re-estimated models are specified as:

$$\boldsymbol{FNS\_own_{ij} = \varphi_{0j} + \varphi_{1j} AC_i + \varphi_{2j} X_{i1} + \varepsilon_{ij1}} \quad (3.33)$$

$$\boldsymbol{FNS\_pur_{ij} = \phi_{0j} + \phi_{1j} AC_i + \phi_{2j} X_{i1} + \epsilon_{ij1}} \quad (3.34)$$

Where FNS_own and FNS_pur are, respectively, food and nutrition security outcomes from own and purchased foods. Due to data limitation, the estimation of equation (3.33) and

equation (3.34) are undertaken for only the GLSS7 data and only food and nutrition security outcomes of HDDS, FCS, vitamin A, protein, and hem iron. These are the outcomes for which data is available to partition into own and purchased food consumption. If commercialisation dampens the availability of own-produced food, the impact estimate (i.e., φ) should be significantly negative. A significantly positive estimate of ϕ would imply that commercialisation stimulates purchases of nutrients.

Finally, the role of income as a key transmission channel (argued in Figure 3.2 as a pathway of commercialisation) is examined using the specifications:

$$\boldsymbol{INCOME_i = \varpi_0 + \varpi_1 AC_i + \varpi_2 X_{i1} + \varepsilon_{ij1}} \quad (3.35)$$

$$\boldsymbol{FNS_{ij} = \varrho_{0j} + \varrho_{1j} INCOME_i + \varrho_{2j} X_{i1} + \epsilon_{ij1}} \quad (3.36)$$

Where $INCOME$ is the total household income. The hypotheses are that $\boldsymbol{\varpi_1}$ and $\boldsymbol{\varrho_1}$ are significantly positive. Equation (3.35) and equation (3.36) are not estimated jointly and not estimated to measure impact but association. Estimating impact would require instrument(s) for income and joint estimation of each model with a commercialisation model (i.e., equation (3.30)).

3.5.4 Quadruple-hurdle model of agricultural commercialisation

The theoretical model presented in equation (3.8) defines that the proportion of sale is a function of some established characteristics (such as transaction costs, price of produce, endowments and inputs). However, before arriving at the proportion of sale, three initial decisions must be made by a farm household. The first is the decision to produce. Without producing a crop, a farm household cannot proceed to sell. The second decision is whether to

sell or not. Again, without the decision to sell, a farm household cannot decide the proportion to sell. The third decision is the choice of market, that is, whether the farm household will sell at the farmgate or market centre. It is when these three hurdles are cleared that a farm household then decides the proportion of sale. Therefore, the theoretical model in equation (3.8) nests these three initial hurdles. Figure 3.3 provides a graphical representation of the hurdles of commercialisation.

Based on these and Figure 3.3., the task here is to develop and simultaneously model the following:

$$\boldsymbol{PROD_{ij} = \alpha_{0j} + \alpha_{1j}X_{i1} + \varepsilon_{ij1}} \quad (3.37)$$

$$\boldsymbol{PART_{ij} = \beta_{0j} + \beta_{1j}X_{i1} + \epsilon_{ij1}} \quad (3.38)$$

$$\boldsymbol{MKTCH_{ij} = \gamma_{0j} + \gamma_{1j}X_{i1} + \mu_{ij1}} \quad (3.39)$$

$$\boldsymbol{CCI_{ij} = \delta_{0j} + \delta_{1j}X_{i1} + \nu_{ij1}} \quad (3.40)$$

Where $PROD_{ij}$ is the decision to produce crop j by household i (i.e., produce crop versus not produce), $PART_{ij}$ is the decision to sell crop j (i.e., sell crop versus not sell), $MKTCH_{ij}$ is the choice of the market to sell (i.e., sell at the farmgate versus the market centre), and CCI_{ij} is the proportion or sale (i.e., crop-specific commercialisation). X_{i1} is a vector of explanatory variables (see Table 3.2), $\alpha's$, $\beta's$, $\gamma's$ and $\delta's$ are the parameters to be estimated. The respective dependent variables represent the four hurdles of commercialisation.

It is important to note that the quadruple-hurdle model can only be developed on crop and or livestock specific basis.

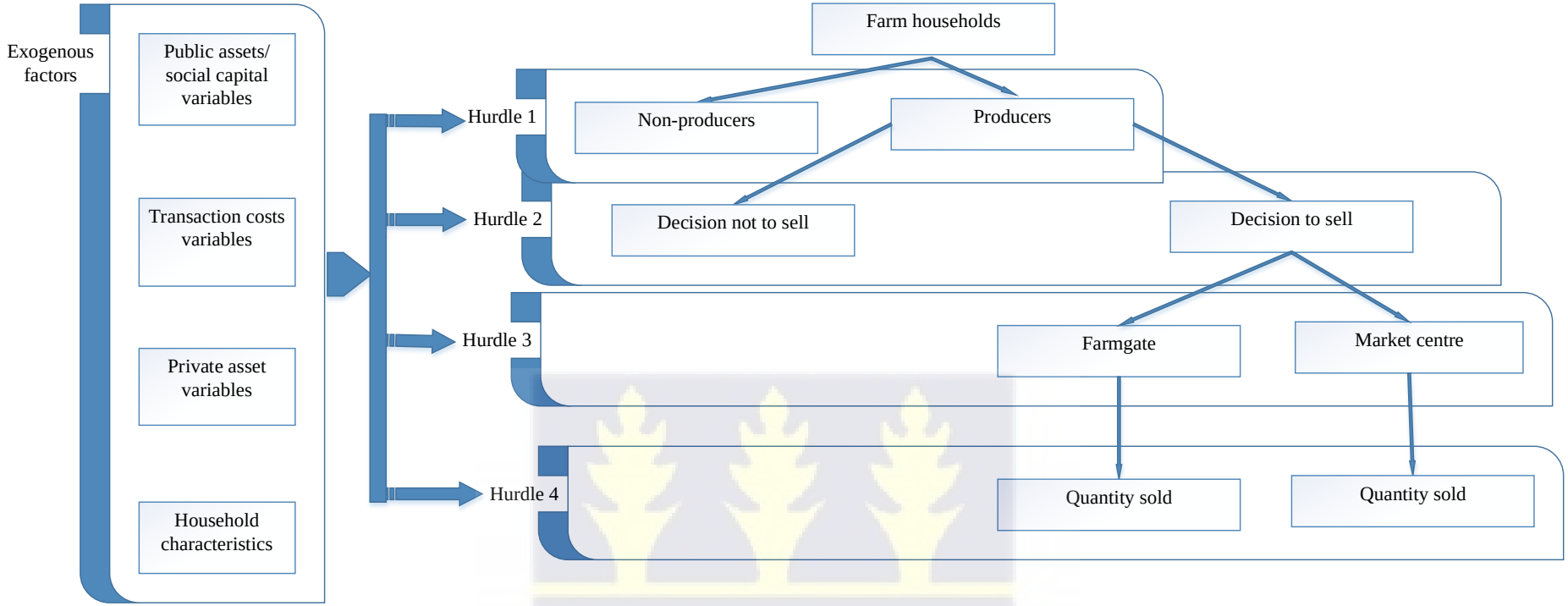


Figure 3.3: Graphical depiction of the quadruple-hurdle
Source: Author's conceptualisation based on the literature

It cannot be applied to aggregate crops and livestock because of the binary decisions of the first and second hurdles. For example, if multiple crops are considered, it would be impossible to measure the first hurdle of production decision. If a farmer does not produce crop A, the farmer may produce crop B and thus the decision to produce will be undefined. Similarly, if a farmer does not sell crop A, the farmer may sell crop B and the decision to participate in the market will also be undefined.

For a simultaneous estimation of equation (3.37)-equation (3.40), a likelihood function is developed for the purpose of expressing the general functional relationship among the unknown parameters estimated in the various hurdles. That is, the likelihood function provides the theoretical insight of how the unknown parameters are related and how they will be generated or estimated in the quadruple-hurdle model framework.

3.5.4.1 The quadruple-hurdle likelihood function

The first stage of the quadruple-hurdle model (equation (3.37)) is the same as the triple-hurdle model, where from a nationally representative sample, we identify the factors that determine the binary decision to produce a particular crop using a probit model. However, while the second stage of the two models are operationally similar in what they seek to measure, they differ in how the measurements are constructed. In a departure from the triple-hurdle, and indeed the model by Bellemare and Barrett (2006), the quadruple-hurdle uses a binary probit – instead of an ordered probit – to identify factors influencing the decision process of being a seller or otherwise (equation (3.38)). Thus, this study does not classify the decision of market participation into the earlier net buyer, an autarchic household or net seller categories.

The first reason for not considering this categorisation is that, in developing economies, and indeed from policy perspective, stimulating the capacity of farm households to raise marketable surpluses to participate in markets as sellers reduce poverty (Ogutu & Qaim, 2019) and improve household income (Haji, 2022; Kilimani et al., 2022; Ogutu et al., 2020). Second, and perhaps more importantly, considering net buyer, autarchic and net seller categories as an ordered outcome is not appropriate. In previous studies (e.g., Bellemare & Barrett, 2006; Burke et al., 2015), the empirical modelling shows that being a net seller is better than being autarchic, which is also better than being a net buyer. Theoretically, however, this ordering is untenable, especially for positioning net buyers and autarchic households. There are circumstances under which net buyer is better than autarchy and vice versa. For example, in pursuing a nutritional agenda, being a net buyer may be more important than being autarchic. While it is relatively easy to think that being a net seller provides the capacity to avoid food shortages, the same cannot be extended to autarchy. It is difficult to determine what autarchy in producing a particular crop means for hunger and nutrition.

The third stage provides another departure and novelty to the commercialisation literature. While the triple-hurdle presents a truncated model that identifies the determinants of the quantities net buyers and net sellers buy and sell, respectively, the quadruple-hurdle provides another probit model identifying the factors that determine the choice of farmgate and designated market centre sale decision (equation (3.39)). Then finally, in the fourth stage (equation (3.40)), the quadruple-hurdle presents a truncated model of the determinants of quantities marketed by farmgate sellers and designated market centre sellers.

We need to consider each of the four hurdles to derive the likelihood function of the quadruple-hurdle model. Given the description of the possible econometric model of each of the hurdles, the task is made much easier because the first three stages are based on binary probit models. Denoting q_j as the quantity of crop production, x as a vector of all relevant and applicable explanatory variables and w_1 as a binary indicator function such that:

$$\boldsymbol{w_1 = 1[q_j > 0]} \tag{3.41}$$

$$\boldsymbol{w_1 = 0[q_j = 0]} \tag{3.42}$$

From equation (3.41) and equation (3.42), a binary probit formulation can be specified as:

$$\boldsymbol{Pr(w_1 = 1|x_1, \gamma) = \Phi(x_1\gamma)} \tag{3.43}$$

$$\boldsymbol{Pr(w_1 = 0|x_1, \gamma) = 1 - \Phi(x_1\gamma)} \tag{3.44}$$

Where Φ is the standard normal cumulative distribution function, x_1 is a vector of variables hypothesised to influence the production level (see Table 3.2) and γ is a vector of estimated parameters. Given these, the distribution of w_1 can be specified as:

$$\boldsymbol{f(w_1|x_1) = [1 - \Phi(x_1\gamma)]^{1[w_1=0]}[\Phi(x_1\gamma)]^{1[w_1=1]}} \tag{3.45}$$

Because the second and third stages are also probit models, we derive them together. We define c_j as the quantity consumed of a crop produced, t_{pj}^{s} as the level of proportional transaction costs incurred for selling, w_2 and w_3 as binary indicator functions such that:

For the second stage:

$$\boldsymbol{w_2 = 1[q_j - c_j = m_j > 0]} \quad (3.46)$$

$$\boldsymbol{w_2 = 0[q_j - c_j = m_j \leq 0]} \quad (3.47)$$

For the third stage:

$$\boldsymbol{w_3 = 1[t_{pj}^s > 0]} \quad (3.48)$$

$$\boldsymbol{w_3 = 0[t_{pj}^s = 0]} \quad (3.49)$$

Where m_j is the level of marketable surplus generated by the household, which is positive if there is a surplus. The cases of $m_j < 0$ and $m_j = 0$, respectively provide the net buyer and autarchy situations modelled by Bellemare and Barrett (2006) and Burke et al. (2015). $t_{pj}^s > 0$ presents the case where farmers incur transaction costs associated with travelling to a designated market centre to sell while $t_{pj}^s = 0$ presents the case where farmers avoid these transaction costs by selling at the farmgate (see Abu et al., 2016; Fafchamps & Hill, 2005; Muamba, 2011). Equation (3.46) – (3.49), will also produce binary probit formulations similar to equation (3.43) – (3.44) and the distributions of w_2 and w_3 similar to equation (3.45).[11]

In the fourth and final stage, the proportion of sale of farmgate and market centre sellers is modelled. If we define y_4 and y_5 as the proportion of sale of farmgate and market centre sellers, respectively, then mathematically:

$$\boldsymbol{y_4 = m_j} \text{ if } \boldsymbol{w_3 = 0} \text{ or } \boldsymbol{t_{pj}^s = 0} \quad (3.50)$$

$$\boldsymbol{y_5 = m_j} \text{ if } \boldsymbol{w_3 = 1} \text{ or } \boldsymbol{t_{pj}^s > 0} \quad (3.51)$$

[11] The difference will be in variable and parameter notations.

$\boldsymbol{t_{pj}^{s} = 0}$ because farmgate sales come at no proportional transaction costs. Defining x_4 and x_5 as vectors of hypothesised explanatory variables, respectively, influencing sales of farmgate sellers and market centre sellers and assuming a log-normally distributed y_4 and y_5, the distributions of equation (3.50) and equation (3.51) are stated as:

$$\boldsymbol{f(y_4|x_4,\eta_4) = \phi[\{log(y_4) - x_4\eta_4\}/\sigma_4]/(y_4\sigma_4)} \quad (3.52)$$

$$\boldsymbol{f(y_5|x_5,\eta_5) = \phi[\{log(y_5) - x_5\eta_5\}/\sigma_5]/(y_5\sigma_5)} \quad (3.53)$$

Where ϕ represents the standard normal probability density function, and σ_j represents the standard deviation of the random variable y_j. Based on these distribution functions of the various stages of the quadruple-hurdle model, the likelihood function for w_1, w_2, w_3, and (y_4, y_5), respectively representing the various hurdles of the model can be stated as:

$$\boldsymbol{f(w_1,w_2,w_3,y_4,y_5|x,\theta) = [1-\Phi(x_1\gamma)]^{1[w_1=0]} * \left[\Phi(x_1\gamma)\left\{[1-\Phi(x_2\alpha)]^{1[w_2=0]}[\Phi(x_2\alpha)]\left[\left\{\left[1-\Phi(x_3\beta)\frac{\phi\left[\frac{\{\log(y_4)-x_4\eta_4\}}{\sigma_4}\right]}{y_4\sigma_4}\right]^{1[w_3=0]}\left[\Phi(x_3\beta)\frac{\phi\left[\frac{\{\log(y_5)-x_5\eta_5\}}{\sigma_5}\right]}{y_5\sigma_5}\right]^{1[w_3=1]}\right\}^{1[w_2=1]}\right]\right\}^{1[w_1=1]}\right]} \quad (3.54)$$

The likelihood function can be maximised simultaneously to yield the determinants of the various hurdles using the Maximum Likelihood Estimation (MLE). The likelihood function possesses a separability property such that the production decision, market participation decision and choice of market decision can be separately estimated with binary probit models to yield their respective parameters, and the sale quantities of farmgate and market centre sellers can also be separately modelled using a log-normal (truncated) model.

3.5.4.2 Estimation of the quadruple-hurdle function

There are four hurdles and five different models to be estimated. As already indicated, hurdles one to three are binary, while hurdle four contains two log-normal equations. Therefore, we have a mixed system of equations to estimate. If the path of separate estimation were to be chosen, this study would have employed two models – probit for the three binary choices of production, market participation and market choice, and truncated regression for the two sale quantity models. However, this study aims to model these hurdles as a system (i.e., simultaneously or in a multi-stage fashion), as this approach would produce more efficient and precise parameter estimates by using more information in the estimation process (Roodman, 2011).

The appropriate econometric procedure that can handle the mixed nature of the hurdles (i.e., probit models for the first three hurdles and fractional model for the last hurdle), the different observations involved in the four hurdles, the conditionality of some of the hurdles (i.e., the second hurdle of decision to sell is conditioned on the first hurdle of decision to produce, and the third and fourth hurdles of the choice of market and proportion to sell are conditioned on the second hurdle of decision to sell) and the simultaneous modelling approach (i.e., model all the four hurdles together) is the conditional mixed process (CMP) model proposed by Roodman (2011). The CMP allows for constructing and estimating different models in a mixed and multi-equation fashion (Roodman, 2011). Its suitability is further proven by its reliance on the maximum likelihood estimation technique. The main assumption of CMP in handling these hurdles is the joint modelling of all these hurdles with a cross-equation correlation of the error terms.

Given that the triple-hurdle model is basically nested in the quadruple-hurdle model, a likelihood ratio test is used to test whether indeed the triple-hurdle model is nested in the quadruple-hurdle model. The likelihood ratio test is specified following Lewis et al. (2011) as:

$$\boldsymbol{LR = 2\left(LL_{QHM} - LL_{THM}\right)} \tag{3.55}$$

Where LR is the likelihood ratio statistic, LL_{QHM} is the log likelihood of the quadruple-hurdle model (i.e., the full or unrestricted model) and LL_{THM} is the log likelihood of the triple-hurdle model (i.e., the restricted model). The likelihood ratio test has a chi-square distribution under a null hypothesis, in this case, that the triple-hurdle model is not nested in the quadruple-hurdle model. If the calculated chi-square value is greater than the tabulated value (i.e., p-value of the test statistic is less than 10 percent), the null hypothesis is rejected.

The Akaike information criterion (AIC) and the Bayesian information criterion (BIC) are also estimated for both models to determine the best model. The decision criterion is that the model with lower AIC and BIC values is the best model.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the findings of this study. After presenting the descriptive statistics of variables used, the rest of the chapter is organised according to the findings of the four specific objectives.

4.2 Descriptive statistics of the sample

The descriptive statistics of variables of the samples are reported in Table 4.1 and Table 4.2, respectively, for the GLSS7 and primary data. As expected, most households have males as heads (75.9% and 87.8%, respectively, for GLSS7 and primary data), with market participants having on average more males as heads (81.4% and 90.4%, respectively, for GLSS7 and primary data) relative to non-market participants (74.4% and 75.9%, respectively, for GLSS7 and primary data). The average age of heads of farm households is about 49 years, with no statistically significant difference between the average ages of market participants and non-market participants for both datasets. In addition, majority of the samples (76.7% and 73.1%) are above 35 years. Given high unemployment among the youth (i.e., 12.6% for 15-35 years versus 8.4% for active population in 2019 reported by the Ghana Statistical Service), it is imperative that strategies are put in place to attract young people into agriculture. The mean household size is 6 people apiece for both the GLSS7 and primary data, with market participants consistently having statistically significant larger sizes on average than non-market participants.

Table 4.1: Descriptive statistics of variables (GLSS7 data)

Variable	All Sample			Non-market participants			Market participants			Diff.
	Sample	Mean	S.D.	Sample	Mean	S.D.	Sample	Mean	S.D.	
Food and nutrition security indicators										
Per capita real food expenditure (GHS)	7,332	1,806	1,992	5,722	1,721	1,932	1,610	2,107	2,165	-385.998***
Per adult real food expenditure (GHS)	7,332	1,565	1,586	5,722	1,524	1,546	1,610	1,708	1,713	-183.966***
Dietary diversity (no. of food groups)	7,332	6.214	1.893	5,722	6.022	1.867	1,610	6.896	1.826	-0.873***
Food consumption score (number)	7,332	10.30	4.188	5,722	9.811	3.969	1,610	12.06	4.466	-2.245***
Vitamin A (frequency)	7,332	7.587	4.957	5,722	7.184	4.663	1,610	9.019	5.660	-1.835***
Protein (frequency)	7,332	4.995	3.804	5,722	4.578	3.395	1,610	6.476	4.705	-1.898***
Hem iron (frequency)	7,332	1.952	1.611	5,722	1.818	1.508	1,610	2.429	1.859	-0.610***
Socioeconomic characteristics										
Gender of head (1=male)	7,332	0.759	0.428	5,722	0.744	0.437	1,610	0.814	0.389	-0.071***
Age of head (years)	7,332	48.74	15.57	5,722	48.80	15.74	1,610	48.51	14.93	0.294
Household size	7,332	5.103	3.123	5,722	4.898	2.927	1,610	5.832	3.645	-0.934***
Head's marital status (1=married)	7,332	0.739	0.439	5,722	0.724	0.447	1,610	0.792	0.406	-0.068***
Education of head (years)	7,332	4.675	4.965	5,722	4.786	5.007	1,610	4.281	4.791	0.506***
Cash remittance (1=yes)	7,332	0.341	0.474	5,722	0.333	0.471	1,610	0.367	0.482	-0.034**
Nonfarm engagement (1=yes)	7,332	0.160	0.367	5,722	0.164	0.371	1,610	0.145	0.353	0.019*
Value of assets (GHS)	7,332	661.1	8,776	5,722	521.0	8,982	1,610	1,159	7,983	-637.896**
Household income (GHS)	7,332	4,476	10,284	5,722	4,403	10,645	1,610	4,733	8,880	-329.488
Stop work due to illness (number)	7,332	0.700	2.354	5,722	0.680	2.312	1,610	0.772	2.496	-0.092
Children in agriculture households										
Stunting (HAZ < -2SD) (1=yes)	2,864	0.414	0.493	2,160	0.464	0.499	704	0.259	0.438	0.206***
Underweight (WAZ < -2SD) (1=yes)	2,864	0.331	0.471	2,160	0.399	0.490	704	0.125	0.331	0.274***
Wasting (WHZ < -2SD) (1=yes)	2,864	0.316	0.465	2,160	0.390	0.488	704	0.087	0.282	0.304***
Farm characteristics										
Number of crops produced	7,332	2.383	1.641	5,722	2.185	1.585	1,610	3.086	1.643	-0.901***
Agric land endowment (ha)	7,332	11.17	298.5	5,722	11.30	320.4	1,610	10.70	202.3	0.604
Expenditure on agrochemicals (GHS/ha)	7,332	221.2	1,054	5,722	213.3	700.9	1,610	249.2	1819.3	-35.957
Expenditure on hired labour (GHS/ha)	7,332	130.5	620.1	5,722	126.9	596.1	1,610	143.2	698.8	-16.278
Community characteristics										
Agric extension office (1=yes)	7,332	0.145	0.353	5,722	0.132	0.338	1,610	0.199	0.399	-0.063***
Agric cooperatives (1=yes)	7,332	0.106	0.308	5,722	0.0947	0.293	1,610	0.152	0.359	-0.052***
Irrigation fields (1=yes)	7,332	0.112	0.316	5,722	0.111	0.315	1,610	0.120	0.325	-0.004
Perceived rain pattern (1=better)	7,332	0.567	0.496	5,722	0.577	0.494	1,610	0.537	0.499	0.046***
Navigable road (1=yes)	7,332	0.676	0.468	5,722	0.610	0.488	1,610	0.912	0.283	-0.301***
Public transport availability (1=yes)	7,332	0.535	0.499	5,722	0.491	0.500	1,610	0.688	0.464	-0.202***
Mobile phone network (1=yes)	7,332	0.524	0.499	5,722	0.471	0.499	1,610	0.707	0.455	-0.241***

Bank (1=yes)	7,332	0.156	0.363	5,722	0.143	0.350	1,610	0.201	0.401	-0.060***
Market (1=yes)	7,332	0.234	0.424	5,722	0.214	0.410	1,610	0.305	0.461	-0.091***
HCLCI average (%)	7,332	26.44	19.23	5,722	24.69	19.28	1,610	32.76	17.71	-7.987***
Market orientation (%)	7,332	23.10	20.49	5,722	20.82	20.42	1,610	31.22	18.62	-10.386***
Location characteristics										
Resides in rural area (1=yes)	7,332	0.830	0.376	5,722	0.809	0.393	1,610	0.902	0.298	-0.093***
Lives in southern Ghana (1=yes)	7,332	0.454	0.498	5,722	0.466	0.499	1,610	0.409	0.492	0.058***
Lives in coastal zone (1=yes)	7,332	0.113	0.317	5,722	0.122	0.327	1,610	0.083	0.276	0.039***
Lives in forest zone (1=yes)	7,332	0.361	0.480	5,722	0.365	0.481	1,610	0.347	0.476	0.018
Lives in savannah zone (1=yes)	7,332	0.521	0.500	5,722	0.508	0.500	1,610	0.566	0.496	-0.059***
Lives in Greater Accra area (1=yes)	7,332	0.005	0.070	5,722	0.005	0.073	1,610	0.003	0.056	0.002
Ordered characteristics										
	Freq.	%		Freq.	%		Freq.	%		
FIES										0.011
Severe food insecurity	2,584	35.24		2,015	35.21		569	35.34		
Moderate food insecurity	1,977	26.96		1,532	26.77		445	27.64		
No hunger to mild food insecurity	2,771	37.79		2,175	38.01		596	37.02		

Note(s): * $p<0.1$; ** $p<0.05$; *** $p<0.01$; Diff defines t-test of the means of farm households who sold at least a crop or livestock and farm households who did not sell; FIES is food insecurity experience scale (FIES); 6,637 households cultivated at least one crop; 7,260 households reared at least one livestock; 6,565 households jointly produced crop and livestock.

Table 4.2: Descriptive statistics of variables (primary data)

Variable	All sample			Non-market participants			Market participants			Diff.
	Sample	Mean	S.D.	Sample	Mean	S.D.	Sample	Mean	S.D.	
Food and nutrition security indicators										
Per capita food expenditure (GHS)	858	1,375	1,734	158	451.2	329.5	700	1,584	1,851	-1132.376***
Total food expenditure (GHS)	858	6,630	7,850	158	1,753	794.9	700	7,730	8,296	-5977.275***
Dietary diversity (no. of food groups)	858	5.590	3.781	158	1.861	1.452	700	6.431	3.633	-4.571***
Food consumption score (number)	858	26.51	22.31	158	15.03	9.899	700	29.11	23.48	-14.073***
Vitamin A (frequency)	858	6.997	6.720	158	5.848	5.959	700	7.256	6.858	-1.408***
Protein (frequency)	858	10.67	8.32	158	9.56	7.684	700	10.92	8.437	-1.359**
Hem iron (frequency)	858	6.746	5.605	158	5.785	4.566	700	6.963	5.794	-1.178***
Socioeconomic characteristics										
Gender of head (1=male)	858	0.878	0.328	158	0.759	0.429	700	0.904	0.294	-0.145***
Age of head (years)	858	45.44	12.92	158	44.47	12.12	700	45.66	13.09	-1.184
Household size	858	5.605	2.422	158	4.886	2.215	700	5.767	2.439	-0.881***
Head's marital status (1=married)	858	0.907	0.291	158	0.835	0.372	700	0.923	0.267	-0.087***
Education of head (years)	858	3.992	5.710	158	3.348	5.168	700	4.137	5.819	-0.789
Cash remittance (1=yes)	858	0.085	0.279	158	0.101	0.303	700	0.081	0.274	0.020
Nonfarm engagement (1=yes)	858	0.168	0.374	158	0.190	0.393	700	0.163	0.369	0.027
Value of assets (GHS)	858	7,244	16123	158	3,043	3,913	700	8,193	17618	-5150.024***
Household income (GHS)	858	16389.9	33872.3	158	2891.06	3437.58	700	19436.8	36790.4	-16545.75***
Stop work due to illness (number)	858	5.362	28.29	158	4.354	35.11	700	5.590	26.54	-1.236
Farm characteristics										
Number of crops produced	858	1.795	0.791	158	1.310	0.585	700	1.904	0.790	-0.594***
Agric land endowment (ha)	858	7.106	35.41	158	2.908	2.888	700	8.054	39.13	-5.146*
Expenditure on agrochemicals (GHS/ha)	858	390.2	674.7	158	376.3	524.4	700	393.4	703.9	-17.090
Expenditure on hired labour (GHS/ha)	858	148.0	480.4	158	200.1	618.6	700	136.3	442.9	63.794
Community characteristics										
Agric extension office (1=yes)	858	0.371	0.483	158	0.366	0.482	700	0.454	0.498	-0.088
Agric cooperatives (1=yes)	858	0.166	0.372	158	0.156	0.364	700	0.203	0.402	-0.047
Irrigation fields (1=yes)	858	0.233	0.423	158	0.209	0.408	700	0.239	0.427	-0.030
Perceived rain pattern (1=better)	858	0.685	0.465	158	0.544	0.500	700	0.717	0.451	-0.173***
Navigable road (1=yes)	858	0.605	0.489	158	0.529	0.500	700	0.741	0.438	-0.212***
Public transport availability (1=yes)	858	0.547	0.498	158	0.522	0.500	700	0.670	0.471	-0.148***
Mobile phone network (1=yes)	858	0.934	0.249	158	0.962	0.192	257	0.946	0.227	0.035
Bank (1=yes)	858	0.099	0.299	158	0.098	0.298	700	0.121	0.327	-0.023
Market (1=yes)	858	0.354	0.479	158	0.309	0.463	700	0.434	0.496	-0.125***
HCLCI average (%)	858	28.57	11.80	158	19.56	10.57	700	30.61	11.10	-11.048***
Market orientation (%)	858	37.10	13.86	158	26.33	14.53	700	39.53	12.49	-13.193***
Location characteristics										

Resides in northern region (1=yes)	858	0.300	0.458	158	0.304	0.461	700	0.299	0.458	0.005
Lives in upper east region (1=yes)	858	0.273	0.446	158	0.443	0.498	700	0.234	0.424	0.209***
Lives in upper west region (1=yes)	858	0.202	0.401	158	0.108	0.311	700	0.223	0.416	-0.115***
Lives in savannah region (1=yes)	858	0.121	0.327	158	0.0886	0.285	700	0.129	0.335	-0.040
Resides in northeast region (1=yes)	858	0.105	0.307	150	0.057	0.233	700	0.116	0.320	-0.059**
Ordered characteristics										
	Freq.	%		Freq.	%		Freq.	%		
FIES										-0.968***
Severe food insecurity	297	34.62		124	78.48		173	24.71		
Moderate food insecurity	260	30.30		34	21.52		226	32.29		
No hunger to mild food insecurity	301	35.08		0	0.00		301	43.00		
HHS										-1.224***
Severe hunger	308	35.90		135	85.44		173	24.71		
Moderate hunger	118	13.75		23	14.56		95	13.57		
Little to no hunger	432	50.35		0	0.00		432	61.71		
HFIAS										-1.685***
Severely food insecure	339	39.51		138	87.34		201	28.71		
Moderately food insecure	87	10.14		16	10.13		71	10.14		
Mildly food insecure	73	8.51		4	2.53		69	9.86		
Food secure	359	41.84		0	0.00		359	51.29		

Note(s): * $p<0.1$; ** $p<0.05$; *** $p<0.01$; Diff defines t-test of the means of farm households who sold at least a crop or livestock and farm households who did not sell; FIES is food insecurity experience scale (FIES); HHS is household hunger scale; HFIAS is household food insecurity access scale.

Again, as expected, farm households typically have a maximum formal educational qualification of primary school, as the mean level of education is 4.7 years and 4 years, respectively, for the GLSS7 and primary data. For the GLSS7 data, non-market participants have statistically more years in education than market participants, however, for the primary data, there is no statistical difference in the years of education between market and non-market participants. Northern Ghana has a majority (63.5%) of farm households with no formal education (i.e., 0 years of formal education) as compared to 44.5 percent in Ghana. The evidence of formal educational qualification has consequences for the growth of human capital and the capacity to maximise opportunities and production technology to improve farm productivity in Ghana (Anang et al., 2020). Nonfarm engagement is an important source of diversification for farm households, as households use it to raise alternative income. The GLSS7 data indicates that 16.0 percent of farm households diversified into nonfarm activities, with non-market participants diversifying more than market participants. For northern Ghana (i.e., primary data), 16.8 percent of farmers engaged in nonfarm activities, with no statistical difference between market and non-market participants.

The average per capita real food consumption expenditure is estimated as GHS1,806 with market participants significantly spending more on average (GHS2,107) than non-market participants (GHS1,721). The Ghana Statistical Service (2019) reported an average per capita real food consumption expenditure of GHS4,234 for the entire sample (i.e., 14,009 households). However, this study's consideration of only farm households (i.e., 7,332 households) accounts for the difference in expenditures. With an average per adult real food consumption expenditure of GHS1,565, market participants spend more on average (GHS1,708) than non-market participants (GHS1,524). The mean number of food groups consumed by households (i.e., household dietary diversity score) is 6.2. This implies that

farm households on average consume about 6 food groups. Nkegbe and Abdul Mumin (2022) report a dietary diversity score of 9.07 from the GLSS6 data for both farm and nonfarm households. The number of food groups consumed is statistically higher for market participants than non-market participants. However, total annual food consumption expenditure, per capita annual food consumption expenditure, dietary diversity score and food consumption score are statistically higher for market participants in northern Ghana. Further, the evidence in Table 4.1 indicates that the prevalence of anthropometric conditions of stunting, underweight and wasting of children in farm households are 41.4 percent, 33.1 percent and 31.6 percent, respectively, with statistically significant differences among market and non-market participants. Children in non-market participant households have higher prevalence ratios. The prevalence rates of these anthropometric conditions are alarming and stakeholders need to find urgent solutions to these challenges. Previous findings estimate much lower prevalence rates. For example, Issahaku and Abu (2024) observed prevalence rates of stunting, underweight and wasting to be 34.7 percent, 18.3 percent and 11.1 percent, respectively, for children in farm households in Ghana's Savannah Accelerated Development Authority (SADA) zone.

The average number of crops produced by farmers (i.e., crop production diversity) is 2.4 (i.e., about 3 crops), distributed into 2.2 for non-market participants and 3.1 for market participants, the difference being statistically significant. The number of crops cultivated in northern Ghana (i.e., 1.8) is relatively lower. On average, farm households own 11.2 ha of agricultural lands, with no statistical difference between the endowment of market participants (10.7 ha) and non-market participants (11.3 ha). However, in northern Ghana, the land endowment is slightly lower (7.1 ha), with market participants owning more land (8.1 ha) than non-market participants (2.9 ha). Only 27.9 percent of farm households do not own

any land but only access land for farming through various means such as renting and borrowing. The average farm size from the GLSS7 data is 2.68 ha. Out of 6,637 households that cultivated at least one crop, 58.61 percent cultivated less than 2 ha. This implies that the majority of farmers are smallholders. This confirms the state of agriculture in Ghana, where majority are described as smallholders cultivated less than 2 ha in a production season (Ministry of Food and Agriculture, 2021). Evidence on investment in productivity-enhancing inputs is low. For example, the average expenditure per hectare on agrochemicals (i.e., inorganic fertiliser, insecticides and herbicides) for the GLSS7 is GHS221.2, with market participants statistically spending more than non-market participants. Expenditure on agrochemicals is however higher in northern Ghana (GHS390.2/ha). This confirms Ghana's low adoption of agricultural technology (Anang et al., 2020).

Focusing on community characteristics for the GLSS7, 14.5 percent of farm households live in communities with a presence of agriculture extension office. This implies that farmers have low access to extension services, which is consistent with the high extension-farmer ratio in Ghana (Anang et al., 2020; Peasant Farmers Association of Ghana, 2019; Yaro et al., 2018). It is estimated that 1 extension agent serves 1,250 farmers in Ghana (Peasant Farmers Association of Ghana, 2019). Despite the importance of farmer organisations on farmer welfare (see e.g., Grashuis & Su, 2019; Wedig & Wiegratz, 2018), farmer participation in agricultural cooperatives is low, since 10.6 percent of farm households live in communities with agricultural cooperatives. Therefore, government and other stakeholders working in the agricultural sector should strategize to increase the number of farmers participating in farmer cooperatives. Furthermore, 67.6 percent of farm households live in communities with navigable roads, 53.5 percent live in communities with access to public transport, 15.6 percent live in communities with a financial institution (e.g., bank), 23.4 percent live in

communities with an established market, and 52.4 percent live in communities with mobile phone network. Market participating households statistically have more endowment of these community resources than non-market participating households. Similar trends of these community characteristics are observed for the primary data. For location characteristics, the GLSS7 shows that the majority of households (83.0%) reside in rural areas, whiles the majority (54.6%) reside in northern Ghana. Further, majority of households reside in the savannah zone (52.1%), followed by those residing in the forest zone (36.1%).

4.3 An extended metric of agricultural commercialisation

In presenting the results of the extended metric of agricultural commercialisation, the separate estimates of crop (i.e., HCCI) and livestock (i.e., HLCI) commercialisation indices are discussed first before the combined (i.e., HCLCI) index is presented.

4.3.1 Crop and livestock commercialisation indices

Table 4.3 reports the separate crop and livestock commercialisation indices for the two data sources[12]. The individual constituents of crop and livestock sub-groups are reported in Table A1 in Appendix 2. The results show that in the GLSS7 data, 90.52 percent of the sample households produced at least one crop in the 2016/2017 production season. Disaggregating production status by regional distribution, northern Ghana has more crop-producing households (94.2%) than southern Ghana (86.0%). This evidence is consistent with the results (in Table 4.3) where all households in the primary data produced at least one crop. A disaggregation of the data based on food and non-food crop production reveals that, expectedly, more households (82.7% and 100.0%, respectively, for GLSS7 and primary data)

[12] Statistical test of significant differences between the corresponding values of the GLSS7 and primary data shows that most of the values are statistically different between the two datasets (i.e., values without the asterisk 'a').

produced food crops relative to non-food crops (14.8% and 0.12%, respectively, for GLSS7 and primary data).

Table 4.3: Crop and livestock commercialisation indices

Product	GLSS7				Primary data			
	% producing (n = 7,332)	% selling among producers	CI among producers	CI conditional on producing and selling	% producing (n = 858)	% selling among producers	CI among producers	CI conditional on producing and selling
Crops								
All	90.52	62.95	35.20	55.91	100.0	74.13	38.24	51.59
Food	82.73	54.88	31.60	50.03[a]	100.0	74.13	38.24	51.59[a]
Non-food	14.76	92.05 [a]	73.10 [a]	79.05 [a]	0.12	100.0 [a]	85.11 [a]	85.11 [a]
Cereals	70.38	41.45	29.70	52.05 [a]	83.45	62.15	36.00	52.32 [a]
Legumes	35.42	50.13	24.82	43.27	57.11	78.98	44.41	53.67
Roots/tubers	27.50	59.52	42.76 [a]	57.94	8.86	85.53	45.60 [a]	51.87
Vegetables	9.68	55.77	39.68 [a]	56.35 [a]	0.70	100.0	55.04 [a]	55.04 [a]
Fruits	1.77	86.15 [a]	67.02 [a]	70.48 [a]	0.35	100.0 [a]	93.33 [a]	93.33 [a]
Industrial	16.58	89.06 [a]	69.85 [a]	77.60 [a]	0.12	100.0 [a]	100.0 [a]	100.0 [a]
Livestock								
All	99.02	38.25	10.94	28.56	83.22	44.96	8.10	18.01
Large	9.96	25.34	8.06	31.82 [a]	27.51	16.10	5.04	31.29 [a]
Small	56.71	36.05	10.59	27.03	66.40	26.49	7.76	21.63
Poultry	69.05	33.46 [a]	10.93	28.24	65.97	30.92 [a]	8.21	15.41

Note(s): 40 and 17 different crops are considered in the GLSS7 and primary data, respectively (see Table A1 in Appendix 2). Out of this, 32 and 16 are respectively food crops, 8 and 1 are, respectively, non-food crops. At the specific crop level, 4 apiece are, respectively, cereals, 2 and 5 are, respectively, legumes, 5 and 3 are, respectively, roots and tubers, 9 and 3 are, respectively, vegetables, 10 and 1 are, respectively, fruits, and 10 and 1 are, respectively, industrial. For livestock, 11 and 12 are, respectively, included. CI is commercialisation index; "a" denotes difference between the corresponding values across the two datasets are not statistically significant at 1% or 5% or 10%.

Also, more food crops are produced in northern Ghana (91.19%) than southern Ghana (72.55%) while more cash crops are produced in southern Ghana (27.18%) than northern Ghana (7.79%). These observations are consistent with the pattern of crop production in Ghana observed by Ghana Statistical Service (2019), where northern Ghana is generally more agrarian than southern Ghana. Further, cereals are the major crops households produced than any of the other food categories (i.e., legumes, roots and tubers, vegetables, fruits, and cash crops) in both datasets, whiles fruits and cash crops are the least produced, respectively.

In terms of selling crop produce, 62.95 percent and 74.13 percent of crop-producing households sell at least one crop within a production season for the GLSS7 and primary data,

respectively. Therefore, some farm households exhibit autarchic characteristics. As expected, more cash crops are sold relative to food crops. In addition, cash crops (cereals) are the most (least) sold by households. The estimate of the level of crop commercialisation for all farm households (using the crop commercialisation index) shows that 35.20 percent and 38.24 percent of all crops produced are sold for the GLSS7 and primary data, respectively. This represents surplus-oriented agriculture of Ghanaian farmers based on the classification of FAO (1989). Thus, Ghanaian farmers on average have not yet made the needed transition to commercial-oriented production. However, when agricultural commercialisation is conditioned on only crop producers (i.e., within the overall sample, the sample of only crop producers), commercialisation increases to 55.91 percent and 51.59 percent for the GLSS7 and primary data, respectively. These levels of commercialisation fall within the bracket of commercial-oriented agriculture. The fact that the averages are just within the cusp of the commercial-oriented classification shows the need for strategies to help boost commercial orientation of farmers. Expectedly, non-food crops have better commercialisation than food crops, explained by the fact that the food consumption needs of households would have to be met before marketed surpluses are generated. But for non-food crops, marketed surpluses are greater because of low demand of these crops for local nonfarm enterprises. Cash crops have higher commercialisation indices than the other crop categories for all the sample or when conditioned on only crop producers.

Table A1 (in the Appendix) provides more details on crop-specific commercialisation indices. For example, the evidence shows that among cereals, maize is the dominant crop produced in the GLSS7 (62.82% of households producing) and in the primary data (74.59% of household producing). Regarding households' decision to sell cereals among farm households, rice is the dominant crop in the GLSS7 and the primary data, as 37.22 percent

and 68.09 percent of households sold it, respectively. Among only cereal producers, maize has the highest commercialisation index in Ghana, with 20.19 percent of its value produced sold by households, whiles rice is the dominant commercialised crop in northern Ghana as 44.54 percent of its production value is sold. However, among only cereal producers selling their produce, millet has the highest commercialisation index in both Ghana and northern Ghana.

Now considering the livestock dimension of commercialisation, almost all farm households (99.02%) reared at least one livestock in the GLSS7 data. In the primary data, the proportion of livestock rearing (83.22%) is lower. Thus, in Ghana, more households engage in livestock production than crop production (i.e., 99.02% versus 90.52% respectively). However, considering the sale of crops and livestock, the narrative changes to a situation where more households sell crops (62.95% and 74.13%, respectively, for the GLSS7 and primary data) than livestock (38.25% and 44.96%, respectively, for the GLSS7 and primary data). The level of livestock commercialisation follows a similar pattern where 10.94 percent and 8.10 percent are the respective commercialisation indices for the GLSS7 and primary data, which are lower than crop commercialisation indices. Conditioned on livestock production, the commercialisation indices are higher (28.56% and 18.01%, respectively, for the GLSS7 and primary data), but still much lower than crop commercialisation. Several reasons may account for the low livestock commercialisation relative to crop commercialisation. A notable factor may be the difference in gestation period between crops and livestock. Whiles the output of crops is harvested every production season, and may be produced twice in the season, it takes relatively more time for livestock to reach maturity and become available for sale. The traditional and cultural views of keeping livestock could also explain the difference. Traditionally, livestock (especially, large and small) is kept as a store of wealth for

households rather than for commercial purposes (see Baltenweck et al., 2020; Upton, 2004). With this view, livestock is sold when there is no alternative, especially when crops fail, and households need to smoothen consumption.

4.3.2 Household crop-livestock commercialisation

The discussion of the estimates of HCLCI starts with joint production and sales of crops and livestock (Table 4.4).[13] Out of the sample of 7,332 farm households for the GLSS7 data, 89.54 percent simultaneously produced at least one crop and livestock in the 2016/2017 season. This implies that the majority of Ghanaian farm households jointly operate crop and livestock production. Northern Ghana simultaneously produces more crop and livestock relative to southern Ghana. A subsample of northern Ghana in the GLSS7 reveals that the majority of farmers (93.3%) engage in joint crop and livestock production. This is corroborated by the primary data, where 83.22 percent of northern Ghana farmers jointly produce crop and livestock. Considering joint crop and livestock sales, the evidence shows that only 21.96 percent of farmers jointly sold crop and livestock in the 2016/2017 production season.

Though the observation is higher for the primary data (29.95%), the level of joint crop and livestock sales in Ghana can be described as low. A regional disaggregation of the GLSS7 data reveals that 19.78 percent and 23.76 percent of southern and northern farm households, respectively, sell crop and livestock jointly.

[13] Statistical test of significant differences between the corresponding values of the GLSS7 and primary data shows that most of the values are statistically different between the two datasets (i.e., those with 'Yes').

Table 4.4: Crop-livestock commercialisation indices

Metric	GLSS7 %	Primary %	Significant diff. between datasets
Produced crop and livestock for all farm households (n = 7,332 | n = 858)	89.54	83.22	Yes
Sold crop and livestock for all farm households (n = 7,332 | n = 858)	21.96	29.95	Yes
Sold crop and livestock for crop and livestock producers (n = 6,565 | n = 714)	24.52	35.99	Yes
Sold at least crop or livestock (n = 7,332 | n = 858)	72.90	81.59	Yes
Sold at least crop or livestock for only crop and livestock producers (n = 6,565 | n = 714)	77.94	85.01	Yes
HCLCI for all farm households (n = 7,332 | n = 858)	26.44	29.76	Yes
HCLCI for only crop and livestock producers (n = 6,565 | n = 714)	28.38	28.26	No
HCLCI for only crop and livestock producers and sellers (n = 1,610 | n = 257)	40.44	33.92	Yes
HCLCI for only crop and livestock producers and sellers of at least crop or livestock (n = 5,117 | n = 607)	36.21	33.24	Yes
HCLCI for only crop producers (n = 6,637 | n = 858)	28.31	29.76	No
HCLCI for only livestock producers (n = 7,260 | n = 714)	26.49	28.26	No
HCLCI for crop and livestock producers but only crop sale (n = 4,146 | n = 543)	41.24	36.03	Yes
HCLCI for crop and livestock producers but only livestock sale (n = 2,581 | n = 321)	30.78	29.07	No
Female headed (n = 1,766 | n = 105)	24.38*	22.13*	No
Female headed (conditioned on joint production) (n = 1,520 | n = 75)	26.91*	19.42*	Yes
Female headed (conditioned on joint sales) (n = 299 | n = 12)	45.33*	34.28*	No
Female headed (conditioned on at least one sale) (n = 1,170 | n = 67)	36.45	34.69	No
Male headed (n = 5,566 | n = 753)	27.10*	30.82*	Yes
Male headed (conditioned on joint production) (n = 5,045 | n = 639)	28.83*	29.30*	No
Male headed (conditioned on joint sales) (n = 1,311 | n = 245)	39.32*	33.90*	Yes
Male headed (conditioned on at least one sale) (n = 4,175 | n = 633)	35.95	36.66	No
Farm size (conditioned on joint production)			
Less than 0.5 ha (n = 1,175 | n = 32)	18.34	9.14	Yes
Between 0.5 and 1 ha (n = 1,013 | n = 52)	24.58	13.74	Yes
Between 1 and 2 ha (n = 1,653 | n = 117)	28.09	22.04	Yes
2 ha or more (n = 2,724 | n = 513)	34.30	32.34	No
Farm size (conditioned on joint sales)			
Less than 0.5 ha (n = 152 | n = 2)	43.43	32.71	No
Between 0.5 and 1 ha (n = 183 | n = 8)	43.03	22.59	Yes
Between 1 and 2 ha (n = 391 | n = 23)	40.21	35.71	No
2 ha or more (n = 884 | n = 224)	39.48	34.15	Yes
Farm size (conditioned on at least one sale)			
Less than 0.5 ha (n = 691 | n = 19)	30.60	16.71	Yes
Between 0.5 and 1 ha (n = 725 | n = 38)	34.46	35.79	No
Between 1 and 2 ha (n = 1,339 | n = 110)	35.00	36.00	No
2 ha or more (n = 2,394 | n = 533)	39.19	37.32	No

Note(s): First sample sizes are for GLSS7 and second sample sizes are for Primary data; * denotes that differences between males and females are statistically significant; Source: Produced by author using the GLSS7 and Primary Data.

While the production of crop, livestock, and crop and livestock have similar statistics (90.52%, 99.02% and 89.54% respectively), the same cannot be said about sales (Figure 4.1). Figure 4.1 shows that sale of crop is consistently higher than sale of livestock and joint sale

of crop and livestock for the two datasets. Thus, the use of crop commercialisation to measure agricultural commercialisation reveals higher sale decision of farm households. However, when the livestock dimension of commercialisation is accounted for, the sale decision is relatively lower.

The results on the estimate of HCLCI reported in Table 4.4 is discussed next. The overall levels of agricultural commercialisation among farm households (producing either crop or livestock) measured using the extended metric of commercialisation developed in this study are 26.44 percent and 29.76 percent for the GLSS7 and primary data, respectively.

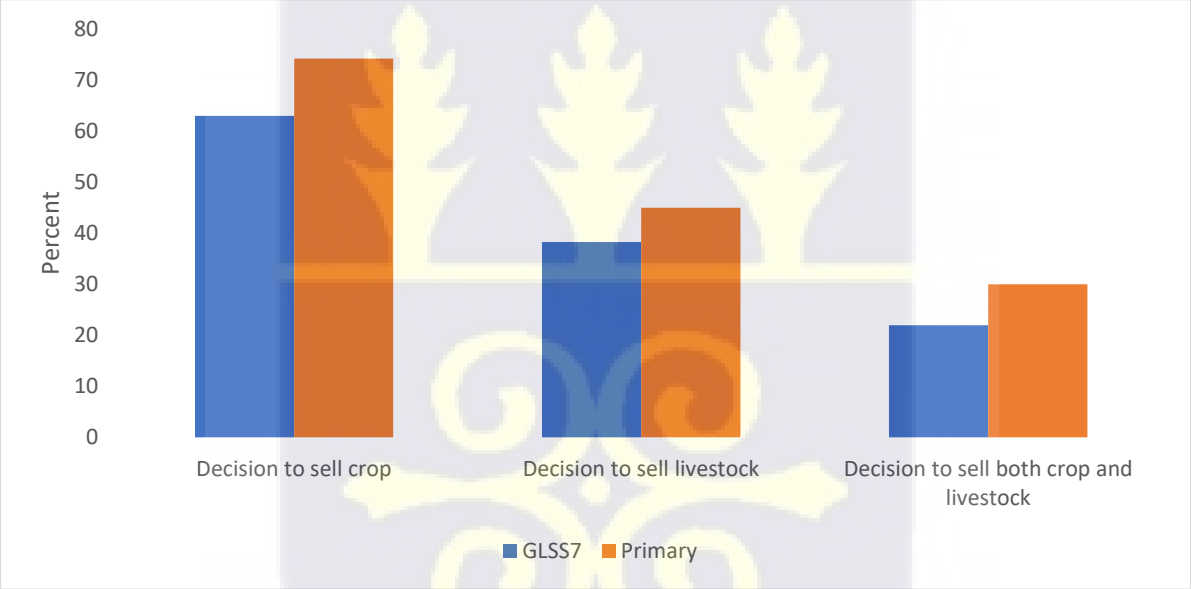


Figure 4.1: Sale of crop and livestock
Source: Produced by author using the GLSS7 and Primary data

Further results (Figure 4.2) report that the joint sale of crop and livestock is lower than sale of either crop or livestock.

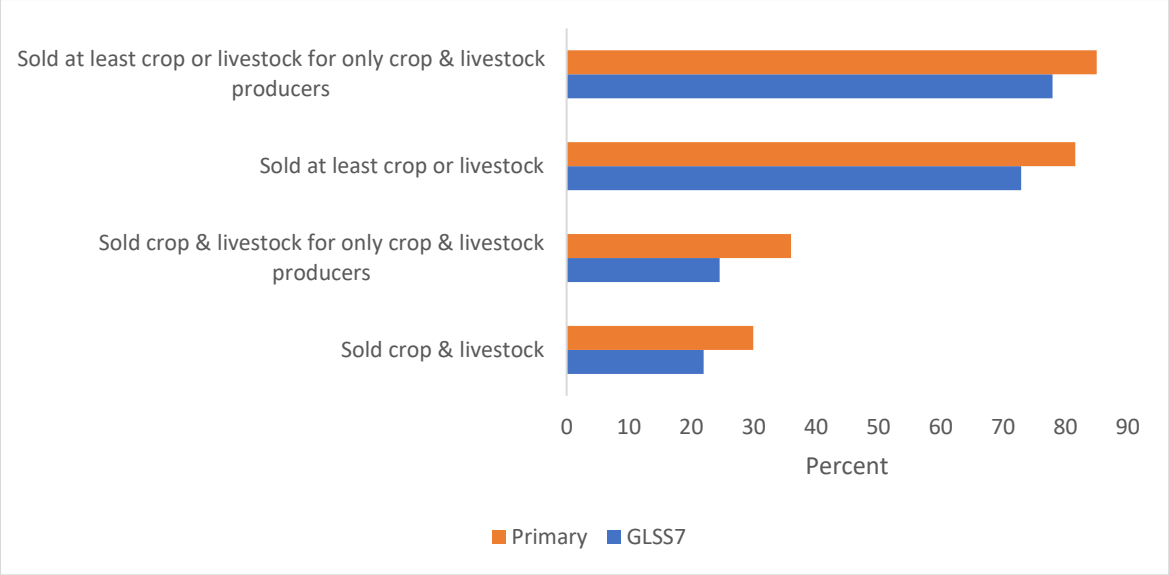


Figure 4.2: Crop and livestock sale decisions
Source: Produced by author using the GLSS7 and Primary data

This implies that in a production season, farm households in Ghana sell 26.44 percent (or 29.76% using the primary data) of their joint crop and livestock output. Compared to the level of agricultural commercialisation in Ghana using the crop commercialisation index (35.2%), the evidence indicates the extended metric – crop livestock commercialisation index – is lower. It is however important to note that both the extended metric and the crop index show the same characterisation of agriculture in Ghana – surplus-oriented agriculture because the average indices fall within the surplus-oriented classification. The difference is however that the extended metric includes the livestock dimension of commercialisation and thus captures the true state of agricultural commercialisation since livestock production cannot be disentangled from agriculture. The extended metric is better in estimating the level of commercialisation because unlike the crop commercialisation metric which ignores engagement in livestock production, the extended metric considers it in the estimation. Therefore, the crop commercialisation index overstates the level of commercialisation. Accounting for farmers who jointly produced crop and livestock, similar levels of

commercialisation are obtained (i.e., 28.38% and 28.26% for the GLSS7 and primary data, respectively). Figure 4.3 further presents the differences in commercialisation indices.

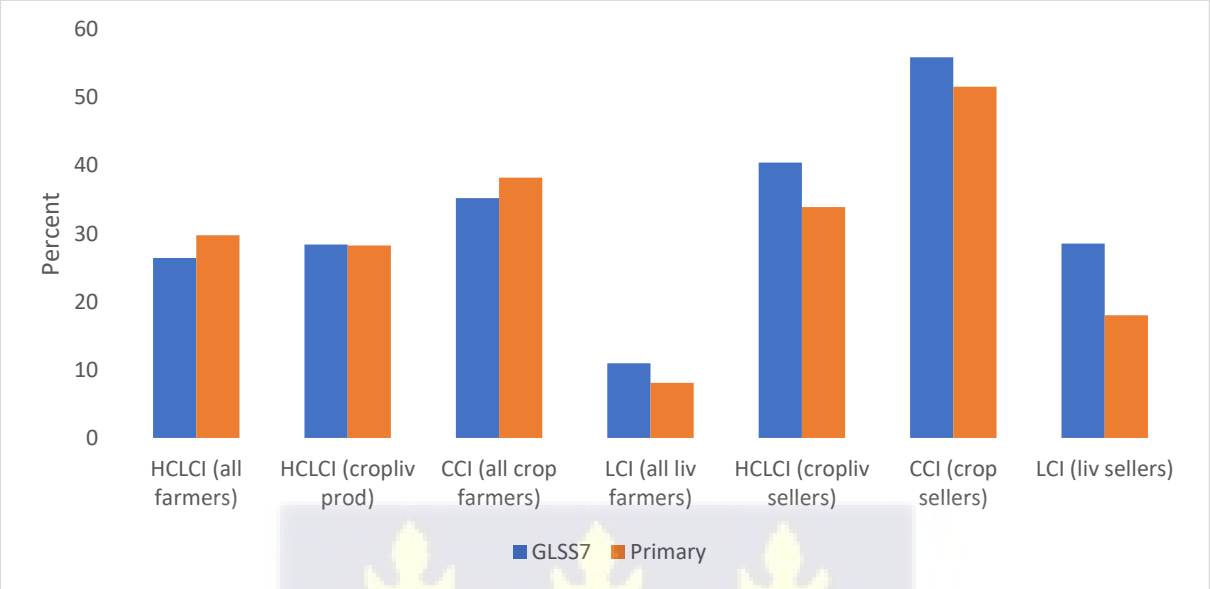


Figure 4.3: Comparison of commercialisation indices
Source: Produced by author using the GLSS7 and Primary data

The level of commercialisation is also reported based on gender in Table 4.4 but more specifically in Figure 4.4. The evidence points to gender disparity in agricultural commercialisation. Male-headed households have higher commercialisation ratios for the overall level of commercialisation and commercialisation conditioned on the joint production of crop and livestock, and the differences are statistically significant.

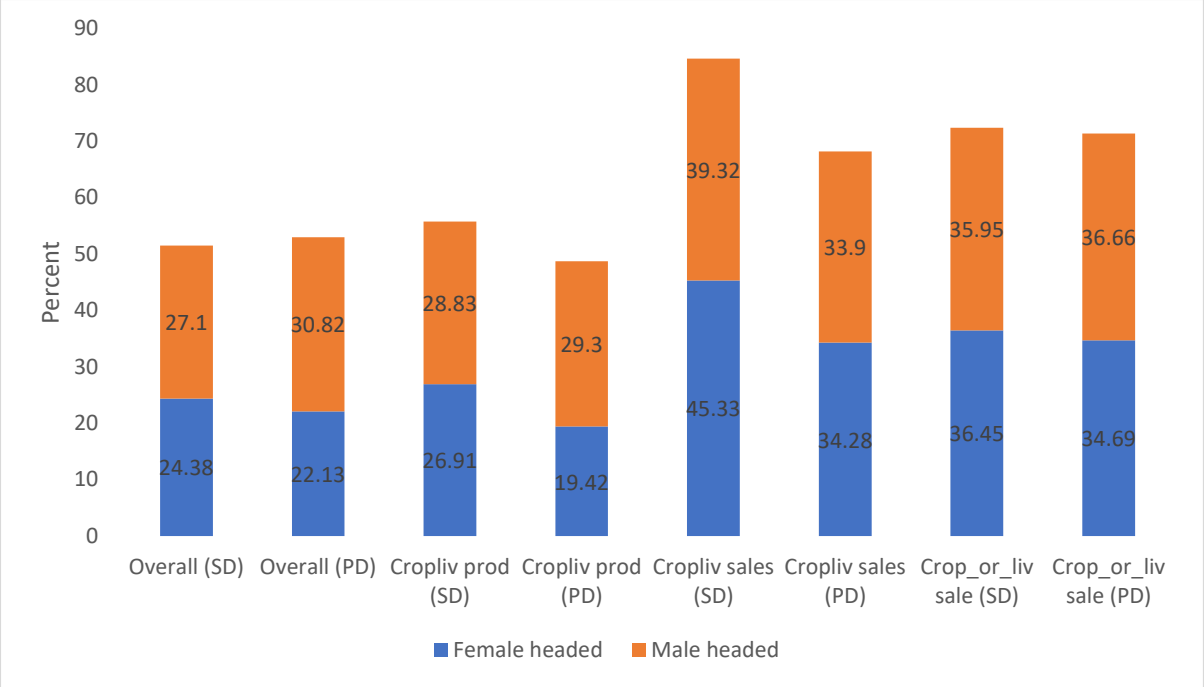


Figure 4.4: Gender differences in commercialisation indices
Note: 'SD' is secondary data; 'PD' is primary data; Source: Produced by author using the GLSS7 and Primary data

However, when commercialization is conditioned on joint production and sale, female-headed households have higher commercialisation ratios, with a statistically significant difference. Figure 4.5 further presents differences in commercialisation based on farm size. The evidence shows that large-scale farmers commercialise more than small-scale farmers when commercialisation is conditioned on the joint production of crop and livestock (Panel A). However, small-scale farmers have slightly higher commercialisation ratios than large farmers when conditioned on the joint sale of crop and livestock.

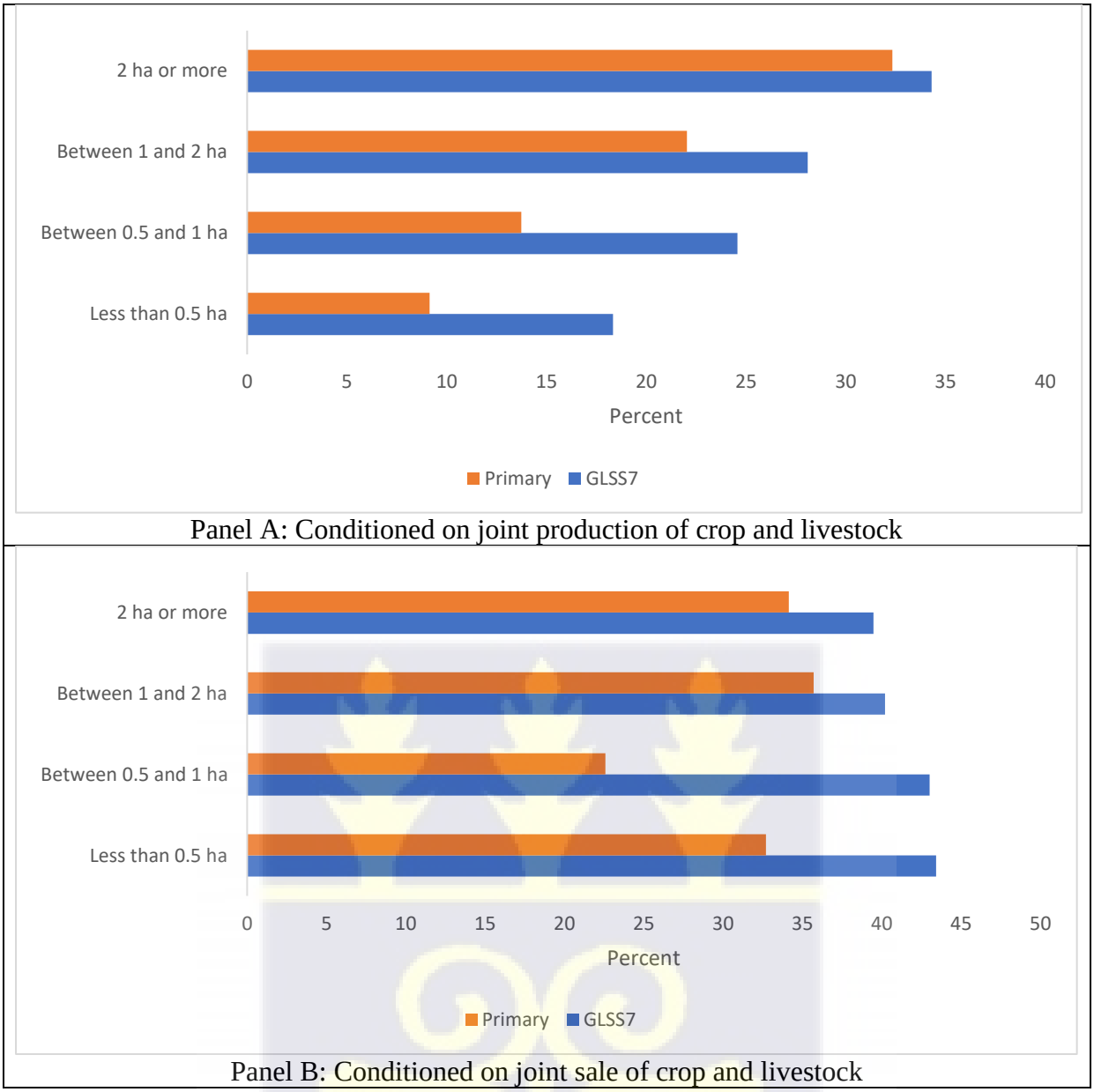
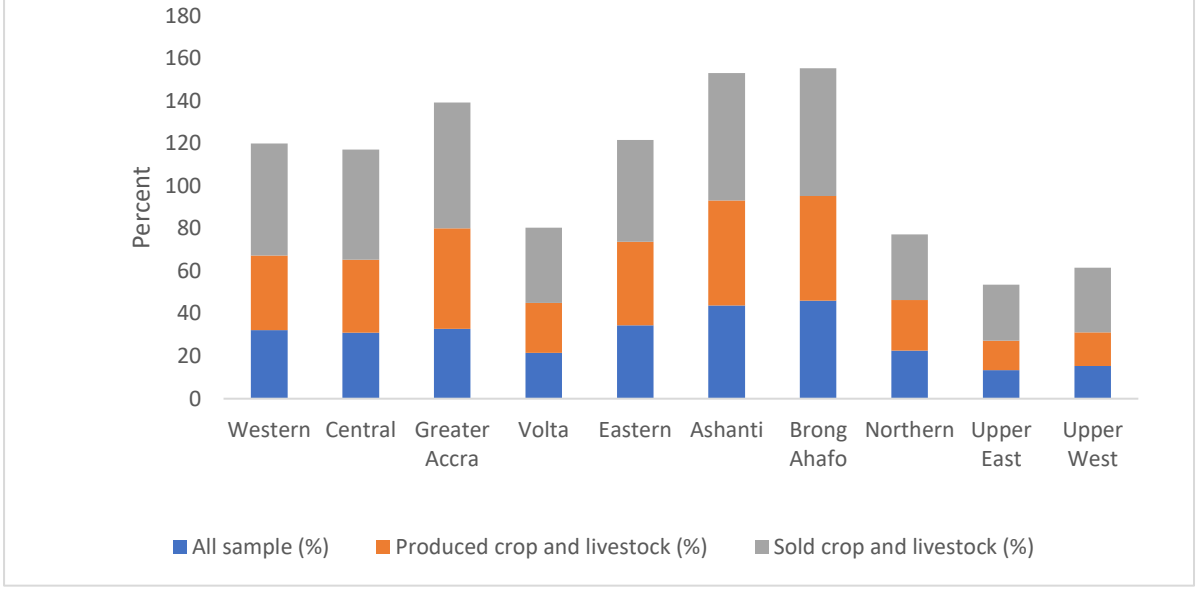
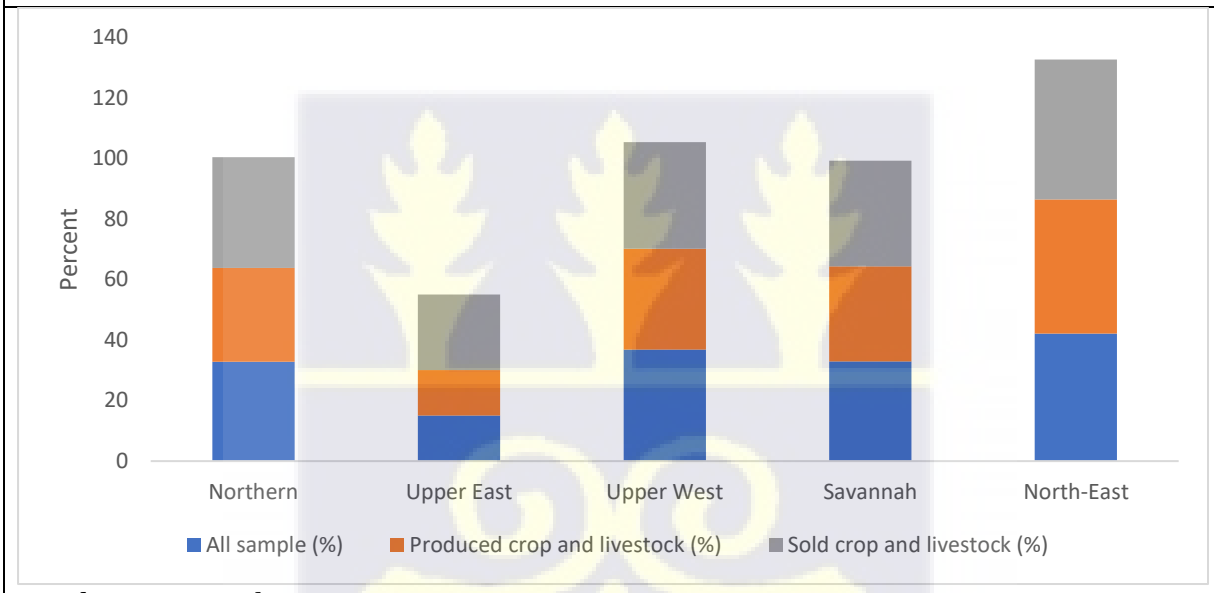


Figure 4.5: Farm size differences in commercialisation indices
Source: Produced by author using the GLSS7 and Primary data

In terms of regional distribution of commercialisation, farmers from southern Ghana commercialise more than their counterparts in northern Ghana (Figure 4.6, Panel A).



Panel A: GLSS7



Panel B: Primary data

Figure 4.6: Regional distribution of commercialisation
Source: Produced by author using the GLSS7 and Primary data

Farmers in Brong Ahafo, Ashanti and Eastern regions are the most commercialised, while farmers in Upper West and Upper East are the least commercialised. The results from the primary data in Panel B are generally similar to the results of the GLSS7. In further analysis, farm households are categorised according to their level of commercialisation into three broad categories of subsistent-oriented, surplus-oriented and commercial-oriented based on

classification of FAO (1989) and Pingali and Rosegrant (1995) presented earlier in the methodology. Based on these categorisations, Figure 4.7 presents the results.

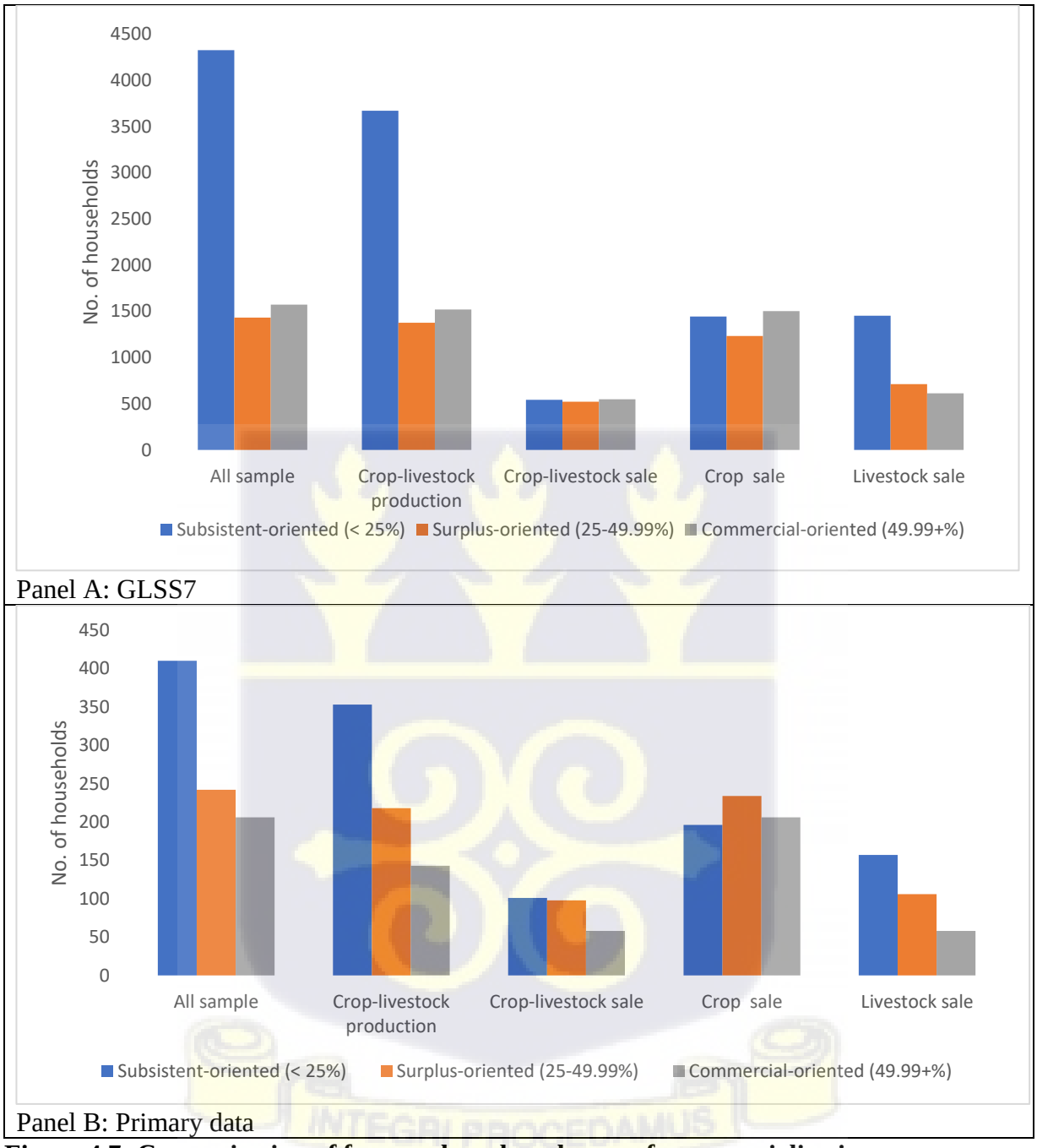


Figure 4.7: Categorisation of farmers based on degree of commercialisation
Source: Produced by author using the GLSS7 and Primary data

The results reveal that majority of farmers are described as subsistent-oriented farmers, irrespective of the subsamples of commercialisation or data considered. For example, 59.0

percent, 55.9 percent and 33.7 percent of farmers are subsistent-oriented farmers for all the sample farm households, a subsample of joint crop and livestock production and a subsample of joint crop and livestock sale, respectively, in the case of the GLSS7 data. This evidence suggests that though on average Ghanaian agriculture is characterised as surplus-oriented (because the average levels of crop-livestock commercialisation of 26.44% and 29.96% for the GLSS7 and primary data, respectively are within the surplus-oriented classification), majority of farm households are subsistent-oriented when the analysis is done at the class level. It further revealed that crop farm households are more commercial-oriented and surplus-oriented than livestock farm households in both absolute terms (as shown in Figure 4.7) and proportional terms. However, proportionally, livestock farm households are more subsistent-oriented than crop farmers.

4.4 Determinants of an extended metric of agricultural commercialisation

After estimating the extended metric of agricultural commercialisation in the first objective, the task here is to estimate the factors that influence it. As stated in the methodology, a fractional regression is estimated for both datasets. In the GLSS7 data, two models are estimated, including (i) a model without correcting for selectivity bias and (ii) a model that corrects for selectivity bias. The baseline model (i.e., the preferred) is where selectivity bias has been accounted for.

Table 4.5 reports the results of the determinants of the extended metric of agricultural commercialisation. Columns 1 and 2 report the results for the GLSS7 data and column 3 reports that of the primary data. Column 1 presents the results without correcting for selectivity bias and column 2 reports results that correct for selectivity bias.

Table 4.5: Determinants of an extended metric of agricultural commercialisation

	Dependent variable: HCLCI		
	GLSS7		Primary
Variable	(1) Fractional regression	(2) Fractional regression (IMR)	(3) Fractional regression
Sex of head	0.047	0.029	0.056
	(0.034)	(0.035)	(0.070)
Age of head	-0.001	-0.001	-0.005***
	(0.001)	(0.001)	(0.002)
Household size	-0.017***	-0.019***	0.006
	(0.004)	(0.004)	(0.010)
Locality of household	0.467***	0.395***	
	(0.065)	(0.067)	
Marital status of head	-0.024	-0.015	-0.199**
	(0.029)	(0.030)	(0.078)
Years of education of head	0.000	0.001	0.005
	(0.003)	(0.003)	(0.004)
Received cash remittance	0.016	0.016	0.020
	(0.027)	(0.026)	(0.069)
No. of days stop work due to ill-health	-0.003	-0.002	0.001
	(0.004)	(0.004)	(0.001)
Ownership of nonfarm enterprise	-0.091***	-0.078**	-0.121**
	(0.031)	(0.032)	(0.060)
Agric cooperative in community	0.253***	0.311***	0.292***
	(0.063)	(0.065)	(0.073)
Bank in community	0.484***	0.447***	0.255**
	(0.049)	(0.048)	(0.102)
Mobile phone network in community	0.050	0.027	-0.825***
	(0.050)	(0.048)	(0.116)
Agric extension office in community	0.100**	0.068	0.169***
	(0.047)	(0.048)	(0.055)
Irrigated fields in community	0.314***	0.456***	-0.124**
	(0.074)	(0.078)	(0.056)
Perceived rain pattern in community	-0.064	-0.054	0.001
	(0.042)	(0.040)	(0.078)
Log of expenditure on agrochemicals	0.012*	-0.001	-0.002
	(0.007)	(0.007)	(0.009)
Log of expenditure on hired labour	0.012**	0.007	-0.007
	(0.006)	(0.006)	(0.009)
No. of crops produced	0.056***	0.024**	0.078***
	(0.012)	(0.011)	(0.028)
Log of total value of household assets	-0.007	-0.004	-0.055***
	(0.005)	(0.005)	(0.010)
Log of agric land endowment	0.067***	0.064***	0.139***
	(0.020)	(0.020)	(0.028)
Market in community	0.622***	0.652***	0.310***
	(0.044)	(0.044)	(0.051)
Navigable road to community	0.752***	0.398***	0.504***
	(0.112)	(0.132)	(0.075)
Access to public transport	0.254***	0.139**	0.433***
	(0.081)	(0.059)	(0.080)
Household in southern Ghana/NR	-0.125**	-0.115**	-0.640***
	(0.054)	(0.053)	(0.090)
Household in coastal zone/UER	-0.052	-0.117	-0.767***
	(0.107)	(0.112)	(0.084)
Household in forest zone/UWR	0.106	0.014	-0.795***
	(0.103)	(0.108)	(0.116)
Household in savannah zone/SR	-0.205*	-0.297**	-0.695***
	(0.116)	(0.121)	(0.108)

Inverse mills ratio		-0.305***	
		(0.060)	
Constant	-2.108***	-1.322***	0.438**
	(0.129)	(0.203)	(0.194)
Observations	7332	7332	858
F-statistic/Wald chi-square	98.995***	96.612***	1194.111***

Note(s): * $p<0.1$; ** $p<0.05$; *** $p<0.01$; HCLCI is the household crop-livestock commercialisation index; Standard errors in parentheses; Survey weights are applied in estimating the GLSS7 data; Columns 1 and 3 are results without correcting for selectivity bias, while column 2 corrects for selectivity bias; Source: Produced by the author using GLSS7 and Primary Data.

The results of the probit model based on which the IMR is constructed to detect and correct for selectivity bias is reported in Table A2 in Appendix 2. The IMR estimate in column 2 (Table 4.5) is negative and statistically significant. This implies that there is indeed selectivity bias for using the subsample from the original sample and intrinsically corrects for it. The negative coefficient of the inverse mills ratio implies that farm households with relatively low agricultural commercialisation propensity are more likely to self-select into market participation. Generally, the evidence is that the model without correcting for selection bias has large coefficients. Therefore, selection bias causes upward bias of the coefficients. The F-statistic (GLSS7) and Wald chi-square (primary data) are statistically significant, implying that the estimated models have explanatory power.

The results reveal two classes of determinants – robust determinants across the GLSS7 and primary data (i.e., determinants from the GLSS7 that are validated by the determinants from the primary data in terms direction/sign and statistical significance) and determinants that are not robust across the two datasets (i.e., determinants from the GLSS7 that are not validated by the determinants from the primary data). Thus, robust determinants are simultaneously significant determinants of agricultural commercialisation in the two datasets with the same or different sign. The robust determinants are ownership of nonfarm enterprise, agricultural cooperative in community, bank in community, number of crops cultivated, agricultural land endowment, presence of community market, navigable road to community, access to public

transport and presence of irrigation in community. All these determinants exhibit homogeneous effects on agricultural commercialisation (i.e., they have the same directional effects) except presence of irrigation in community, which has different effects for the GLSS7 and primary data.

Households that engage in nonfarm enterprises have lower agricultural commercialisation. This implies that when they participate in the agricultural markets to sell crops and livestock, they sell lower proportions (specifically 7.8% and 12.1% less, respectively, for the GLSS7 and primary data) of their produce relative to households that do not participate in nonfarm enterprises. Given the liquidity-relaxing and lost-labour transmission channels between nonfarm engagement and agricultural commercialisation presented in the literature (see e.g., Babatunde, 2015; Woldehanna & Oskam, 2001), this observation is consistent with the lost-labour transmission channel. The lost-labour transmission channel argues that the allocation of household labour to nonfarm activities yields extra income that is further invested in nonfarm activities and household consumption dampens agricultural investments ultimately reducing agricultural commercialisation (see e.g., Babatunde, 2015). Thus, nonfarm engagement in this regard competes for labour and investment with agricultural production and commercialisation. This finding corroborates the evidence reported by Sekyi et al. (2020) which suggests that engagement in nonfarm activities through the ownership of nonfarm business equipment by Ghanaian farm households reduces commitment to agriculture, production, and commercialisation.

Farm households which have agricultural cooperatives in their communities commercialise crop and livestock produce more relative to those that do not have these organisations. Specifically, presence of cooperatives respectively increases commercialisation by 31.1

percent for the GLSS7 and 29.2 percent for the primary data. These findings meet expectation and corroborate several studies in the literature (see e.g., Abu & Issahaku, 2017; Aku et al., 2018; Hagos et al., 2020; Hao et al., 2018; Kyaw et al., 2018). Agricultural cooperatives provide participants with the relevant farming techniques that help increase farm production and raise marketable surpluses. Agricultural cooperatives provide members with collective bargaining power that helps obtain favourable market prices and thus stimulate commercialisation (Ochieng et al., 2019). Cooperatives also help in providing relevant market information that stimulates commercialisation. In addition, cooperatives may represent a platform to raise large volumes of output that may encourage large-scale buyers. Indeed, these explanations are supported by extant literature. For example, Aku et al. (2018) noted that farmer organisations improve farmer welfare by improving market access, reducing transaction costs to agricultural marketing, and providing social capital. They observed further that those farmers who participated in organisations had lower transaction costs in transporting produce to market centres than farmers who did not participate in organisations.

The presence of bank or financial institution in community has a positive effect on agricultural commercialisation. It implies that farmers that reside in communities with banks or financial institutions sell respectively 44.7 percent and 25.5 percent more crop and livestock output value than farmers who reside in communities without any financial institution for the GLSS7 and primary data. The presence of financial institutions serves as a proxy for financial inclusion, and the role of financial inclusion in the agricultural commercialisation literature is clearly emphasised (see Abu & Issahaku, 2017; Misra et al., 2016; Nkegbe et al., 2022; Sekyi et al., 2020). For example, Abu and Issahaku (2017) report that financially-included farmers sell higher quantities of their farm produce than financially-

excluded farmers in Ghana. They argue that the presence of financial institutions serves as an advertisement for farmers to participate in financial services (e.g., credit and savings). Some literature (e.g., Abu & Issahaku, 2017; Manda et al., 2021; Sekyi et al., 2020) have shown how access to credit stimulates agricultural commercialisation. Thus, the presence of banks serves as a proxy for credit; thus, this finding corroborates this earlier evidence. The main transmission channel of financial inclusion to agricultural commercialisation is productivity gains. For instance, Narayanan (2016) and Misra et al. (2016) observed that access to credit promotes technology adoption, which increases productivity and farm output.

The results further show that access to infrastructure is a key stimulant of joint crop and livestock commercialisation. Specifically, farmers from communities with designated markets, navigable roads and with access to public transport sell higher proportions of crops and livestock than farmers without this infrastructure. The presence of market increases joint crop and livestock commercialisation by 65.2 percent and 31.0 percent, respectively, for the GLSS7 and primary data. Access to navigable roads increases joint crop and livestock commercialisation by 39.8 percent and 50.4 percent, respectively, for the GLSS7 and primary data, while access to transport increases joint crop and livestock commercialisation by 13.9 percent and 43.3 percent, respectively, for the GLSS7 and primary data. These findings are expected and corroborate several earlier findings in the literature that emphasised the stimulating role of infrastructure in increasing agricultural commercialisation (e.g., Abu & Issahaku, 2017; Acheampong et al., 2018; Alhassan et al., 2020; Nkegbe et al., 2022; Sekyi et al., 2020). These variables exhibit double channels of effect on commercialisation. First, markets, roads and transport are productivity boosters as they facilitate technology adoption. For example, markets reduce transaction costs in buying inputs. The bulk of the commercialisation literature explained the role of reducing transaction costs through the

provision of road and transport infrastructure and improving market access (see e.g., Abdul-Rahaman & Abdulai, 2020; Andaregie et al., 2021; Ochieng et al., 2015; Stifel et al., 2016; Stifel & Minten, 2017; Usman & Haile, 2022). Good roads and transport availability also ensure that the transaction costs in searching and procuring inputs are reduced. Second, markets, roads and transport availability directly influence commercialisation as they further reduce transaction costs in selling farm produce.

The scale of production is important in boosting agricultural commercialisation as the number of crops produced and agricultural land endowment are positive determinants. This implies that diversified crop production and large-scale production increase commercialisation. An additional crop produced increases the joint commercialisation of crop and livestock by 2.4 percent and 7.8 percent, respectively, for GLSS7 and primary data. On the other hand, an additional hectare of land endowment increases commercialisation by 0.064 percent and 0.139 percent, respectively, for the GLSS7 and primary data. When farm households diversify crop production, the opportunity to increase marketed surplus increases, boosting increase commercialisation. Tesfaye (2022) reports that crop diversification improves farm income (essentially through commercialisation). This finding corroborates the evidence of Sekyi et al. (2020) who reported increased commercialisation when farm households produce multiple crops. Agricultural land endowment can increase the scale of production thus increasing output and marketed surplus. This is consistent with the evidence of Abu and Issahaku (2017), who reported that agricultural land endowment provides the potential to expand farm sizes. The results also corroborate studies that observed that large farm sizes and/or land endowment are associated with increased agricultural commercialisation (e.g., Andaregie et al., 2021; Endalew et al., 2020; Hagos et al., 2020; Manda et al., 2021; Nkegbe

et al., 2022; John Olwande et al., 2015; Owusu & İşcan, 2021; Sekyi et al., 2020; Tafesse et al., 2020).

Presence of community irrigation fields is the only variable that has differing effects in the two datasets. In the GLSS7, households who live in communities with irrigated fields are more likely to sell crop and livestock – an expected observation, since irrigated fields can stimulate increased production – while in the primary data, it is the reverse. This study is unable to explain the contradictory observation.

Focusing now on the non-robust determinants, the results reveal that larger households (i.e., with more members) have lower commercialisation relative to small households for only the GLSS7 data. An additional household member reduces the level of joint crop and livestock commercialisation by 1.9 percent. This is consistent with the commercialisation literature (e.g., Abu et al., 2016; Alhassan et al., 2020; Kyaw et al., 2018; Megerssa et al., 2020; Nkegbe et al., 2022) that explains that more household members increase food consumption and reduced marketable surplus. The primary data shows that young farmers commercialise more than aged farmers and this is consistent with the findings of Sekyi et al. (2020), Abu and Issahaku (2017), Abu et al. (2014) and Alhassan et al. (2020) that explain that older farmers may be more concerned with meeting food security needs of households than selling. An additional year of the farmer reduces the joint commercialisation of crop and livestock by 0.5 percent. However, this is inconsistent with the finding of Mariyono (2018), who observed that older vegetable farmers in Indonesia have higher commercialisation ratios than younger farmers, explaining that risk differential in cultivating vegetables and other food crops accounts for the negative effect.

More endowed farmers (i.e., in terms of assets) tend to commercialise less in the primary data. This may suggest that endowed farmers prioritise food security over selling, since they already have the liquidity to meet household needs. This corroborates the finding of Fafchamps and Hill (2005) who reported that wealthy farmers have a lower probability of selling coffee at the market, explaining that the higher shadow value of their time may be responsible for this behaviour. The primary data further indicate that farmers who reside in communities with agricultural extension offices have higher commercialisation ratios implying that extension services provide technical knowledge that boost productivity and thus more marketable surpluses (see (Abu & Issahaku, 2017; Andaregie et al., 2021; Endalew et al., 2020; Kyaw et al., 2018; Nkegbe et al., 2022). Access to extension increases joint crop and livestock commercialisation by 16.9 percent. Key unexpected evidence relates to the negative coefficient of mobile phone network in community in the primary data, which is a proxy for information access. This means that farmers who reside in communities with mobile phone network sell low proportions of crop and livestock relative to their counterparts. It is expected that access to mobile phone network will provide farming and marketing information, as well as other related information – if farmers make the necessary investments to use the network – that can facilitate increased production and marketing of produce. For example, Issahaku et al. (2018) report that Ghana's farmers who own and use mobile phones achieve higher maize yields than those who do not use mobile phone. They explained that mobile phones facilitate information acquisition on input and other farming techniques that improve productivity. Perhaps, the changing trends in the use of mobile phones for other activities (e.g., games, gambling and other entertainments) may explain this contradictory observation.

It is found that the household location variable (only for the GLSS7) is positive and implies that farmers in rural Ghana commercialise more than farmers in urban Ghana. Rural areas are more agrarian than urban areas, and this may explain this observation. This observation is consistent with the negative effect of the regional dummy, which implies that farmers in southern Ghana commercialise less relative to farmers in the northern Ghana. As rural areas are more agrarian than urban areas so is northern Ghana more agrarian than southern Ghana.

Beyond the estimates of the baseline determinants of agricultural commercialisation, some additional models were estimated to provide robustness. The first robustness model estimates the determinants using an alternative specification that is similar to the fractional regression model – the Tobit model (truncated from both below and above). The results are reported in Table A3 in Appendix 2. The Tobit estimates are similar to the fractional regression estimates. In the GLSS7 results, except the age of household head (negative and significant coefficient in Tobit but negative and insignificant coefficient in fractional regression), the rest of the significant determinants in the fractional regression model are also the significant determinants in the Tobit model. In the primary data, there are no differences in the determinants. Therefore, it can be concluded that the fractional regression model is generally robust to similar alternative specifications. However, the main difference between the fractional and Tobit results here is that the fractional regression estimates are consistently larger in magnitude relative to the Tobit estimates.

The second robustness model estimated the determinants of agricultural commercialisation on the subsample of households who sold at least 25 percent of their crop and livestock output. The rationale for this consideration is the observation by FAO (1989) that farmers who sell at least 25 percent of their produce are defined as surplus-oriented (sales between 25 and 50%)

or commercial-oriented (sales of at least 50%). This estimation drops the sample of farmers characterised as subsistent-oriented (sales less than 25%). Table A4 in the appendix presents the results (Table A2, columns 2 and 3, reports the probit models for estimating IMR). Generally, the estimates of the subsamples from the two datasets are similar to the estimates of the respective full samples. The only exceptions are that in the GLSS7 results, where age of farmer, expenditure on agrochemicals, expenditure on hired labour, perceived rain pattern and extension are significant determinants in the subsample results unlike in the main results. Thus, the subsample results provide extra evidence of significant determinants of agricultural commercialisation. For instance, access to extension and expenditure on agrochemicals and hired labour are boost commercialisation for the subsample. Moreover, in the primary data results, age of household head, ownership of nonfarm enterprise, agricultural cooperative in community, irrigation facility in community, extension, number of crops produced and navigable road in community which are significant determinants in the main results are insignificant in the subsample results. Thus, the subsample results from the primary data do not provide any new evidence.

The third robustness model (Table A5 in Appendix 2) estimated the determinants of crop commercialisation and livestock commercialisation separately and compared these with the extended metric. It is revealed from the comparison that the determinants of agricultural commercialisation from the three separate measures (i.e., HCLCI, HCCI and HLCI) are generally similar in terms of robust determinants across the measures. However, the key difference between the HCLCI determinants on the one hand, and the HCCI and HLCI on the other hand is that the HCLCI determinants are generally larger in coefficients than the estimates of determinants from the HCCI and the HLCI. This implies that the HCCI and HLCI underestimate the effects of the determinants of agricultural commercialisation.

4.5 Impact of agricultural commercialisation on food and nutrition security

The discussion of the impact of the extended metric of agricultural commercialisation on food and nutrition security starts with presenting the results of the validity of the instruments – market in community, community average of household commercialisation index and community average of market orientation index. The rationale is that the estimated impacts' reliability depends on instruments' validity. In the quasi-experimental literature, the validity of an instrument depends on meeting two basic criteria, relevance and exogeneity (e.g., Ogutu et al., 2020).

4.5.1 Relevance and exogeneity of instruments

The estimates that provide the evidence to evaluate the relevance of the instruments are reported in Table A6 in Appendix 2. The evidence suggests that all three instruments are statistically significant determinants of agricultural commercialisation in both the secondary and primary data models and for both cases where commercialisation is continuous or ordered. These results provide the statistical evidence to conclude that the instruments satisfy the requirement of relevance (i.e., the instruments should be significant determinants of agricultural commercialisation).

The second validity test of the instruments is to test their exogeneity. This implies proving that the instruments are orthogonal to the outcomes (i.e., all the food and nutrition measures). In other words, providing evidence that shows the instruments do not directly influence food and nutrition outcomes, but only do so through agricultural commercialisation. Tables A7 (for the secondary data) and A8 (for primary data) in Appendix 2 report the results. However, Table 4.6 provides a summary of the exogeneity of instruments and the decisions in estimating the impact.

The first observation from the results is that, in a multi outcome study, the instruments tend to show differing exogeneity for the various outcomes. In Tables A7 and A8 and specifically in Table 4.6, the three instruments are not all exogenous in any of the outcome models. This implies that they cannot all be used as instruments to estimate the impact of agricultural commercialisation on the various food and nutrition security outcomes. The evidence reveals that in the GLSS7 data, market in community is not exogenous in vitamin A, protein, hem iron and stunting outcomes.

Table 4.6: Exogeneity of instruments

Outcome	Exogeneity			Decision for impact estimation
	mkt	ahclci	amoi	
GLSS7:				
Food expen. (p.c.)	Not exogenous	Not exogenous	Exogenous	Use amoi
Food expen. (adult equiv.)	Exogenous	Not exogenous	Exogenous	Use mkt, amoi
HDDS	Not exogenous	Exogenous	Not exogenous	Use ahclci
FCS	Not exogenous	Exogenous	Not exogenous	Use ahclci
Vitamin A	Not exogenous	Exogenous	Exogenous	Use ahclci, amoi
Protein	Not exogenous	Exogenous	Exogenous	Use ahclci, amoi
Hem iron	Not exogenous	Exogenous	Exogenous	Use ahclci, amoi
Stunting	Not exogenous	Exogenous	Exogenous	Use ahclci, amoi
Wasting	Not exogenous	Exogenous	Not exogenous	Use ahclci
Underweight	Not exogenous	Exogenous	Not exogenous	Use ahclci
FIES	Exogenous	Not exogenous	Exogenous	Use mkt, amoi
Primary:				
Food expen. (p.c.)	Exogenous	Not exogenous	Exogenous	Use mkt, amoi
Food expen. (total)	Exogenous	Not exogenous	Exogenous	Use mkt, amoi
HDDS	Not exogenous	Not exogenous	Exogenous	Use amoi
FCS	Not exogenous	Exogenous	Not exogenous	Use ahclci
Vitamin A	Not exogenous	Not exogenous	Exogenous	Use amoi
Protein	Not exogenous	Exogenous	Not exogenous	Use ahclci
Hem iron	Not exogenous	Exogenous	Not exogenous	Use ahclci
FIES	Not exogenous	Not exogenous	Exogenous	Use amoi
HHS	Not exogenous	Not exogenous	Exogenous	Use amoi
HFIAS	Not exogenous	Not exogenous	Exogenous	Use amoi

Note: Decision to use an instrument is not based on only exogeneity but also on relevance as the evidence has already shown these instruments as relevant (see Table A6); mkt is market in community, ahclci is community average commercialisation index, amoi is community average market orientation index.

Therefore, in estimating the impact for these outcomes, market in community is not used but only average community commercialisation and average community market orientation are used since they both meet relevance and exogeneity criteria. Further, only community average commercialisation meets the exogeneity requirement in household dietary score,

food consumption score, wasting and underweight models. Thus, coupled with meeting the relevance requirement, it is used in estimating the impact on these outcomes. However, average community commercialisation is not exogenous in the real per adult equivalent annual food expenditure and food insecurity experience scale thus only community average market orientation and market in community are used in estimating the impact on these outcomes. In the primary data, community average market orientation is the only instrument exogenous in the household dietary diversity score, vitamin A, food insecurity experience scale, household hunger scale and household food insecurity access scale. It is thus used in the impact estimation of these outcomes. Average commercialisation index in community is exogenous in the food consumption score, proteins and hem iron outcomes and is used for their impact estimation. In the outcomes of per capita annual food consumption expenditure and total annual food consumption expenditure, market in community and average market orientation index in community are exogenous and thus used as instruments for these outcomes.

4.5.2 Impact of agricultural commercialisation

After testing the relevant validity of the instruments and obtaining information on where each instrument may be applicable, the impact of agricultural commercialisation on the various measures of food and nutrition security is estimated using the various econometric techniques outlined in the methodology (i.e., two-step generalised method of moment instrumental variable for continuous outcomes, instrumental variable probit for dummy outcomes and extended ordered probit for ordered outcomes). Table 4.7 (for GLSS7) and Table 4.8 (for primary data) report the results. Table A9 in Appendix 2 presents the first-stage estimates for ordered outcome (i.e., FIES, HHS and HFIAS). Besides the tests of relevance and endogeneity discussed earlier (Table 4.6), the instrumental variable regression provides

statistical tests of the quality of instruments. The first is the weak identification test, which tests whether the instruments are weakly correlated with the endogenous variable (commercialisation). When the instruments are weak, the IV estimator performs poorly. The results in Tables 4.7 and 4.8 indicate that the two tests (i.e., Kleibergen-Paap Wald F statistic and Cragg-Donald Wald F statistic) are statistically significant. Thus, the null hypothesis of weak instruments is rejected. This implies that the instruments are not weakly correlated with commercialisation; thus, the model is not weakly identified. The second test is the under-identification test, which tests whether the estimation model is identified or whether the instruments are relevant (i.e., correlated with commercialisation). The Kleibergen-Paap LM statistic is statistically significant, implying that the instruments are relevant since the null hypothesis that the model is under-identified is rejected. This confirms the earlier test of instrument relevance. The Hansen J statistic, which tests for overidentifying restrictions under the null hypothesis that the instruments are valid (i.e., relevant, and uncorrelated with the outcomes), is not statistically significant in any of the estimated models. This indicates that we fail to reject the null hypothesis. This implies that instruments are valid and confirms the earlier tests of instrument validity. The Wald test of exogeneity estimated for the stunting, wasting and underweight models suggests that commercialisation is endogenous.

After controlling for all relevant factors, the extended metric of agricultural commercialisation significantly affects the food and nutrition security indicators for both datasets. Agricultural commercialisation has a significantly positive effect on food consumption expenditures, household dietary diversity, food consumption score, consumption of vitamin A-rich, protein-rich and hem iron-rich foods, food insecurity experience scale, household hunger scale and household food insecurity access scale; and a significantly negative effect on child anthropometric measures of stunting, wasting and

underweight. Specifically, increasing joint crop and livestock commercialisation by 1 percent increases annual per capita food consumption expenditure by GHS8.519 and GHS38.285, respectively, for GLSS7 and primary data; increases annual adult equivalent consumption expenditure by GHS7.563 (only GLSS7); increases annual food consumption expenditure by GHS166.567 (only primary data); increases the number of food groups consumed by 0.038 and 0.086 respectively for GLSS7 and primary data; increases weighted number of food groups (FCS) consumed by 0.091 and 0.311, respectively, for GLSS7 and primary data; increases consumption of vitamin A-rich, protein-rich and hem iron-rich foods by 0.063, 0.034 and 0.018 respectively for GLSS7 and 0.091, 0.124 and 0.082 respectively for primary data.

Further, for the FIES estimate, a 1 percent increase in commercialisation increases the probability of experiencing 'food security to mild food insecurity' by 0.4 percent and 3.7 percent, respectively, for GLSS7 and primary data; for the HHS estimate, a 1 percent increase in commercialisation increases the probability of experiencing 'little to no hunger' by 4.5 percent (only primary data). For the HFIAS estimate, a 1 percent increase in commercialisation increases the probability of achieving food security by 3.3 percent (estimated only for the primary data). For the child anthropometric measures (only for the GLSS7), it is revealed that a 1 percent increase in commercialisation reduces the probability of children stunting, wasting and being underweight by 0.9 percent, 4.0 percent and 2.1 percent, respectively.

Table 4.7: Impact of agricultural commercialisation on food and nutrition security outcomes (GLSS7)

Variable	(1) PCFEXP	(2) PAEFEXP	(3) HDDS	(4) FCS	(5) Vit. A	(6) Protein	(7) H. iron
HCLCI	8.519***	7.563***	0.038***	0.091***	0.063***	0.034***	0.018***
	(2.712)	(1.734)	(0.002)	(0.004)	(0.006)	(0.004)	(0.002)
Sex of head	441.128***	65.173	-0.249***	-0.380***	-0.902***	-0.261**	0.030
	(65.631)	(53.137)	(0.058)	(0.110)	(0.147)	(0.103)	(0.043)
Age of head	2.651**	4.244***	-0.001	-0.002	0.005*	-0.002	-0.001
	(1.282)	(1.072)	(0.001)	(0.003)	(0.003)	(0.003)	(0.001)
Household size	-206.249***	-166.140***	0.083***	0.183***	0.169***	0.177***	0.060***
	(8.501)	(6.765)	(0.007)	(0.014)	(0.018)	(0.017)	(0.007)
Locality of household	-314.956***	-326.926***	-0.164***	-0.213*	-1.250***	-0.166	-0.098**
	(60.424)	(48.190)	(0.056)	(0.109)	(0.145)	(0.106)	(0.047)
Marital status of head	-502.581***	-210.316***	0.281***	0.526***	1.060***	0.586***	0.243***
	(66.808)	(50.150)	(0.059)	(0.109)	(0.142)	(0.102)	(0.043)
Years of education of head	12.625***	12.461***	0.006	-0.014	0.009	-0.018**	-0.003
	(4.510)	(3.723)	(0.004)	(0.009)	(0.012)	(0.009)	(0.004)
Received cash remittance	357.522***	274.304***	0.240***	0.401***	0.381***	0.612***	0.221***
	(46.296)	(37.576)	(0.042)	(0.086)	(0.113)	(0.090)	(0.039)
No. of days stop work due to health	-4.414	-4.604	0.010	0.022	-0.012	0.036**	0.012
	(7.366)	(6.367)	(0.008)	(0.016)	(0.020)	(0.017)	(0.007)
Ownership of nonfarm enterprise	105.299*	96.424**	0.057	0.071	0.032	0.223**	0.097**
	(56.527)	(46.753)	(0.052)	(0.104)	(0.137)	(0.112)	(0.048)
Agric cooperative in community	-229.654**	-198.715**	-0.080	-0.143	-1.234***	-0.070	0.006
	(97.791)	(77.402)	(0.082)	(0.170)	(0.225)	(0.175)	(0.076)
Bank in community	-26.614	-69.992	-0.464***	-0.440**	-0.357	0.041	-0.136*
	(109.651)	(78.897)	(0.091)	(0.190)	(0.258)	(0.185)	(0.079)
Mobile phone network in community	101.633*	52.659	-0.187***	-0.587***	-0.663***	-0.498***	-0.305***
	(53.523)	(42.289)	(0.050)	(0.104)	(0.139)	(0.119)	(0.050)
Extension office in community	190.683**	131.248**	-0.128*	-0.308**	0.102	-0.436***	-0.063
	(83.061)	(64.585)	(0.071)	(0.143)	(0.211)	(0.151)	(0.065)
Irrigated fields in community	-37.767	-55.036	-0.302***	-0.089	0.032	-0.244*	-0.198***
	(72.253)	(57.857)	(0.066)	(0.135)	(0.173)	(0.125)	(0.055)
Perceived rain pattern	50.068	16.911	0.109***	0.314***	0.322***	0.347***	0.037
	(38.454)	(31.731)	(0.038)	(0.075)	(0.098)	(0.078)	(0.033)
Log of expenditure on agrochemicals	32.795***	24.308***	0.031***	0.126***	0.125***	0.073***	0.032***
	(9.350)	(7.758)	(0.008)	(0.016)	(0.021)	(0.015)	(0.007)
Log of expenditure on hired labour	44.825***	35.856***	0.036***	0.059***	0.130***	0.076***	0.033***

	(9.699)	(7.918)	(0.008)	(0.017)	(0.023)	(0.018)	(0.008)
No. of crops produced	-5.495	-17.245	0.072***	0.137***	0.322***	0.328***	-0.018
	(15.622)	(11.957)	(0.013)	(0.027)	(0.037)	(0.029)	(0.013)
Log of total value of hh assets	8.963	10.696*	0.074***	0.126***	0.163***	0.168***	0.070***
	(6.825)	(5.652)	(0.007)	(0.014)	(0.019)	(0.016)	(0.007)
Log of agric land endowment	200.960***	166.861***	0.084***	0.237***	0.149***	0.349***	0.156***
	(24.805)	(19.874)	(0.020)	(0.040)	(0.054)	(0.050)	(0.022)
Navigable road to community	596.209***	252.313***	0.071	0.139	0.273	0.927***	0.231***
	(71.617)	(53.446)	(0.070)	(0.137)	(0.173)	(0.149)	(0.064)
Access to public transport	206.268***	71.509	-0.061	-0.140	0.239	-0.673***	-0.104*
	(62.392)	(48.409)	(0.060)	(0.120)	(0.150)	(0.131)	(0.055)
Household in southern Ghana	-36.633	-0.791	0.324***	0.240	1.473***	-0.496***	0.048
	(90.849)	(73.528)	(0.071)	(0.156)	(0.209)	(0.155)	(0.067)
Household in coastal zone	-384.651	-331.358	0.108	0.487	-1.497*	-0.334	-0.189
	(308.517)	(254.055)	(0.297)	(0.463)	(0.778)	(0.470)	(0.212)
Household in forest zone	-291.121	-255.370	0.065	0.624	-0.471	-0.094	0.081
	(302.441)	(249.834)	(0.295)	(0.456)	(0.770)	(0.463)	(0.209)
Household in savannah zone	-981.333***	-828.687***	-0.207	0.009	-1.564**	-1.062**	-0.465**
	(313.119)	(258.439)	(0.303)	(0.480)	(0.797)	(0.481)	(0.218)
Constant	2397.139***	2343.380***	4.344***	5.674***	4.237***	2.087***	0.960***
	(325.944)	(270.617)	(0.315)	(0.508)	(0.825)	(0.510)	(0.228)
Observations	7332	7332	7332	7332	7332	7332	7332
F-statistic	85.825***	76.964***	106.031***	145.322***	81.914***	58.669***	59.152***
R-squared	0.340	0.300	0.318	0.446	0.314	0.250	0.250
KP Weakid test	1161.909***	1142.592***	1805.243***	1805.24***	911.934***	911.934***	911.934***
C-D Weakid test	1335.569***	1427.695***	2121.263***	2121.26***	1072.21***	1072.205***	1072.205***
KP Underid test	785.614***	1050.153***	1059.26***	1059.26***	1075.36***	1075.360***	1075.360***
Hansen J (Overid test)	0.000	1.057	0.000	0.000	0.015	1.021	0.046

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; Standard errors in parentheses; HCLCI is the household crop-livestock commercialisation index; PCFEXP, PAEFEXP. HDDS, FCS, Vit. A, Protein, H. iron are estimated using ivreg2; Stunting, Wasting and Underweight are estimated using ivprobit; FIES is estimated using eoprobit (see Table A9 for its first-stage estimates); 0.000 Hansen J for HDDS, FCS and Vit. A implies no Hansen test since only one instrument is used in the estimation (see Table 4.6); Source: Produced by the author using the GLSS7 Data.

Table 4.7 continued

Variable	(8) Stunting	(9) Wasting	(10) Underweight	(11) FIES
HCLCI	-0.009**	-0.040***	-0.021***	0.004***
	(0.004)	(0.005)	(0.004)	(0.001)
Sex of head	-0.109	-0.025	0.177	0.098**
	(0.128)	(0.149)	(0.145)	(0.042)
Age of head	0.000	0.003	-0.004	0.004***
	(0.003)	(0.003)	(0.003)	(0.001)
Household size	0.024**	-0.039***	0.001	-0.036***
	(0.012)	(0.014)	(0.013)	(0.005)
Locality of household	-0.388***	-0.176	-0.363***	-0.167***
	(0.109)	(0.125)	(0.120)	(0.041)
Marital status of head	-0.001	-0.010	-0.266*	0.106***
	(0.145)	(0.167)	(0.160)	(0.040)
Years of education of head	0.001	0.012	-0.003	0.044***
	(0.008)	(0.009)	(0.009)	(0.003)
Received cash remittance	-0.094	0.071	-0.116	0.136***
	(0.071)	(0.083)	(0.079)	(0.031)
No. of days stop work due to health	0.023	-0.036*	0.005	-0.020***
	(0.015)	(0.019)	(0.017)	(0.006)
Ownership of nonfarm enterprise	0.070	0.012	0.159	0.309***
	(0.089)	(0.103)	(0.098)	(0.040)
Agric cooperative in community	-0.124	-0.098	-0.140	-0.197***
	(0.143)	(0.191)	(0.173)	(0.056)
Bank in community	-0.549***	0.292	-0.042	-0.023
	(0.167)	(0.210)	(0.193)	(0.060)
Mobile phone network in community	-0.445***	-0.436***	-0.568***	-0.218***
	(0.075)	(0.089)	(0.083)	(0.036)
Extension office in community	-0.031	0.076	0.050	0.127***
	(0.122)	(0.161)	(0.146)	(0.048)
Irrigated fields in community	-0.256**	0.033	-0.090	0.202***
	(0.122)	(0.136)	(0.134)	(0.048)
Perceived rain pattern	0.123*	-0.014	0.098	0.021
	(0.066)	(0.076)	(0.073)	(0.028)
Log of expenditure on agrochemicals	-0.029*	-0.005	-0.036**	0.010
	(0.015)	(0.017)	(0.016)	(0.006)
Log of expenditure on hired labour	-0.017	0.016	0.010	0.028***

	(0.014)	(0.017)	(0.016)	(0.006)
No. of crops produced	-0.021	-0.004	-0.021	0.014
	(0.022)	(0.026)	(0.024)	(0.010)
Log of total value of hh assets	-0.017	0.006	-0.014	0.054***
	(0.011)	(0.013)	(0.013)	(0.005)
Log of agric land endowment	0.010	-0.133***	-0.041	0.002
	(0.035)	(0.042)	(0.039)	(0.015)
Navigable road to community	-1.052***	-1.121***	-1.221***	-0.017
	(0.101)	(0.110)	(0.105)	(0.050)
Access to public transport	-0.392***	-0.150	-0.276***	0.142***
	(0.088)	(0.105)	(0.099)	(0.044)
Household in southern Ghana	0.237*	-0.117	-0.006	-0.005
	(0.130)	(0.161)	(0.147)	(0.053)
Household in coastal zone	0.243	0.042	-0.091	-0.203
	(0.752)	(0.903)	(0.784)	(0.206)
Household in forest zone	0.004	-0.294	-0.191	-0.085
	(0.747)	(0.898)	(0.777)	(0.204)
Household in savannah zone	0.295	-0.272	-0.189	-0.515**
	(0.756)	(0.910)	(0.789)	(0.211)
Constant	1.276*	1.765*	2.002**	
	(0.771)	(0.925)	(0.807)	
Observations	2452	2452	2452	7332
Wald Chi-square	755.366***	877.493***	913.549***	1455.347***
Wald test of exogeneity	14.545***	8.224***	10.017***	

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; Standard errors in parentheses; HCLCI is the household crop-livestock commercialisation index; PCFEXP, PAEFEXP. HDDS, FCS, Vit. A, Protein, H. iron are estimated using ivreg2; Stunting, Wasting and Underweight are estimated using ivprobit; FIES is estimated using eoprobit (see Table A9 for its first-stage estimates); 0.000 for HDDS, FCS and Vit. A implies no Hansen test since only one instrument is used in the estimation (see Table 4.6); Source: Produced by the author using the GLSS7 Data.

Table 4.8: Impact of agricultural commercialisation on food and nutrition security outcomes (primary data)

Variable	(1) PCFEXP	(2) FEXP	(3) HDDS	(4) FCS	(5) Vit. A	(6) Protein	(7) H. iron
HCLCI	38.285***	166.567***	0.086***	0.311***	0.091**	0.124***	0.082***
	(7.335)	(33.202)	(0.016)	(0.094)	(0.036)	(0.036)	(0.025)
Sex of head	76.791	-558.673	-0.838***	-3.510	-1.500**	-3.282***	-1.572***
	(131.962)	(375.064)	(0.323)	(2.150)	(0.695)	(0.816)	(0.532)
Age of head	-4.465	0.051	-0.012	-0.010	-0.022	-0.018	-0.017
	(3.533)	(15.056)	(0.009)	(0.058)	(0.018)	(0.021)	(0.014)
Household size	-225.951***	-59.513	0.053	0.292	0.225**	0.010	-0.088
	(20.309)	(92.682)	(0.045)	(0.306)	(0.099)	(0.107)	(0.081)
Marital status of head	-393.066*	336.268	0.254	1.729	0.391	1.268	0.714
	(228.440)	(577.221)	(0.354)	(2.411)	(0.750)	(1.011)	(0.693)
Years of education of head	10.734	10.193	0.001	0.143	0.058	0.086*	0.057*
	(7.759)	(34.753)	(0.018)	(0.112)	(0.037)	(0.045)	(0.032)
Received cash remittance	-44.065	155.378	-0.471	-0.119	-0.416	-1.153	-0.329
	(135.162)	(674.769)	(0.330)	(2.432)	(0.715)	(0.819)	(0.578)
No. of days stop work due to health	-1.070*	-1.757	-0.000	-0.023*	-0.012***	-0.021***	-0.014***
	(0.563)	(2.894)	(0.003)	(0.012)	(0.004)	(0.005)	(0.003)
Ownership of nonfarm enterprise	61.983	131.325	0.574**	3.915**	2.533***	2.428***	1.477***
	(88.923)	(393.396)	(0.286)	(1.774)	(0.592)	(0.708)	(0.470)
Agric cooperative in community	-63.718	272.669	0.492	0.488	-0.396	-0.036	0.386
	(163.113)	(657.215)	(0.402)	(2.759)	(0.862)	(1.077)	(0.741)
Bank in community	239.335	1151.770	-1.816***	-3.876	-0.402	0.261	-0.066
	(283.233)	(1167.010)	(0.526)	(3.032)	(1.111)	(1.249)	(0.868)
Mobile phone network in community	15.713	1199.568	0.651	0.022	0.765	-0.453	0.400
	(269.353)	(1146.804)	(0.620)	(3.281)	(1.206)	(1.439)	(1.008)
Extension office in community	12.276	-17.431	-0.582**	1.971	-1.608***	-1.000	0.088
	(96.543)	(384.944)	(0.296)	(2.041)	(0.585)	(0.749)	(0.520)
Irrigated fields in community	200.764*	707.461*	0.396	1.585	0.322	0.294	0.061
	(110.934)	(424.206)	(0.250)	(1.471)	(0.492)	(0.615)	(0.429)
Perceived rain pattern	82.703	2.873	-0.041	-0.333	0.543	0.990	1.024*
	(134.407)	(594.729)	(0.341)	(2.098)	(0.688)	(0.815)	(0.574)
Log of expenditure on agrochemicals	17.071	-21.623	0.148***	-0.104	0.159*	0.256**	0.170**
	(15.822)	(69.747)	(0.046)	(0.284)	(0.087)	(0.107)	(0.071)
Log of expenditure on hired labour	-10.605	70.721	0.135***	0.793***	0.436***	0.493***	0.266***
	(15.165)	(72.170)	(0.040)	(0.231)	(0.084)	(0.105)	(0.073)
No. of crops produced	-138.940**	-164.084	0.180	0.139	-0.961***	-0.801**	-0.369

	(58.288)	(294.534)	(0.147)	(0.946)	(0.302)	(0.359)	(0.245)
Log of total value of hh assets	85.567***	289.101*	0.315***	-0.889*	0.683***	1.009***	0.518***
	(25.705)	(154.690)	(0.067)	(0.507)	(0.154)	(0.172)	(0.123)
Log of agric land endowment	128.341	437.865	-0.079	2.020**	0.335	0.050	0.095
	(81.505)	(292.138)	(0.138)	(0.868)	(0.304)	(0.358)	(0.288)
Navigable road to community	-341.135**	-1138.446	1.363***	0.039	-2.084**	-3.264***	-2.131***
	(172.554)	(791.629)	(0.365)	(2.101)	(0.812)	(0.872)	(0.582)
Access to public transport	67.512	-498.409	0.457	-1.497	0.371	-0.610	-0.714
	(153.567)	(689.343)	(0.355)	(2.040)	(0.688)	(0.800)	(0.553)
Household in NR	-1402.225***	-9151.246***	-0.230	-2.486	-1.009	-3.608***	-4.143***
	(280.940)	(1249.729)	(0.450)	(3.032)	(1.103)	(1.164)	(0.770)
Household in UER	-1402.141***	-9336.883***	-2.242***	-13.932***	-4.366***	-8.706***	-6.290***
	(285.514)	(1304.885)	(0.462)	(3.048)	(1.081)	(1.157)	(0.816)
Household in UWR	-1150.880***	-6539.944***	-0.342	-9.677**	-4.313***	-9.000***	-6.727***
	(336.068)	(1470.995)	(0.620)	(3.916)	(1.375)	(1.522)	(1.060)
Household in SR	-1374.574***	-8516.219***	0.467	7.275**	1.281	-0.742	-2.690***
	(298.176)	(1367.620)	(0.560)	(3.485)	(1.379)	(1.438)	(0.928)
Constant	2538.708***	6635.762**	-0.563	25.180***	1.670	8.092**	6.326***
	(641.433)	(2836.051)	(1.273)	(8.265)	(2.813)	(3.166)	(2.292)
Observations	858	858	858	858	858	858	858
F-statistic	24.012***	33.820***	41.431***	16.788***	13.046***	21.616***	18.788***
R-squared	0.543	0.565	0.465	0.374	0.267	0.309	0.303
Log likelihood	-7279.991	-8554.644	-2089.741	-3679.927	-2718.422	-2875.903	-2541.128
KP Weakid test	65.984***	65.984***	95.318***	126.731***	95.318***	126.731***	126.731***
C-D Weakid test	62.819***	62.819***	100.208***	144.201***	100.208***	144.201***	144.201***
KP Underid test	96.424***	96.424***	78.608***	91.102***	78.608***	91.102***	91.102***
Hansen J (Overid test)	1.941	1.104	0.000	0.000	0.000	0.000	0.000

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; Standard errors in parentheses; HCLCI is the household crop-livestock commercialisation index; PCFEXP, FEXP, HDDS, FCS, Vit. A, Proteins and H. iron are estimated using ivreg2; FIES, HHS and HFIAS are estimated using eoprobit (see Table A9 for their first-stage estimates); Source: Produced by the author using Primary Data 2022.

Table 4.8: continued

Variable	(8) FIES	(9) HHS	(10) HFIAS
HCLCI	0.037***	0.045***	0.033***
	(0.009)	(0.007)	(0.007)
Sex of head	-0.351**	0.162	0.033
	(0.167)	(0.167)	(0.150)
Age of head	0.000	0.006	-0.003
	(0.004)	(0.004)	(0.004)
Household size	-0.024	-0.063***	-0.055**
	(0.021)	(0.023)	(0.023)
Marital status of head	0.036	0.145	0.335*
	(0.182)	(0.199)	(0.183)
Years of education of head	0.002	-0.001	0.001
	(0.008)	(0.009)	(0.008)
Received cash remittance	0.096	0.001	0.147
	(0.153)	(0.172)	(0.159)
No. of days stop work due to health	-0.002	0.000	-0.003
	(0.002)	(0.001)	(0.002)
Ownership of nonfarm enterprise	-0.101	0.120	-0.326***
	(0.115)	(0.133)	(0.126)
Agric cooperative in community	0.268	0.462**	0.189
	(0.176)	(0.197)	(0.180)
Bank in community	0.176	-0.955***	-0.843***
	(0.282)	(0.267)	(0.225)
Mobile phone network in community	-0.028	0.041	0.161
	(0.309)	(0.290)	(0.290)
Extension office in community	0.109	0.227	0.303**
	(0.130)	(0.142)	(0.133)
Irrigated fields in community	0.039	0.386***	0.174*
	(0.109)	(0.117)	(0.104)
Perceived rain pattern	-0.090	-0.600***	-0.014
	(0.167)	(0.171)	(0.152)
Log of expenditure on agrochemicals	-0.035*	-0.021	-0.032
	(0.021)	(0.022)	(0.022)
Log of expenditure on hired labour	0.009	-0.013	-0.010
	(0.020)	(0.021)	(0.020)
No. of crops produced	0.030	0.112*	0.112*
	(0.063)	(0.066)	(0.065)
Log of total value of hh assets	0.095***	0.058*	0.108***
	(0.028)	(0.031)	(0.027)
Log of agric land endowment	0.021	-0.008	-0.120*
	(0.070)	(0.082)	(0.069)
Navigable road to community	0.750***	0.611***	0.573***
	(0.180)	(0.204)	(0.182)
Access to public transport	-0.175	-0.106	0.029
	(0.172)	(0.163)	(0.164)
Household in NR	-0.059	0.254	-0.218
	(0.238)	(0.237)	(0.229)
Household in UER	-0.109	0.153	0.018
	(0.245)	(0.242)	(0.253)
Household in UWR	0.168	0.635**	0.534*
	(0.314)	(0.312)	(0.304)
Household in SR	0.208	0.510*	-0.070
	(0.299)	(0.296)	(0.294)
Cut1	1.065	1.944***	1.838***
	(0.661)	(0.634)	(0.638)
Cut2	2.392***	2.564***	2.240***
	(0.681)	(0.623)	(0.634)
Cut3			2.558***

			(0.633)
Corr(hclci&fies)	0.141	-0.217	-0.131
	(0.130)	(0.136)	(0.132)
Observations	858	858	858
Wald Chi-square	405.054***	583.594***	447.409***
Log likelihood	-4212.516	-4153.193	-4365.064

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; Standard errors in parentheses; HCLCI is the household crop-livestock commercialisation index; PCFEXP, FEXP, HDDS, FCS, Vit. A, Proteins and H. iron are estimated using ivreg2; FIES, HHS and HFIAS are estimated using eoprobit (see Table A9 for their first-stage estimates); Source: Produced by the author using Primary Data 2022.

Taking all these findings together, the results suggest that the extended metric of agricultural commercialisation improves the food and nutrition security of farm households in Ghana. This evidence corroborates the extant literature. For example, the positive impact of commercialisation on dietary diversity observed in this study confirms several studies (e.g., Chegere & Kauky, 2022 in Tanzania; Koppmair et al., 2017 in Malawi; Nkegbe & Abdul Mumin, 2022 in Ghana; Ochieng et al., 2015, 2019 in Central Africa; Seng, 2016 in Cambodia; Sibhatu et al., 2022 in Zambia; Usman & Haile, 2022 in Ethiopia and Tanzania). Further, this study corroborates the evidence that suggests that commercialisation is a positive correlate of weighted diet diversity (i.e., food consumption score) (see e.g., Abdul Mumin & Abdulai, 2022; Chegere & Kauky, 2022; Nkegbe & Abdul Mumin, 2022; Sibhatu et al., 2022; Usman & Haile, 2022).

This study further corroborates the findings of Kilimani et al. (2022), Nkegbe and Abdul Mumin (2022), and Abdul Mumin and Abdulai (2022) who reported a significantly positive impact of commercialisation on the intake of protein, iron, and vitamin A. The finding of Sibhatu et al. (2022), Usman and Haile (2022), and Kuma et al. (2019) that report that households with higher levels of commercialisation have better food security outcomes is corroborated by the positive estimates of the impact of commercialisation on the self-reported food security indicators of FIES, HHS and HFIAS. For child anthropometric measures of stunting, wasting and underweight, this study corroborates the evidence of Haji (2022), who

reported that more commercialised households have children with less probability of stunting, wasting and underweight. However, several studies (e.g., Carletto et al., 2017; Chegere & Kauky, 2022) have not found a significant effect of commercialisation on stunting and wasting, while Anderman et al. (2014) observed a negative effect.

The main channel or transmission mechanism for explaining the role of commercialisation in boosting food and nutrition security is income (i.e., crop sale income). Several studies (e.g., Aku et al., 2018; Carletto et al., 2017; Haji, 2022; Kilimani et al., 2022; Mmbando et al., 2015; Montalbano et al., 2018; Muriithi & Matz, 2015; Ochieng et al., 2019; Ogutu et al., 2020) have reported farm income is the prominent channel through which commercialisation stimulates food and nutrition security. Income gains from commercialisation improve food and nutrition security through the capacity it provides households to purchase food and other essential calories and micro-nutrients (Abdulai & Aubert, 2004; Carletto et al., 2017; Ecker, 2018; Kuijpers, 2018; Kuma et al., 2019; Ogutu et al., 2020; von Braun, 1995). Beyond the raising of income, commercialisation is found to be a complement rather than a competitor for the consumption of own-produced food (Ogutu et al., 2020) through its productivity-boosting potentials, especially the opportunity of specialisation which provides the liquidity to procure productivity-enhancing inputs (Barrett, 2008; Minten et al., 2009; Muriithi & Matz, 2015; von Braun & Kennedy, 1994). Rios et al. (2009) corroborate this by estimating a positive correlation between commercialisation and productivity in Vietnam and Guatemala.

4.5.3 Robustness of impacts

To complement these results, several robustness tests are conducted. The first robustness is the use of alternative econometric specifications to verify the sensitivity of these baseline results. Table 4.9 reports summarised results of alternative econometric specifications (full

results are presented in Tables A10-A11 in Appendix 2; the alternative econometric models used are presented in the notes of Table 4.9).

Table 4.9: Impacts from alternative econometric specifications

Outcome	Estimate	Std. error
GLSS7:		
Annual food expenditure (p.c.)	8.519***	2.713
Annual food expenditure (adult equivalent)	7.751***	1.745
HDDS	0.038***	0.002
FCS	0.091***	0.004
Vitamin A	0.063***	0.006
Protein	0.033***	0.004
Hem iron	0.018***	0.002
Stunting	-0.008***	0.004
Wasting	-0.039***	0.004
Underweight	-0.021***	0.004
FIES	0.004***	0.001
Primary:		
Annual food expenditure (p.c.)	39.998***	7.600
Annual food expenditure (total)	197.060***	37.435
HDDS	0.086***	0.016
FCS	0.311***	0.094
Vitamin A	0.091**	0.036
Protein	0.124***	0.036
Hem iron	0.082***	0.025
FIES	0.037***	0.008
HHS	0.046***	0.009
HFIAS	0.034***	0.008

Note(s): * $p<0.1$; ** $p<0.05$; *** $p<0.01$; HDDS is household dietary diversity; FIES is food insecurity experience scale; FCS is food consumption score; HHS is household hunger score; HFIAS is household food insecurity access scale; extended regression is used to estimate for food expenditures, HDDS, FCS, vitamin A, protein, and hem iron; extended probit is used for stunting, wasting and underweight; control function ordered probit is used for FIES, HHS and HFIAS.

The evidence suggests that the impact of agricultural commercialisation on food and nutrition security from the baseline estimates (i.e., Tables 4.7 and 4.8) is robust to alternative econometric specifications. The positive estimate of the impact of agricultural commercialisation on food consumption expenditures, household dietary diversity, food consumption score, vitamin A, protein, hem iron, food insecurity experience scale, household hunger score, household food insecurity access scale; and the negative impact on stunting, wasting and underweight – implying that agricultural commercialisation boosts food and

nutrition security – are the same as the baseline estimates. The two are also generally similar in terms of magnitudes.

The second robustness classified the continuous commercialisation indices into four quadrants. Households with commercialisation indices falling from 0 to 24.99 represents quadrant 1 (cat 0); households with commercialisation indices falling from 25 to 49.99 represents quadrant 2 (cat 1); households with commercialisation indices falling from 50 to 74.99 represents quadrant 3 (cat 2); and households with commercialisation indices falling from 75 to 100 represents quadrant 4 (cat 3). This strategy is like the baseline estimation except that the classified variable is ordered, and thus, ordered models are applied to derive the impacts. Table 4.10 reports summarised results of the ordered commercialisation effect (full results are presented in Tables A12-A13 in Appendix 2). The evidence shows that the impact of commercialisation on food and nutrition security outcomes is generally robust to alternative measurements of commercialisation.

In addition to pointing to the robustness, the ordered commercialisation provides further insights of the impact. The first insight is that households with commercialisation ratios within the second, cat 1 (commercialisation ratio in the range 25%-<50%), third, cat 2 (commercialisation ratio in the range 50%-<75%), and fourth, cat 3 (commercialisation ratio in the range ≥75%) quadrants have consistently higher impacts relative to households in the first quadrant (commercialisation ratio in the range <25%). For example, the estimates on diet diversity from the GLSS7 indicate that households commercializing within the second, third and fourth quadrants of their crop and livestock produce consume 1.075, 2.150 and 3.224 more food groups, respectively, relative to those commercializing within the first quadrant.

Table 4.10: Impact of ordered commercialisation on food and nutrition security outcomes

	GLSS7			Primary		
Outcome	(cat 1 vs cat 0)	(cat 2 vs cat 0)	(cat 3 vs cat 0)	(cat 1 vs cat 0)	(cat 2 vs cat 0)	(cat 3 vs cat 0)
PCFDEXP	336.852***	673.704***	1010.556***	1132.930***	2265.861***	3398.791***
	(39.100)	(78.200)	(117.301)	(92.275)	(184.549)	(276.824)
PAFEXP/FDEXP	262.669***	525.339***	788.008***	5079.102***	10158.20***	15237.31***
	(32.495)	(64.990)	(97.484)	(427.237)	(854.473)	(1281.710)
HDDS	1.075***	2.150***	3.224***	1.297***	2.595***	3.892***
	(0.045)	(0.089)	(0.134)	(0.283)	(0.565)	(0.848)
FCS	3.079***	6.158***	9.237***	10.127***	20.255***	30.382***
	(0.080)	(0.159)	(0.239)	(1.301)	(2.601)	(3.902)
Vitamin A	2.572***	5.143***	7.715***	3.258***	6.516***	9.774***
	(0.108)	(0.216)	(0.324)	(0.774)	(1.547)	(2.321)
Proteins	1.433***	2.865***	4.298***	4.249***	8.499***	12.748***
	(0.083)	(0.167)	(0.250)	(0.835)	(1.669)	(2.504)
Hem iron	0.666***	1.331***	1.997***	2.875***	5.750***	8.625***
	(0.037)	(0.074)	(0.111)	(0.506)	(1.012)	(1.518)
Stunting	-0.080***	-0.153***	-0.218***			
	(0.021)	(0.038)	(0.050)			
Wasting	-0.117***	-0.208***	-0.276***			
	(0.025)	(0.040)	(0.043)			
Underweight	-0.055***	-0.104***	-0.148***			
	(0.019)	(0.035)	(0.047)			
FIES (Pr0)	-0.037***	-0.072***	-0.105***	-0.241***	-0.404***	-0.479***
	(0.014)	(0.022)	(0.031)	(0.080)	(0.110)	(0.093)
FIES (Pr1)	-0.000	-0.003*	-0.007*	0.040	-0.050*	-0.189***
	(0.000)	(0.001)	(0.004)	(0.031)	(0.027)	(0.071)
FIES (Pr2)	0.037***	0.074***	0.113***	0.201***	0.454***	0.667***
	(0.011)	(0.023)	(0.036)	(0.051)	(0.132)	(0.161)
HHS (Pr0)				-0216***	-0.377***	-0.468***
				(0.049)	(0.075)	(0.072)
HHS (Pr1)				-0.004	-0.051***	-0.108***
				(0.006)	(0.012)	(0.023)
HHS (Pr2)				0.220***	0.428***	0.575***
				(0.044)	(0.084)	(0.091)
HFIAS (Pr0)				-0.125**	-0.236**	-0.327***
				(0.052)	(0.093)	(0.114)
HFIAS (Pr1)				-0.002	-0.015**	-0.035*
				(0.003)	(0.007)	(0.019)
HFIAS (Pr2)				0.006	0.003	-0.009
				(0.005)	(0.003)	(0.009)
HFIAS (Pr3)				0.121***	0.249**	0.371***
				(0.046)	(0.098)	(0.141)
Observations	7332	7332	7332	858	858	858

Note(s): * $p<0.1$; ** $p<0.05$; *** $p<0.01$; Standard errors in parentheses; HDDS is household dietary diversity; FIES is food insecurity experience scale; FCS is food consumption score; HHS is household hunger score; HFIAS is household food insecurity access scale; 1 vs 0 is the impact estimates for the 1 category of commercialisation (i.e., 25%-<50%) relative to the 0 category (i.e., base category of <25%); 2 vs 0 is the impact estimates for the 2 category of commercialisation (i.e., 50%-<75%) relative to the base category; 3 vs 0 is the impact estimates for the 3 category of commercialisation (i.e., ≥75%) relative to the base category; Pr0, Pr1, Pr2, Pr3 and Pr4 are the impact estimates for the first, second, third and fourth categories of the respective categorical variables (i.e., FIES, HHS and HFIAS).

The second insight is that the impact of commercialisation on food and nutrition security outcomes is progressively higher with increasing commercialisation ratios. Drawing on the

diet diversity again, it is revealed that the impacts for commercialisation in the fourth quadrant (3.224) is greater than the impacts for the third quadrant (2.150) and second quadrant (1.075). The third robustness involved estimating the impact models on a restricted sample that ignores households that have commercialisation indices less than 25 percent.[14] Table 4.11 reports summarised results of the impact on the restricted sample (full results are presented in Tables A14-A15 in Appendix 2).

Table 4.11: Impact of restricted commercialisation sample on food and nutrition security

Outcome	Estimate	Std. error
GLSS7:		
Annual food expenditure (p.c.)	6.804*	3.856
Annual food expenditure (adult equivalent)	6.149**	3.131
HDDS	0.050***	0.005
FCS	0.126***	0.011
Vitamin A	0.079***	0.015
Protein	0.038***	0.011
Hem iron	0.026***	0.005
Stunting	-0.019**	0.010
Wasting	-0.046***	0.013
Underweight	-0.006	0.011
FIES	0.004*	0.002
Observations	3005	
Primary:		
Annual food expenditure (p.c.)	53.524***	20.718
Annual food expenditure (total)	292.957***	103.216
HDDS	0.097**	0.041
FCS	-0.438	0.372
Vitamin A	0.306***	0.098
Protein	0.320***	0.124
Hem iron	0.220**	0.088
FIES	0.028	0.025
HHS	0.050***	0.019
HFIAS	0.030	0.020
Observations	448	

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; HDDS is household dietary diversity; FIES is food insecurity experience scale; FCS is food consumption score; HHS is household hunger score; HFIAS is household food insecurity access scale; extended regression is used to estimate for food expenditures, HDDS, FCS; extended probit is used for stunting and wasting; extended ordered probit is used for FIES, HHS and HFIAS; underweight model does not achieve convergence.

[14] The basis for this is already presented in section 4.4.

After dropping the sample of households commercializing less than 25 percent of their crop and livestock produce, the evidence shows that the impact of agricultural commercialisation is still robust to the impact shown by the baseline estimates, except that the estimates are generally lower and not consistently significant across all the outcomes (i.e., impacts are not statistically significant for underweight in the GLSS7 and food consumption score, food insecurity experience scale and household food insecurity access scale in the primary data). These observations suggest that even among farm households that are regarded as commercialised, the level of commercialisation matters for food and nutrition security. Specifically, commercial farmers with relatively higher commercialisation ratios have relatively better food and nutrition outcomes than commercial farmers with lower commercialisation ratios.

4.5.4 Comparing impacts: extended metric (HCLCI) versus crop (HCCI) and livestock (HLCI) metrics

The impact of the three metrics of agricultural commercialisation (i.e., HCLCI, HCCI and HLCI) on food and nutrition security indicators are compared. The respective estimates are compiled and reported in Table 4.12 (see Tables 4.7 and 4.8 for full estimates of the HCLCI and Tables A16-A19 in Appendix 2 for full estimates of HCCI and HLCI). Several findings are deduced from the comparative analysis of the impacts of the three metrics. It is revealed that while the estimated impacts are consistently significant for the extended metric (HCLCI) for the GLSS7 data; they are not consistently significant for the HCCI and HLCI metrics. The impacts are not statistically significant for stunting in HCCI and all the anthropometric outcomes (i.e., stunting, wasting and underweight) in HLCI. However, in the primary data, the impacts are consistently significant for the HCLCI and HCCI but not for the HLCI.

Importantly, the results show that consistently the estimated impacts for the HLCI metric are larger than the impacts for the HCLCI and HCCI, though the estimates for anthropometric outcomes are not statistically significant. Further, the estimated impacts for the HCLCI are also larger relative to the HCCI. These findings point to a key implication; that comparatively, livestock commercialisation exerts more impacts on food and nutrition security than crop commercialisation.

Table 4.12: Comparative impacts of three metrics of agricultural commercialisation

	Estimate		
Outcome	HCLCI	HCCI	HLCI
GLSS7:			
Annual food expenditure (p.c.)	8.519***	6.619***	139.687**
Annual food expenditure (adult equivalent)	7.563***	4.761***	101.196**
HDDS	0.038***	0.028***	0.476**
FCS	0.091***	0.068***	1.552**
Vitamin A	0.063***	0.038***	1.240**
Protein	0.034***	0.024***	0.768**
Hem iron	0.018***	0.012***	0.330**
Stunting	-0.009**	-0.003	-0.699
Wasting	-0.040***	-0.028***	-0.419
Underweight	-0.021***	-0.014***	-0.522
FIES	0.004***	0.003***	0.034***
Observations	7332	6637	7260
Primary:			
Annual food expenditure (p.c.)	38.285***	33.084***	223.851*
Annual food expenditure (total)	166.567***	155.789***	1196.649*
HDDS	0.086***	0.069***	0.582
FCS	0.311***	0.294***	2.734
Vitamin A	0.091**	0.073**	0.541
Protein	0.124***	0.117***	0.943
Hem iron	0.082***	0.077***	0.618
FIES	0.037***	0.027***	0.064***
HHS	0.045***	0.034***	0.064***
HFIAS	0.033***	0.025***	0.061***
Observations	858	858	714

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; HCLCI is household crop-livestock commercialisation index; HCCI is household crop commercialisation index; HLCI is household livestock commercialisation index; HDDS is household dietary diversity; FIES is food insecurity experience scale; FCS is food consumption score; HHS is household hunger score; HFIAS is household food insecurity access scale.

By extension, this implication is what accounts for the consistently larger impacts of the extended metric of commercialisation relative to the crop commercialisation metric. The importance of the livestock subsector to agricultural commercialisation cannot be discounted. Given that the impacts of the extended metric of commercialisation on food and nutrition security relative to the crop commercialisation are larger in magnitude due to the influence of the livestock commercialisation, the hypothesis that the extended metric of agricultural commercialization reflects the impact of agricultural commercialization on food and nutrition security better is satisfied.

4.5.5 Income pathway and substitution of own and purchased food

The last section of the impact results is to test whether agricultural commercialisation affects household income. As mentioned in the methodology, this is not an estimate of causality but association between agricultural commercialisation and household income. The results presented in Table A20 in Appendix 2 indicate that agricultural commercialisation positively affects household income. A 1 percent increase in joint crop and livestock commercialisation increases household income by 2.2 percent and 1.5 percent, respectively, for the GLSS7 and primary data. This confirms the income pathway posited in the conceptual framework in Figure 3.2, indicating that agricultural commercialisation boosts farm incomes. After establishing the association between commercialisation and income, Tables A21 and A22 assessed whether income affects the food and nutrition security. The results suggest that household income is consistently positively associated with all food and nutrition security outcomes across the two datasets, except for stunting, wasting and underweight, with a negative association in the GLSS7 data. This implies that household income boosts household food and nutrition security. This is consistent with the evidence of Ogutu et al.

(2020) who reported a positive association between income and food and nutrition security outcomes in Kenya.

Finally, this study examines the impact of commercialisation on the substitution of own-produced food for purchased food, as this further helps to understand the transmission of commercialisation to food and nutrition security. This assessment is done for only the GLSS7 data and for only outcomes such as HDDS, FCS, vitamin A, protein, and hem iron consumption because these are the outcomes for which data are available to partition the outcomes into own produced and purchased. The results are presented in Table A23 in Appendix 2 and suggest that commercialisation has no statistically significant impact on own-produced food and nutrition security outcomes. However, the impact is consistently and significantly positive for purchased food and nutrition security outcomes. This may appear contradictory because increased commercialisation may reduce food available for consumption such that a statistically significant negative impact of commercialisation on own-produced food is expected. But the results show that commercialisation does not statistically hold such a tendency. Following the explanation of Ogutu et al. (2020), this observation may be due to changes in production diversity and farm productivity. The positive effect on purchased food only confirms the role of income from sales in stimulating the procurement of diverse diets.

4.6 Quadruple-hurdle model of agricultural commercialisation

The quadruple-hurdle model estimates of agricultural commercialisation was done using the GLSS7.[15] The results are reported in Table 4.13. Marginal effects are reported for columns

[15] There is no convergence for the only model for maize in the primary data and other crops in the GLSS7. Upon oversampling, the analysis could not be performed for the primary data.

1a, 1b, 2a, 2b, and 3a since they are probit models. Column 1a presents the estimates for the determinants of the probability of producing maize (hurdle 1). Column 2a presents the estimates for the probability of of selling maize (hurdle 2). Column 3a presents the estimates for the determinants of the probability of selling maize in a market centre (hurdle 3). Column 4a presents the estimates for the determinants of the proportion of maize sold in a market centre (conditioned on selling at the market centre in hurdle 3) and the determinants of the proportion of maize sold in at farmgate (conditioned on selling at the farmgate in hurdle 3) (hurdle 4). The significance of the Wald chi-square indicates the model's fitness to the data. The results reveal varying characteristics that influence the four hurdles of agricultural commercialisation. Presence of bank and market in community are the only variables that simultaneously determine all the four hurdles. They have positive coefficients.

The presence of bank in community (a relevant proxy for financial inclusion) increases the probability of farmers to produce maize, decide to sell maize and choose a market centre as their preferred market to sell maize, and sell higher proportion of maize relative to farmers who do not have banks in their communities. Farm households who reside in communities with a bank are 32.9 percent more likely to produce maize. Conditioned on producing maize, the probability of selling maize increases by 27.6 percent for farm households residing in communities with a bank. Conditioned on selling maize, presence of a bank increases the probability of selling maize at a market centre by 12.9 percent. Conditioned on selling maize in a market centre, the proportion of maize sold is 88.1 percent more for farm households residing in communities with banks. However, conditioned on selling maize at farmgate, the proportion of maize sold is 47.4 percent more for farm households residing in communities with banks. These observations are expected as the presence of banks increases the likelihood of securing credit to invest in the farm business.

Table 4.13: Determinants of quadruple-hurdle of maize commercialisation

	Quadruple-hurdle					Triple-hurdle		
	(1a)	(2a)	(3a)	(4a)		(1b)	(2b)	(3b)
	Hurdle 1:	Hurdle 2:	Hurdle 3:	Hurdle 4:		Hurdle 1:	Hurdle 2:	Hurdle 3:
	PROD	PART	POS	HCCI		PROD	PART	HCCI
Variable				Market	Farmgate			
	Probit	Probit	Probit	Fractional	Fractional	Probit	Probit	Fractional
Sex of head	0.039***	0.036**	0.040	0.083	0.081	0.039***	0.036**	0.100*
	(0.013)	(0.018)	(0.030)	(0.052)	(0.083)	(0.013)	(0.017)	(0.052)
Age of head	-0.000	-0.000	0.002***	-0.000	-0.002	-0.000	-0.000	0.001
	(0.000)	(0.000)	(0.001)	(0.001)	(0.002)	(0.000)	(0.000)	(0.001)
Household size	0.003*	-0.003***	-0.010***	-0.010	-0.016	0.003*	-0.003	-0.019***
	(0.002)	(0.001)	(0.004)	(0.007)	(0.011)	(0.002)	(0.002)	(0.006)
Locality of household	-0.003	0.088***	0.054*	0.199***	0.188*	-0.003	0.088***	0.216***
	(0.013)	(0.019)	(0.029)	(0.062)	(0.100)	(0.013)	(0.018)	(0.059)
Marital status of head	0.022*	-0.025	-0.018	-0.022	-0.058	0.022*	-0.024	-0.045
	(0.013)	(0.017)	(0.028)	(0.047)	(0.077)	(0.013)	(0.017)	(0.047)
Years of education of head	-0.003**	-0.002	0.003	0.005	-0.008	-0.003**	-0.002	0.003
	(0.001)	(0.001)	(0.002)	(0.005)	(0.007)	(0.001)	(0.001)	(0.004)
Received cash remittance	-0.021**	-0.004	0.036*	-0.025	0.014	-0.021**	-0.004	0.020
	(0.010)	(0.012)	(0.021)	(0.036)	(0.059)	(0.010)	(0.012)	(0.035)
No. of days stop work due to ill-health	0.003	0.001	-0.001	0.002	-0.006	0.003	0.001	-0.003
	(0.002)	(0.002)	(0.004)	(0.007)	(0.009)	(0.002)	(0.002)	(0.006)
Ownership of nonfarm enterprise	-0.006	-0.032**	0.059**	-0.056	-0.147*	-0.006	-0.032**	-0.026
	(0.013)	(0.016)	(0.029)	(0.055)	(0.089)	(0.012)	(0.016)	(0.048)
Agric cooperative in community	0.104***	0.159***	0.061***	0.480***	0.162	0.104***	0.157***	0.331***
	(0.022)	(0.020)	(0.025)	(0.070)	(0.110)	(0.021)	(0.020)	(0.070)
Bank in community	0.329***	0.276***	0.129**	0.881***	0.474***	0.329***	0.276***	0.866***
	(0.024)	(0.023)	(0.054)	(0.079)	(0.156)	(0.024)	(0.023)	(0.090)
Mobile phone network in community	-0.052***	0.053***	-0.053**	0.104*	-0.025	-0.052***	0.054***	0.032
	(0.013)	(0.015)	(0.027)	(0.057)	(0.070)	(0.013)	(0.015)	(0.043)
Agric extension office in community	0.040**	0.068***	0.018	0.110*	0.021	0.040**	0.069***	0.083
	(0.017)	(0.021)	(0.028)	(0.057)	(0.089)	(0.017)	(0.021)	(0.052)
Irrigated fields in community	0.004	-0.004	0.032	-0.021	-0.115	0.005	-0.002	-0.033
	(0.016)	(0.021)	(0.033)	(0.066)	(0.086)	(0.016)	(0.020)	(0.059)
Perceived rain pattern	-0.010	0.018*	-0.047**	0.076**	0.128**	-0.010	0.018*	0.060*
	(0.009)	(0.011)	(0.020)	(0.038)	(0.064)	(0.009)	(0.011)	(0.034)
Log of expenditure on agrochemicals	0.036***	0.004	0.025***	0.033**	0.005	0.036***	0.004	0.041***
	(0.002)	(0.005)	(0.007)	(0.015)	(0.026)	(0.002)	(0.004)	(0.011)
Log of expenditure on hired labour	0.004**	0.003	0.002	0.013*	0.015	0.004**	0.003	0.014**

	(0.002)	(0.002)	(0.004)	(0.007)	(0.010)	(0.002)	(0.002)	(0.007)
No. of crops produced	0.084***	-0.023***	-0.031***	-0.121***	-0.039	0.084***	-0.024***	-0.113***
	(0.003)	(0.009)	(0.010)	(0.018)	(0.037)	(0.003)	(0.009)	(0.017)
Log of total value of household assets	0.004**	-0.004*	-0.003	-0.004	0.007	0.004**	-0.004*	-0.001
	(0.002)	(0.002)	(0.004)	(0.006)	(0.010)	(0.002)	(0.002)	(0.006)
Log of agric land endowment	0.077***	0.042***	0.013	0.067**	-0.021	0.002	0.042***	0.029
	(0.025)	(0.007)	(0.013)	(0.027)	(0.041)	(0.005)	(0.007)	(0.028)
Market in community	0.065***	0.178***	0.113***	0.771***	0.526***	0.065***	0.178***	0.702***
	(0.017)	(0.016)	(0.043)	(0.055)	(0.123)	(0.017)	(0.016)	(0.064)
Navigable road to community	0.034**	0.152***	0.280***	0.279***	0.077	0.034**	0.152***	0.322***
	(0.016)	(0.019)	(0.056)	(0.106)	(0.206)	(0.016)	(0.019)	(0.086)
Access to public transport	0.015	0.070***	0.056	0.158***	0.015	0.014	0.070***	0.114**
	(0.014)	(0.015)	(0.035)	(0.057)	(0.090)	(0.014)	(0.015)	(0.055)
Household in southern Ghana	-0.067***	0.043**	0.037	0.021	-0.174	-0.067***	0.043**	-0.021
	(0.017)	(0.022)	(0.034)	(0.064)	(0.120)	(0.017)	(0.022)	(0.061)
Household in coastal zone	0.116*	-0.079	0.154	-0.590**	-0.255	0.114*	-0.069	-0.098
	(0.063)	(0.052)	(0.123)	(0.269)	(0.599)	(0.063)	(0.052)	(0.419)
Household in forest zone	0.039	-0.032	0.185	-0.414	-0.304	0.037	-0.022	0.023
	(0.062)	(0.049)	(0.121)	(0.267)	(0.606)	(0.062)	(0.050)	(0.413)
Household in savannah zone	0.031	-0.123**	0.163	-0.650**	-0.581	0.030	-0.112**	-0.202
	(0.064)	(0.053)	(0.127)	(0.275)	(0.619)	(0.064)	(0.054)	(0.430)
Constant	-1.090***	-1.145***	-0.974	-0.191	0.336	-1.087***	-1.177***	-0.395
	(0.272)	(0.368)	(0.725)	(0.402)	(0.733)	(0.271)	(0.362)	(0.445)
Rho1_234		0.027	-0.295	-0.217*	-0.043		0.018	-0277***
		(0.243)	(0.312)	(0.109)	(0.220)		(0.236)	(0.110)
Rho2_34			0.008	0.698***	-0.052			0.369***
			(0.282)	(0.175)	(0.207)			(0.156)
Rho34				0.139	0.268			
				(0.192)	(0.330)			
Observations	7332	5142	2353	1696	657	7332	5142	2353
Wald Chi-square		5250.209***					4537.002***	
Log pseudolikelihood		-6538.485					-7589.071	
AIC		13250.97					15476.14	
BIC		13851.27					16504.24	
LR test				2101.17***				

Note(s): * $p<0.1$; ** $p<0.05$; *** $p<0.01$; Standard errors in parentheses; PROD is maize production decision; PART is decision to sell maize; POS is choice of maize market; MkHCCI is maize level of commercialisation at market centre; FgHCCI is maize level of commercialisation at farmgate; PROD, PART and POS are probit models while HCCI is a fractional model; 'a' denotes quadruple-hurdle and 'b' denotes triple-hurdle; Source: Produced by the author using the GLSS7 Data.

The transmission channel of banks through the four hurdles of agricultural commercialisation is increased in the liquidity of farmers. Thus, liquidity from credit can be used to purchase inputs (e.g., inorganic fertiliser, pest and disease control chemicals and hire labour), stimulating productivity and increase the scale of production. Increased production and productivity provide more marketed surplus beyond household consumption needs, stimulating market engagement. The stimulation of market centre sale relative to farmgate and sale of higher proportions also follows from the increased production and productivity, where farm households have large volumes of produce to sell at market centres to receive relatively higher prices. These observations corroborate previous studies. For example, Nkegbe et al. (2022) show that farmers who reside in communities with banks are more likely to sell their farm produce relative to their counterparts who do not have banks in their communities, while Abu and Issahaku (2017) observed that farmers who reside in communities with banks sell higher proportions of maize.

The presence of market in community is positive determinant of all four hurdles. Farm households that have markets in their communities are 6.5 percent more likely to produce maize. Conditioned on maize production, they are 17.8 percent more likely to sell maize and conditioned on the decision to sell, they are 11.3 percent more likely to sell in a market centre. Presence of market increases the proportion of maize sold by 77.1 percent and 52.6 percent, respectively, at market centre and farmgate. This implies that markets encourage higher proportions of maize sales in markets centres relative to farmgate. Apart from proportion of maize sold at farmgate, availability of roads increases the likelihood of producing maize by 3.4 percent and conditioned on production, roads increase the likelihood of selling maize by 15.2 percent. Conditioned on selling, the likelihood of selling maize in a market centre increases by 28 percent with the presence of roads. Conditioned on selling

maize in market centre, 27.9 percent of the output of maize in sold. While access to public transport does not significantly determine the likelihood of producing maize, it increases the likelihood of selling maize by 7 percent and conditioned on market centre sales, increases the proportion of maize sold in a market centre by 15.8 percent. These observations imply that reducing transaction costs provides the needed boost for production and remunerative agricultural commercialisation. Markets, good roads, and availability of transport are important variables that reduce transaction costs. For example, when there are markets, farmers can have relatively cheap access to agricultural inputs to increase production beyond household consumption and secure marketable surpluses to sell to these markets, which are more remunerative than selling at farmgate. Further, good roads reduce transaction costs as the time spent travelling is shorter, thus reducing transportation costs in accessing inputs and selling to distant markets. These observations and explanation are generally consistent with the literature that explains the importance of reducing transaction costs in agricultural marketing (e.g., Abu & Issahaku, 2017; Alhassan et al., 2020; Nkegbe et al., 2022).

The evidence further shows that agricultural cooperative in community significantly determine production decision, sale decision, sale at market centre and proportion sold at the market centre. This implies that farm households that have agricultural cooperatives in their communities are more likely, relative to those who do not have these organisations, to produce maize; are more likely to sell maize conditioned on production; are more likely to sell maize at a market centre relative to selling at farmgate conditioned on deciding to sell; and conditioned on selling at the market centre sell higher proportion of maize. The probability of producing maize increases by 10.4 percent for maize farmers with cooperatives in their communities; the probability of selling maize increases by 15.9 percent and the probability of selling maize at a market centre increases by 6.1 percent. The proportion of

maize sold in a market centre is 48 percent for farmers with cooperatives in their communities. Cooperatives may share lessons on technology adoption and pool their collective power in procuring inputs to increase production. These corroborate evidence provided by Abu and Issahaku (2017), and Abu et al. (2016). Specifically, Abu et al. (2016) report that farmers participating in farmer-based organisations are more likely to sell at market centre than farmgate.

It is observed that a higher scale of production measured by the number of crops produced increases the likelihood of farmers to produce maize by 8.4 percent. However, an additional crop produced reduces the probability of selling maize by 2.3 percent and reduces the probability of selling in a market centre by 3.1 percent. Conditioned on market centre sale, the proportion of maize sold reduces by 12.1 percent with an additional crop produced. This contradicts the finding of Sekyi et al. (2020), who observed that farmers who produce multiple crops sell higher proportions of their produce. Perhaps, since maize is an important staple crop, crop production diversity offers the ability to rely on the marketing of other crops while keeping maize to meet dietary needs.

Farm households that have extension office in their communities are 4 percent more likely to produce maize, are 6.8 percent more likely to sell maize conditioned on production and conditioned on selling in a market centre sell 11 percent more maize. Extension office in community does not, however, influence the choice of market. The presence of an extension office stimulates production decisions by providing technical production information for farmers to engage in production and thus stimulate market participation (see Abu & Issahaku, 2017; Nkegbe et al., 2022).

The gender variable reveals gender disparity in production and decision to sell maize but not choice of market and intensity of maize sales. Males are 3.9 percent more likely to produce maize and conditioned on production, they are 3.6 percent more likely to sell maize relative to females. This finding corroborates several previous findings (e.g., Abu et al., 2016; Awotide et al., 2016; Sekyi et al., 2020) that indicate gender disparity in ownership and access to productive resources as a main factor in the disparity in production and commercialisation behaviour between males and females. For example, men have more access to lands and credit than women (see Bhasin, 2009; Fletschner, 2008).

Household size has a positive influence on production decision, a negative influence on the decision to sell, the choice of market and the intensity of maize sales. This suggests that farmers are more likely to produce maize when they have larger family sizes because, household members provide labour for all the stages of production, but these large sizes place more food consumption demands such that households cannot raise marketable surpluses to sell. This observation is reported in previous commercialisation literature (e.g., Abu & Issahaku, 2017; Alhassan et al., 2020; Sekyi et al., 2020).

While there is no disparity in the decision to produce maize between rural and urban farmers, there is disparity in the decision to sell, choice of market and sale intensity. Rural farmers are 8.8 percent more likely to sell their maize produce, are 5.4 percent more likely to sell at market centres condition on deciding to sell and sell 19.9 percent and 18.8 percent more of their maize produce than urban farmers conditioned on market centre and farmgate choice, respectively. These observations may be highlighting the fact that rural Ghana is more agrarian than urban Ghana.

Agricultural technology adoption is identified in the literature as key to increasing farm households' productivity (e.g., Duong & Izumida, 2002; Lawal et al., 2009). The findings of this study thus confirm that agricultural technology adoption boosts commercialisation through productivity gains. Productive farm households are more likely to sell their produce (e.g., Abu et al., 2016; Abu & Issahaku, 2017). Farm households that are more endowed with agricultural lands are more likely to produce maize, more likely to sell conditioned on production and sell higher proportions conditioned on market centre sales. This suggests that agricultural land endowment provides the opportunity for farm expansion to increase output beyond household consumption needs. This is consistent with the studies (e.g., Mariyono, 2018; Martey et al., 2012; Sekyi et al., 2020) that report that farmers that have larger farm sizes are more oriented to commercialise their produce. The evidence further shows that more endowed farm households in assets are 0.4 percent more likely to produce maize but 0.4 percent less likely to sell maize. Such households produce more because of their endowment but decide to consume their own produced maize rather than selling.

Further, farm households in southern Ghana are less likely to produce maize relative to their counterparts in northern Ghana, confirming that northern Ghana is more agrarian than southern Ghana. However, farm households in southern Ghana are more likely to sell maize than farm households in northern Ghana. The relative price differential, where there are favourable prices in southern Ghana relative to northern Ghana, may be explaining the more decision to sell in the southern Ghana than northern Ghana.

Finally, the triple-hurdle commercialisation model is estimated and compared with the quadruple-hurdle model estimates (see Table 4.13). The evidence shows that the estimates of the quadruple-hurdle model and the triple-hurdle model involving the three hurdles for which

they are similar (i.e., decision to produce, decision to sell and quantity sold) are generally robust (i.e., similar in sign and magnitude of the coefficients). However, the pre-eminence of the quadruple-hurdle model over the triple-hurdle is observed in two ways. Firstly, the quadruple-hurdle model provides an additional model of farmers' choice of market centre versus farmgate, thus eliciting important determinants of agricultural marketing behaviours of farm households. Secondly, the quadruple-hurdle model allows testing which of these models is superior using the likelihood ratio test (i.e., equation (3.55)). The test statistic of 2101.17 is statistically significant at 1 percent. This suggests that the null hypothesis of the triple-hurdle model not nested in the quadruple-hurdle model is rejected. Thus, since the quadruple-hurdle model is tested to be the full or unconstrained model, it can be described as an extension of the triple-hurdle model. Further, the quadruple-hurdle model has lower AIC and BIC statistics. This evidence suggests that the quadruple-hurdle model is a better commercialisation model than the triple-hurdle model.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary of key findings, conclusions, policy recommendations, and limitations and suggestions for future research.

5.2 Summary and key findings

Previous studies have provided useful evidence to guide and shape policies to improve agricultural commercialisation. However, there are still lingering challenges with respect to the scope and measurement of agricultural commercialisation, as well as its impact on food and nutrition security. Based on these, this study developed, estimated, and analysed the determinants of an extended metric of agricultural commercialisation that captures crop and livestock dimensions of commercialisation, estimated the impact of this extended metric on various food and nutrition security outcomes, and developed and estimated a quadruple-hurdle model of commercialisation as an extension of the triple-hurdle model. The hypotheses tested in the study are: (i) an extended metric of agricultural commercialisation suggests the importance of the livestock subsector to agricultural commercialisation behaviour of farm households; (ii) key determinants of an extended metric of agricultural commercialisation are infrastructure variables (e.g., road, market, availability of transport), institutional variables (agricultural cooperatives), and farm characteristics (e.g., land endowment and crop diversity); (iii) the extended metric of agricultural commercialization reflects the impact of agricultural commercialization on food and nutrition security better than the widely used crop commercialisation index; and (iv) a quadruple-hurdle model of

agricultural commercialisation is a better modelling approach of commercialisation behaviour of farm households than the triple-hurdle approach.

Secondary data from the recent Ghana Living Standard Survey round 7 (GLSS7) collected by the Ghana Statistical Service between 2016/2017 were used to achieve the objectives of this study. To validate findings, primary data were collected from 858 farm households in northern Ghana in 2022. The extended metric, household crop and livestock commercialisation indices were used to estimate the level of commercialisation. The fractional regression was applied to estimate the determinants of the extended metric of commercialisation. In estimating the impact of commercialisation on food and nutrition security outcomes, instrumental variable approaches were used to account for endogeneity and selectivity of commercialisation. The conditional mixed process was applied to estimate the quadruple-hurdle model.

The summary of key findings pertaining to each specific objective are presented next.

Level of agricultural commercialisation

The level of agricultural commercialisation indicates that commercialisation measured using the extended metric of crop and livestock index (26.44%) is lower than the crop commercialisation index (35.20%) but higher than the livestock commercialisation index (10.94%). From this evidence, the level of agricultural commercialisation is characterised as surplus-oriented from the extended and crop commercialisation metrics and subsistent-oriented from the livestock commercialisation metric, and this is regardless of the data used. When the analysis is conditioned on a sub-sample of farm households which sold their produce, the level of commercialisation is relatively higher but still characterised as surplus-

oriented for the extended metric and commercial-oriented for the crop commercialisation metric for both datasets. The extended metric captures the true state of agricultural commercialisation since livestock production cannot be disentangled from agriculture. This finding confirms the first hypothesis which states that "an extended metric of agricultural commercialisation suggests the importance of the livestock subsector to agricultural commercialisation behaviour of farm households".

Determinants of the extended metric of agricultural commercialisation

Several factors are identified in estimating the extended agricultural commercialisation index's influencing factors. However, the key factors that are simultaneously relevant in explaining commercialisation for the two datasets are ownership of nonfarm enterprise, agricultural cooperative in community, bank in community, number of crops cultivated, agricultural land endowment, presence of community market, navigable road to community and access to public transport. All these determinants have the same directional effects on agricultural commercialisation. Apart from nonfarm enterprises, the rest of these key factors have positive coefficients, implying that they stimulate higher crop and livestock commercialisation. Therefore, infrastructure, institutional and production scale variables are key in boosting agricultural commercialisation in Ghana. This confirms the second hypothesis that states that "key determinants of an extended metric of agricultural commercialisation are infrastructure variables (e.g., road, market, availability of transport), institutional variables (agricultural cooperatives), and farm characteristics (e.g., land endowment and crop diversity". Determinants for each metric (HCLCI, HCCI and HLCI) are similar, however the determinants of the extended metric have larger magnitudes of their coefficients relative to the magnitudes of the coefficients of the separate crop and livestock determinants. This indicates underestimation of the determinants from the crop and livestock

indices. This observation further confirms the first hypothesis that emphasises the importance of the livestock subsector to agricultural commercialisation behaviour of farm household.

Impact of agricultural commercialisation on food and nutrition security outcomes

Using various food and nutrition security indicators, including per capita food consumption expenditure, per adult equivalent food expenditure, household dietary diversity, food consumption score, vitamin A consumption, protein consumption, hem iron consumption, child stunting, child wasting, child underweight, food insecurity experience scale, the evidence show that the extended metric of agricultural commercialisation has a significant impact on all these food and nutrition security indicators. Apart from children anthropometric measures of stunting, wasting and being underweight, the impact is positive for the other outcomes. The negative impact on children's anthropometric measures indicates reducing the incidence of these conditions. This implies that higher crop-livestock commercialisation improves food and nutrition security of farm households in Ghana and this conclusion is robust to use of alternative econometric approaches.

Comparative analysis using the three commercialisation metrics reveals that the estimated impacts are generally larger for the livestock commercialisation index relative to the crop-livestock and the crop indices. The estimated impacts are further larger for the crop-livestock index relative to the crop index. These findings point to a key implication; that comparatively, livestock commercialisation exerts more impacts on food and nutrition security than crop commercialisation. By extension, this implication is what accounts for the consistently larger impacts of the extended metric of commercialisation relative to the crop commercialisation metric. This finding confirms the third hypothesis that states that "the extended metric of agricultural commercialization reflects the impact of agricultural

commercialization on food and nutrition security better than the crop commercialisation index". It is found that the main transmission channel through which commercialisation impacts food and nutrition security is household income. Further, consumption of own-produced food does not suffer due to increased commercialisation whiles it encourages consumption of purchased diets through income gained from sales.

Determinants of quadruple-hurdle model of agricultural commercialisation

In estimating the factors that influence the four hurdles of agricultural commercialisation, namely production, sale, market choice and intensity of sale, the key factors that simultaneously determine these four hurdles are presence of bank and market in community. Other key determinants in the quadruple-hurdle model estimates are number of crops produced (i.e., scale of production), navigable road to community, availability of public transport, agricultural cooperative in community, extension office in community and adoption of agricultural technology. Further, statistical tests (i.e., LR, AIC and BIC) reveal that the quadruple-hurdle is a better model than the triple-hurdle model. This confirms the fourth hypothesis that states that "a quadruple-hurdle model of agricultural commercialisation is a better modelling approach of commercialisation behaviour of farm households than the triple-hurdle approach".

5.3 Conclusions

Based on the key findings, this study concludes as follows:

1. Agricultural commercialisation is characterised as surplus-oriented in Ghana, and the HCLCI is a better measure of agricultural commercialisation than the HCCI because the latter overstates the level of agricultural commercialisation relative to the former.

2. The main drivers of market centre-focused commercialised production of crops and livestock are infrastructure (i.e., navigable road, market, availability of transport and bank), farmer institutional characteristics (i.e., agricultural cooperatives) and scale of production (i.e., crop production diversity).
3. The use of the joint crop-livestock commercialization index to account for the impact(s) of agricultural commercialization on food and nutrition security is a better approach than using the crop commercialization index. Thus, joint commercialisation of crop and livestock is a key strategy for boosting food and nutrition security of farm households in Ghana.
4. The triple-hurdle model of agricultural commercialisation is nested in the quadruple-hurdle model, thus, modelling agricultural commercialisation using a quadruple-hurdle model is a better modelling approach of commercialisation behaviour of farm households than the triple-hurdle approach.

5.4 Recommendations

Based on the conclusions of this study, the following policy recommendation are made.

To induce a shift from subsistent focused agricultural production to commercial-oriented one, investing to boost infrastructure in agricultural producing areas – which are basically rural area – cannot be ignored. Commercialised agriculture can be stimulated if the government of Ghana in collaboration with its development partners aggressively embark on a rural infrastructure delivery. One way to achieve this is to meet the Comprehensive African Agriculture Development Programme (CAADP) commitment of annually allocating 10 percent of the national budget to agriculture. Ghana is currently not meeting this commitment. Meeting this commitment will provide extra financial resources to make the

needed investments. Moreover, strategies and interventions that promote the effectiveness and efficiency of farmer institutions by a collaboration and cooperation of the Ministry of Employment and Labour Relations (MELR) under which the Department of Cooperatives (DOC) operates and the Ministry of Food and Agriculture (MoFA) are needed. For example, DOC and MoFA should be empowered to co-produce a functional and active digital register of farmer organisations that provides the platform to track, monitor, and deliver relevant group efficiency information, trainings, and other essential services such as government-subsidised inputs. Indeed, farmer groups would become effective if the delivery of government and NGO sponsored interventions (such as inputs) and credit provisions are delivered exclusively through these farmer organisations.

While the livestock subsector is equally as important as the crop subsector, there is a disproportionate focus on the latter. Beyond providing infrastructure and strengthening farmer institutional development, which undoubtedly will boost livestock commercialisation, it is imperative to balance attention from policy and interventions for the livestock subsector to support the drive for a transition to productive and commercialised agriculture. To achieve this, the current Ghana Livestock Development Policy and Strategy should be well implemented. Specifically, government should efficiently allocate resources for the implementation of the policy, while MoFA as the lead policy implementation body, should facilitate and coordinate collaborations among stakeholders in its implementation. The Rearing for Food and Jobs (RFJ) initiative is another area that needs commitment from government through stepping up funding as it has been underfunded. To derive the benefits of the RFJ, it is important government and all relevant stakeholders find lasting solutions to the ‘Fulani menace’ regarding cattle rearing and coordinate small ruminant promotion efforts by various stakeholders.

Since agricultural commercialisation holds significant food and nutrition security benefits, it is important to enhance effective collaborative efforts between the Ministry of Health (MoH), Ministry of Trade and Industry (MoTI) and MoFA. In other words, efforts by MoH and relevant stakeholders within the health system to boost food and nutrition security that ignores farmers' marketing behaviour will not yield the desired effect. Thus, this study demonstrates that it is important for Ghana to develop and promote well-functioning food systems through enhancing institutional collaborations and cooperations, and strengthening policy that creates an enabling environment within the food value chain. Food should be produced in the most productive and efficient way (the role of MoFA and other stakeholders in the agricultural ecosystem), food should be efficiently marketed (role of MoFA, MoTI and other relevant stakeholders), and food should be prepared and consumed in the most nutritious and healthy way (role of MoH and other relevant stakeholders in health and nutrition education, especially). This cannot be achieved without the cooperation and collaboration of all the relevant stakeholders. Ideal food systems require all the connecting institutions to collaborate and cooperate, and the evidence of agricultural commercialisation boosting food and nutrition security points in this direction.

To farm households in Ghana, it is recommended that they strategize to make agriculture a business, which basically implies the commercialisation of agriculture. Farmers cannot transform from subsistent-orientation to commercial-orientation if efforts from policies and strategies from government are not complemented with farmer efforts. Farmers can transform to commercial-oriented agriculture by consciously developing a mindset that views agriculture as a business and not a subsistent economic activity, participating in agricultural cooperatives, investing in agricultural technology adoption and prioritising market centre sale over farmgate sale.

This study recommends that the agricultural commercialisation literature should embrace the use of the extended metric of agricultural commercialisation in assessing impacts on farmer/farm households' farm and welfare outcomes. Further, the literature should embrace the quadruple-hurdle modelling approach of commercialisation behaviour of farm households to identify the important determinants of production, market participation, choice of market and intensity of production.

5.5 Limitations and suggestions for future research

Although this study has made contributions to the literature, especially by (i) providing an extended metric of agricultural commercialisation that combines crop and livestock dimensions and its determinants; (ii) considering the commercialisation of diverse crops and livestock that households engaged in producing and marketing; (iii) estimating the impact of the extended metric on a wide range of food and nutrition security indicators using robust econometric approaches; and (iv) presenting a quadruple-hurdle model that extends the triple-hurdle model, it is not without weaknesses.

The first limitation relates to the use of cross-sectional data. Even with the use of instrumental variable approaches and instruments that are argued for and tested to be valid, there are still lingering challenges of endogeneity because not all unobserved heterogeneities (such as innate farm management and entrepreneurial abilities) can be contained. Though, at best, the approaches used can be regarded as fairly robust, the use of panel data puts to rest the challenges that arise from cross-sectional data. Thus, exploring the use of panel data is suggested for future studies. In addition, the food and nutrition security outcomes used do not capture stability and the yet to be accepted pillars of agency and sustainability dimensions of food security, nor is a composite measure of food and nutrition security constructed in this

study. The various measures used in this study capture, individually, availability, access and utilisation dimensions of food security. A study that develops an appropriate food and nutrition security composite variable would be an important addition to the literature.

The extended metric combined crop and livestock dimensions of commercialisation, but it does not comprehensively solve the problem of appropriately measuring commercialisation. Though it is better than individual crop and livestock commercialisation, it still does not capture the input dimension of commercialisation espoused by Pingali and Rosegrant (1995), Pingali (1997), Alemu et al. (2006), and Jaleta et al. (2009). Attempts to develop a metric that simultaneously captures crop, livestock and input dimensions will be a novel addition to the literature. In addition, the index is indivisible at the crop-level. Thus, it cannot be constructed for a single crop, as the livestock dimension cannot be portioned for only that crop.

The quadruple-hurdle model is constructed and estimated for individual crops in this study. This implies that it does not treat different crops as a system. Developing a system approach to modelling all crops produced and marketed by farm households will be a good addition to the literature. A systems approach retains the uniqueness of individuals, and thus possibly relaxing the assumption of independence of the individual crops that this study intrinsically assumes.

REFERENCES

Abafita, J., Atkinson, J., & Kim, C.-S. (2016). Smallholder commercialization in Ethiopia: Market orientation and participation. *International Food Research Journal*, *23*(4), 1797–1807.

Abdul-Rahaman, A., & Abdulai, A. (2020). Vertical coordination mechanisms and farm performance amongst smallholder rice farmers in northern Ghana. *Agribusiness*, *36*(2), 259–280. https://doi.org/10.1002/agr.21628.

Abdul Mumin, Y., & Abdulai, A. (2022). Informing food security and nutrition strategies in sub-Saharan African countries: An overview and empirical analysis. *Applied Economic Perspectives and Policy*, *44*(1), 364–393. https://doi.org/10.1002/aepp.13126.

Abdulai, A., & Aubert, D. (2004). A cross-section analysis of household demand for food and nutrients in Tanzania. *Agricultural Economics*, *31*(1), 67–79. https://doi.org/10.1016/j.agecon.2003.03.001.

Abdulai, A., & Birachi, E. A. (2009). Choice of coordination mechanism in the Kenyan fresh milk supply chain. *Review of Agricultural Economics*, *31*(1), 103–121. https://doi.org/10.1111/j.1467-9353.2008.01428.x.

Abdulai, A., & CroleRees, A. (2001). Determinants of income diversification amongst rural households in Southern Mali. *Food Policy*, *26*(4), 437–452. https://doi.org/10.1016/S0306-9192(01)00013-6.

Abdullah, Rabbi, F., Ahamad, R., Ali, S., Chandio, A. A., Ahmad, W., Ilyas, A., & Din, I. U. (2019). Determinants of commercialization and its impact on the welfare of smallholder rice farmers by using Heckman's two-stage approach. *Journal of the Saudi Society of Agricultural Sciences*, *18*(2), 224–233. https://doi.org/10.1016/j.jssas.2017.06.001.

Abu, B. M. (2015). Groundnut market participation in the Upper West region of Ghana. *Ghana Journal of Development Studies*, *12*(1&2), 106–124. https://doi.org/10.4314/gjds.v12i1-2.7.

Abu, B. M., & Issahaku, H. (2017). Financial inclusion and agricultural commercialization in Ghana: An empirical investigation. *Agricultural Finance Review*, *77*(4), 524–544. https://doi.org/10.1108/AFR-02-2017-0007.

Abu, B. M., Issahaku, H., & Nkegbe, P. K. (2016). Farmgate versus market centre sales: A multi-crop approach. *Agricultural and Food Economics*, *4*. https://doi.org/10.1186/s40100-016-0065-6.

Abu, B. M., Osei-Asare, Y. B., & Seini, A. W. (2014). Market participation of smallholder maize farmers in the upper west region of Ghana. *African Journal of Agricultural Research*, *9*(31), 2427–2435. https://doi.org/10.5897/ajar2014.8545.

Acheampong, E. O., Sayer, J., & Macgregor, C. J. (2018). Road improvement enhances smallholder productivity and reduces forest encroachment in Ghana. *Environmental Science and Policy*, *85*, 64–71. https://doi.org/10.1016/j.envsci.2018.04.001.

African Development Bank. (2016). *Development effectiveness review 2016 on agriculture*. https://www.afdb.org/en/documents/2016-development-effectiveness-review-agriculture

Aker, J. C. (2010). Information from markets near and far: Mobile phones and agricultural markets in Niger. *American Economic Journal: Applied Economics*, *2*(3), 46–59. https://doi.org/10.1257/app.2.3.46.

Akpan, S. B., Nkanta, V. S., & Essien, U. A. (2012). A double-hurdle model of fertilizer adoption and optimum use among farmers in Southern Nigeria. *Tropicultura*, *30*(4), 249–253.

Aku, A., Mshenga, P., Afari-Sefa, V., & Ochieng, J. (2018). Effect of market access provided by farmer organizations on smallholder vegetable farmer's income in Tanzania. *Cogent Food and Agriculture*, *4*(1). https://doi.org/10.1080/23311932.2018.1560596.

Alemu, D., Gebre-Medhin, E., & Dejene, S. (2006). From farmer to market and market to farmer: Characterizing Smallholder commercialization in Ethiopia. *Paper Submitted for ESSP Policy Conference on Bridging, Balancing, and Scaling up: Advancing the Rural Growth Agenda in Ethiopia. 6-8 June 2006, Addis Ababa, Ethiopia.*

Alene, A. D., Manyong, V. M., Omanya, G., Mignouna, H. D., Bokanga, M., & Odhiambo, G. (2008). Smallholder market participation under transactions costs: Maize supply and fertilizer demand in Kenya. *Food Policy*, *33*(4), 318–328. https://doi.org/10.1016/j.foodpol.2007.12.001.

Alhassan, H., Abu, B. M., & Nkegbe, P. K. (2020). Access to credit, farm productivity and market participation in Ghana: A conditional mixed process approach. *Margin—The Journal of Applied Economic Research*, *14*(2), 226–246. https://doi.org/10.1177/0973801020904490.

Anang, B. T., Bäckman, S., & Sipiläinen, T. (2020). Adoption and income effects of agricultural extension in northern Ghana. *Scientific African*, *7*. https://doi.org/10.1016/j.sciaf.2019.e00219.

Andaregie, A., & Astatkie, T. (2020). Determinants of technical efficiency of potato farmers and effects of constraints on potato production in Northern Ethiopia. *Experimental Agriculture*, *56*(5), 699–709. https://doi.org/10.1017/S0014479720000253.

Andaregie, A., Astatkie, T., & Teshome, F. (2021). Determinants of market participation decision by smallholder haricot bean (phaseolus vulgaris l.) farmers in Northwest Ethiopia. *Cogent Food and Agriculture*, *7*(1). https://doi.org/10.1080/23311932.2021.1879715.

Anderman, T. L., Remans, R., Wood, S. A., DeRosa, K., & DeFries, R. S. (2014). Synergies and tradeoffs between cash crop production and food security: A case study in rural Ghana. *Food Security*, *6*, 541–554. https://doi.org/10.1007/s12571-014-0360-6.

Andersson, C. I. M., Chege, C. G. K., Rao, E. J. O., & Qaim, M. (2015). Following up on smallholder farmers and supermarkets in Kenya. *American Journal of Agricultural Economics*, *97*(4), 1247–1266. https://doi.org/10.1093/ajae/aav006.

Asuming-Brempong, S., & Kuwornu, J. K. M. (2013). Policy initiatives and agricultural performance in post-independent Ghana. *Journal of Social and Development Sciences*, *4*(9), 425–434.

Awotide, B. A., Karimov, A. A., & Diagne, A. (2016). Agricultural technology adoption, commercialization and smallholder rice farmers' welfare in rural Nigeria. *Agricultural and Food Economics*, *4*(3), 1–21. https://doi.org/10.1186/s40100-016-0047-8.

Azadi, H., Burkart, S., Moghaddam, S. M., Janečková, K., Sklenička, P., Ho, P., & Nadiri, H. (2021). Famine in the horn of Africa: Understanding institutional arrangements in land tenure systems. *Food Reviews International*. https://doi.org/10.1080/87559129.2021.1888974.

Azzarri, C., Zezza, A., Haile, B., & Cross, E. (2015). Does livestock ownership affect animal source foods consumption and child nutritional status? Evidence from rural Uganda. *Journal of Development Studies*, *51*(8), 1034–1059. https://doi.org/10.1080/00220388.2015.1018905.

Babatunde, R. O. (2015). *On-farm and off-farm works: Complement or substitute? Evidence from Nigeria* (Working Paper No. 2015/02; Maastricht School of Management). https://ageconsearch.umn.edu/record/160437.

Balana, B. B., & Oyeyemi, M. A. (2022). Agricultural credit constraints in smallholder farming in developing countries: Evidence from Nigeria. *World Development Sustainability*, *1*. https://doi.org/10.1016/j.wds.2022.100012.

Baltenweck, I., Enahoro, D., Frija, A., & Tarawali, S. (2020). Why is production of animal source foods important for economic development in Africa and Asia? *Animal*

Frontiers, *10*(4), 22–29. https://doi.org/10.1093/af/vfaa036.

Bambio, Y., Deb, A., & Kazianga, H. (2022). Exposure to agricultural technologies and adoption: The West Africa agricultural productivity program in Ghana, Senegal and Mali. *Food Policy*, *113*. https://doi.org/10.1016/j.foodpol.2022.102288.

Barrett, C. B. (2008). Smallholder market participation: Concepts and evidence from eastern and southern Africa. *Food Policy*, *33*(4), 299–317. https://doi.org/10.1016/j.foodpol.2007.10.005.

Barrett, C. B., Christiaensen, L., Sheahan, M., & Shimeles, A. (2017). On the structural transformation of rural Africa. *Journal of African Economies*, *26*(suppl_1), i11–i35. https://doi.org/10.1093/jae/ejx009.

Beck, T., Senbet, L., & Simbanegavi, W. (2015). Financial inclusion and innovation in Africa: An overview. *Journal of African Economies*, *24*(suppl_1), i3–i11. https://doi.org/10.1093/jae/eju031.

Behrman, J., Alderman, H., & Hoddinott, J. (2004). Hunger and malnutrition. In B. Lomborg (Ed.), *Global crises, global solutions* (pp. 363–442). Cambridge University Press. https://doi.org/10.1017/CBO9780511492624.008.

Belay, G. H., Mengstu, K. A., Mehammedberhan Kahsay, H., Hosseininia, G., Işık Özgüven, A., Viira, A. H., & Azadi, H. (2021). Determinants of smallholder commercialization of livestock: A case study from Tigray, Ethiopia. *Cogent Food and Agriculture*, *7*(1). https://doi.org/10.1080/23311932.2021.1921950.

Bellemare, M. F., & Barrett, C. B. (2006). An ordered tobit model of market participation: Evidence from Kenya and Ethiopia. *American Journal of Agricultural Economics*, *88*(2), 324–337. https://doi.org/10.1111/j.1467-8276.2006.00861.x.

Benjamin, D. (1992). Household composition, labor markets, and labor demand: Testing for separation in agricultural household models. *Econometrica*, *60*(2), 287–322. https://doi.org/10.2307/2951598.

Bhasin, V. (2009). Determinants of technical efficiency of women entrepreneurs in the food processing enterprises in Cape Coast. *Ghana Policy Journal*, *3*, 24–47..

Binswanger, H. P., & von Braun, J. (1991). Technological change and commercialization in agriculture: The effect on the poor. *The World Bank Research Observer*, *6*(1), 57–80. https://doi.org/10.1093/wbro/6.1.57.

Bolarinwa, O. D., Oehmke, J. F., & Moss, C. B. (2021). Agricultural commercialization and food security: An ex-ante approach. *Journal of Agribusiness in Developing and Emerging Economies*, *11*(5), 472–489. https://doi.org/10.1108/JADEE-01-2020-0014.

Boughton, D., Mather, D., Barrett, C. B., Benfica, R., Abdula, D., Tschirley, D., & Cunguara, B. (2007). Market participation by rural households in a low-income country: An asset-based approach applied to Mozambique. *Faith and Economics*, *50*(Fall 2007), 64–101.

Burke, W. J. (2019). Evidence against imposing restrictions on hurdle models as a test for simultaneous versus sequential decision making. *American Journal of Agricultural Economics*, *101*(5), 1473–1481. https://doi.org/10.1093/ajae/aaz026.

Burke, W. J., Myers, R. J., & Jayne, T. S. (2015). A triple-hurdle model of production and market participation in Kenya's dairy market. *American Journal of Agricultural Economics*, *97*(4), 1227–1246. https://doi.org/10.1093/ajae/aav009.

Carletto, C., Corral, P., & Guelfi, A. (2017). Agricultural commercialization and nutrition revisited: Empirical evidence from three African countries. *Food Policy*, *67*, 106–118. https://doi.org/10.1016/j.foodpol.2016.09.020.

Cazzuffi, C., McKay, A., & Perge, E. (2020). The impact of agricultural commercialisation on household welfare in rural Vietnam. *Food Policy*, *94*. https://doi.org/10.1016/j.foodpol.2019.101811.

Chege, C. G. K., Andersson, C. I. M., & Qaim, M. (2015). Impacts of supermarkets on farm

household nutrition in Kenya. *World Development*, *72*, 394–407. https://doi.org/10.1016/j.worlddev.2015.03.016.

Chegere, M. J., & Kauky, M. S. (2022). Agriculture commercialisation, household dietary diversity and nutrition in Tanzania. *Food Policy*, *113*. https://doi.org/10.1016/j.foodpol.2022.102341.

Chitonge, H., & Harvey, R. (2022). Land tenure challenges in Africa: Current and emerging issues. In H. Chitonge & R. Harvey (Eds.), *Land Tenure Challenges in Africa: Current and Emerging Issues. Economic Geography* (pp. 325–339). Springer, Cham. https://doi.org/10.1007/978-3-030-82852-3_16.

Clapp, J., Moseley, W. G., Burlingame, B., & Termine, P. (2022). Viewpoint: The case for a six-dimensional food security framework. *Food Policy*, *106*. https://doi.org/10.1016/j.foodpol.2021.102164.

Coase, R. H. (1937). The nature of the firm. *Economica*, *4*(16), 386–405. https://doi.org/10.1111/j.1468-0335.1937.tb00002.x.

Cooper, M. W., & West, C. T. (2017). Unraveling the Sikasso paradox: Agricultural change and malnutrition in Sikasso, Mali. *Ecology of Food and Nutrition*, *56*(2), 101–123. https://doi.org/10.1080/03670244.2016.1263947.

Courtois, P., & Subervie, J. (2015). Farmer bargaining power and market information services. *American Journal of Agricultural Economics*, *97*(3), 953–977. https://doi.org/10.1093/ajae/aau051.

Dehinenet, G., Mekonnen, H., Kidoido, M., Ashenafi, M., & Bleich, E. G. (2014). Factors influencing adoption of dairy technology on small holder dairy farmers in selected zones of Amhara and Oromia National Regional States, Ethiopia. *Discourse Journal of Agriculture and Food Sciences*, *2*(5), 126–135.

Dewey, K. G. (1981). Nutritional consequences of the transformation from subsistence to commercial agriculture in Tabasco, Mexico. *Human Ecology*, *9*(2), 151–187. https://doi.org/10.1007/BF00889132.

Diallo, M., & Wouterse, F. (2023). Agricultural development promises more growth and less poverty in Africa: Modelling the potential impact of implementing the Comprehensive Africa Agriculture Development Programme in six countries. *Development Policy Review*, *41*(3). https://doi.org/10.1111/dpr.12669.

Dorosh, P., & Thurlow, J. (2018). Beyond agriculture versus non-agriculture: Decomposing sectoral growth–poverty linkages in five African countries. *World Development*, *109*, 440–451. https://doi.org/10.1016/j.worlddev.2016.08.014.

Duong, P. B., & Izumida, Y. (2002). Rural development finance in Vietnam: A microeconometric analysis of household surveys. *World Development*, *30*(2), 319–335. https://doi.org/10.1016/S0305-750X(01)00112-7.

Ecker, O. (2018). Agricultural transformation and food and nutrition security in Ghana: Does farm production diversity (still) matter for household dietary diversity? *Food Policy*, *79*, 271–282. https://doi.org/10.1016/j.foodpol.2018.08.002.

Ecker, O., & Fang, P. (2016). Economic development and nutrition transition in Ghana: Taking stock of food consumption patterns and trends. In N. Covic & S. L. Hendriks (Eds.), *Achieving a nutrition revolution for Africa: The road to healthier diets and optimal nutrition* (pp. 28–50). International Food Policy Research Institute (IFPRI). https://doi.org/10.2499/9780896295933_04.

Ecker, O., & van Asselt, J. (2017). *Food and nutrition security in transforming Ghana: A descriptive analysis of national trends and regional patterns* (Discussion Paper No. 01650; International Food Policy Research Institute (IFPRI)). https://www.ifpri.org/cdmref/p15738coll2/id/131319/filename/131530.pdf.

Endalew, B., Aynalem, M., Assefa, F., & Ayalew, Z. (2020). Determinants of wheat

commercialization among smallholder farmers in Debre Elias Woreda, Ethiopia. *Advances in Agriculture*, *2020*. https://doi.org/10.1155/2020/2195823.

Fafchamps, M. (1992). Cash crop production, food price volatility, and rural market integration in the third world. *American Journal of Agricultural Economics*, *74*(1), 90–99. https://doi.org/10.2307/1242993.

Fafchamps, M., & Hill, R. V. (2005). Selling at the farmgate or traveling to market. *American Journal of Agricultural Economics*, *87*(3), 717–734. https://doi.org/10.1111/j.1467-8276.2005.00758.x.

Fafchamps, M., & Minten, B. (2012). Impact of SMS-based agricultural information on Indian farmers. *World Bank Economic Review*, *26*(3), 383–414. https://doi.org/10.1093/wber/lhr056.

FAO. (1989). *Horticultural marketing: A resource and training manual for extension officers. Rome, FAO*.

FAO, IFAD, UNICEF, WFP, & WHO. (2022). *The state of food security and nutrition in the world 2022. Repurposing food and agricultural policies to make healthy diets more affordable. Rome, FAO*. https://doi.org/10.4060/cc0639en.

Fischer, E., & Qaim, M. (2012). Gender, agricultural commercialization, and collective action in Kenya. *Food Security*, *4*, 441–453. https://doi.org/10.1007/s12571-012-0199-7

Fischer, E., & Qaim, M. (2014). Smallholder farmers and collective action: What determines the intensity of participation? *Journal of Agricultural Economics*, *65*(3), 683–702. https://doi.org/10.1111/1477-9552.12060.

Fletschner, D. (2008). Women's access to credit: Does it matter for household efficiency? *American Journal of Agricultural Economics*, *90*(3), 669–683. https://doi.org/10.1111/j.1467-8276.2008.01143.x.

Fleuret, P., & Fleuret, A. (1983). Socio-economic determinants of child nutrition in Taita, Kenya: A call for discussion. *Culture and Agriculture*, *19*(8), 16–20.

Furlong, W. J., & Slotsve, G. A. (1983). Will that be pickup or delivery? An alternative spatial pricing strategy. *The Bell Journal of Economics*, *14*(1), 271–274. https://doi.org/10.2307/3003553.

Gebremedhin, B., & Jaleta, M. (2010). Commercialization of smallholders: Is market participation enough? *Contributed Paper at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, 19-23 September 2010*. https://core.ac.uk/reader/6614520.

Gebremedhin, B., Jaleta, M., & Hoekstra, D. (2009). Smallholders, institutional services, and commercial transformation in Ethiopia. *Agricultural Economics*, *40*(SUPPL. 1), 773–787. https://doi.org/10.1111/j.1574-0862.2009.00414.x.

Gebreselassie, S., & Sharp, K. (2007). Commercialisation of smallholder agriculture in selected tef-growing areas of Ethiopia. *Ethiopian Journal of Economics*, *16*(1), 57–88. https://doi.org/10.4314/eje.v16i1.39824.

Ghana Statistical Service. (2018). *Multiple Indicator Cluster Survey (MICS2017/18)*. Survey Findings Report. Accra, Ghana.

Ghana Statistical Service. (2019). *Ghana Living Standards Survey Round 7*. Main report, Accra Ghana.

Goedde, L., Ooko-Ombaka, A., & Pais, G. (2019). *Winning in Africa's agricultural market* (McKinsey&Company). https://www.mckinsey.com/industries/agriculture/our-insights/winning-in-africas-agricultural-market.

Goetz, S. J. (1992). A selectivity model of household food marketing behavior in sub-Saharan Africa. *American Journal of Agricultural Economics*, *74*(2), 444–452. https://doi.org/10.2307/1242498.

Goletti, F. (2005). *Agricultural commercialisation, value chains and poverty reduction* (Making Markets Work Better for the Poor, ADB/DFID. Agrifood Consulting International). http://www.agrifooconsulting.com.

Govereh, J., & Jayne, T. S. (2003). Cash cropping and food crop productivity: Synergies or trade-offs? *Agricultural Economics*, *28*(1), 39–50. https://doi.org/10.1016/S0169-5150(02)00066-X.

Govereh, J., Jayne, T. S., & Nyoro, J. (1999). *Smallholder commercialization, interlinked markets and food crop productivity: Cross-country evidence in eastern and southern Africa* (Department of Agricultural Economics and the Department of Economics, Michigan State University (MSU)). http://www.aec.msu.edu/fs2/ag_transformation/atw_govereh.

Gowda, P. H., Steiner, J., Olson, C., Boggess, M., Farrigan, T., & Grusak, M. A. (2018). Agriculture and rural communities. In *Impacts, risks, and adaptation in the United States: The Fourth National Climate Assessment* (Volume II). https://doi.org/10.7930/NCA4.2018.CH10.

Grashuis, J., & Su, Y. (2019). A review of the empirical literature on farmer cooperatives: Performance, ownership and governance, finance, and member attitude. *Annals of Public and Cooperative Economics*, *90*(1), 77–102. https://doi.org/10.1111/apce.12205

Gross, D. R., & Underwood, B. A. (1971). Technological change and caloric costs: Sisal agriculture in Northeastern Brazil. *American Anthropologist*, *73*(3), 725–740. https://www.jstor.org/stable/671765.

Haggblade, S., Hazell, P. B. R., & Reardon, T. (2007). *Transforming the rural non-farm community*. John Hopkins University Press.

Hagos, A., Dibaba, R., Bekele, A., & Alemu, D. (2020). Determinants of market participation among smallholder mango producers in Assosa Zone of Benishangul Gumuz Region in Ethiopia. *International Journal of Fruit Science*, *20*(3), 323–349. https://doi.org/10.1080/15538362.2019.1640167.

Hailua, G., Manjureb, K., & Aymutc, K.-M. (2015). Crop commercialization and smallholder farmer's livelihood in Tigray region. *Journal of Development and Agricultural Economics*, *7*(9), 314–322. https://doi.org/10.5897/JDAE2015.0649.

Haji, J. (2022). Impact of agricultural commercialization on child nutrition in Ethiopia. *Food Policy*, *113*. https://doi.org/10.1016/j.foodpol.2022.102287.

Hao, J., Bijman, J., Gardebroek, C., Heerink, N., Heijman, W., & Huo, X. (2018). Cooperative membership and farmers' choice of marketing channels – Evidence from apple farmers in Shaanxi and Shandong Provinces, China. *Food Policy*, *74*, 53–64. https://doi.org/10.1016/j.foodpol.2017.11.004.

Heckman, J. J., Humphries, J. E., & Veramendi, G. (2018). Returns to education: The causal effects of education on earnings, health, and smoking. *Journal of Political Economy*, *126*(1), S197–S246. https://doi.org/10.1086/698760.

Henning, C. H. C. A., & Henningsen, A. (2007). *Modeling farm households' price responses in the presence of transaction costs and heterogeneity in labor markets*. *89*(3), 665–681. https://doi.org/10.1111/j.1467-8276.2007.00980.x.

Hernandez, M., Hidalgo, C. P., Hernandez, J. R., Madrigal, H., & Chávez, A. (1974). Effect of economic growth on nutrition in a tropical community. *Ecology of Food and Nutrition*, *3*(4), 283–291. https://doi.org/10.1080/03670244.1974.9990393.

Hirvonen, K., & Hoddinott, J. (2017). Agricultural production and children's diets: Evidence from rural Ethiopia. *Agricultural Economics*, *48*(4), 469–480. https://doi.org/10.1111/agec.12348.

Hobbs, J. E. (1997). Measuring the importance of transaction costs in cattle marketing. *American Journal of Agricultural Economics*, *79*(4), 1083–1095.

https://doi.org/10.2307/1244266.

Hoddinott, J., & Haddad, L. (1995). Does female income share influence household expenditures? Evidence from Côte D'Ivoire. *Oxford Bulletin of Economics and Statistics*, *57*(1), 77–96. https://doi.org/10.1111/j.1468-0084.1995.tb00028.x.

Holloway, G. J., Barrett, C. B., & Ehui, S. K. (2005). The double hurdle model in the presence of fixed costs. *Journal of International Agricultural Trade and Development*, *1*, 17–28.

Holloway, G. J., Dorfman, J. H., & Ehui, S. K. (2001). Tobit estimation with unknown point of censoring with an application to milk market participation in the Ethiopian highlands. *Canadian Journal of Agricultural Economics*, *49*(3), 293–311. https://doi.org/10.1111/j.1744-7976.2001.tb00307.x.

Holloway, G. J., Ehui, S., & Teklu, A. (2008). Bayes estimates of distance-to-market: Transactions costs, cooperatives and milk-market development in the Ethiopian highlands. *Journal of Applied Econometrics*, *23*(5), 683–696. https://doi.org/10.1002/jae.1019.

Holloway, G. J., Nicholson, C., Delgado, C., Staal, S., & Ehui, S. (2000). Agroindustrialization through institutional innovation transaction costs, cooperatives and milk-market development in the east-African highlands. *Agricultural Economics*, *23*(3), 279–288. https://doi.org/10.1016/S0169-5150(00)00089-X.

Holloway, G. J., Nicholson, C., Delgado, C., Staal, S., & Ehui, S. (2004). A revised Tobit procedure for mitigating bias in the presence of non-zero censoring with an application to milk-market participation in the Ethiopian highlands. *Agricultural Economics*, *31*(1), 97–106. https://doi.org/10.1016/j.agecon.2003.12.001.

Horton, S., & Ross, J. (2003). The economics of iron deficiency. *Food Policy*, *28*(1), 51–75. https://doi.org/10.1016/S0306-9192(02)00070-2.

IFPRI. (2015). *Global nutrition report 2015: Actions and accountability to advance nutrition and sustainable development*. International Food Policy Research Institute (IFPRI), Washington DC.

Issahaku, H., & Abu, B. M. (2024). Access to credit and child nutritional outcomes in Ghana. *Journal of African Development*, *25*(2). https://doi.org/10.5325/jafrideve.25.2.0131.

Issahaku, H., Abu, B. M., & Nkegbe, P. K. (2018). Does the use of mobile phones by smallholder maize farmers affect productivity in Ghana? *Journal of African Business*, *19*(3), 302–322. https://doi.org/10.1080/15228916.2017.1416215.

Jaleta, M., Gebremedhin, B., & Hoekstra, D. (2009). *Smallholder commercialization: Processes, determinants and impact* (Discussion Paper No. 18; Improving Productivity and Market Success of Ethiopian Farmers Improving Market Opportunities). International Livestock Research Institute, Addis Ababa, Ethiopia.

Jayne, T. S., Haggblade, S., Minot, N., & Rashid, S. (2011). *Agricultural commercialization, rural transformation and poverty reduction: What have we learned about how to achieve this?* Synthesis report prepared for the African Agricultural Markets Programme Policy Symposium, Alliance for Commodity Trade in Eastern and Southern Africa April 20-22, 2011, Kigali, Rwanda.

Jayne, T. S., Mukumbu, M., Duncan, J., Staatz, J., Howard, J., Lundberg, M., Aldridge, K., Nakaponda, B., Ferris, J., Keita, F., & Sanankous, A. K. (1996). *Trends in real food prices in six sub-Saharan African countries* (Technical Paper No. 39; SD Publication Series). US Agency for International Development (USAID), Washington DC.

Jones, A. D., Shrinivas, A., & Bezner-Kerr, R. (2014). Farm production diversity is associated with greater household dietary diversity in Malawi: Findings from nationally representative data. *Food Policy*, *46*, 1–12. https://doi.org/10.1016/j.foodpol.2014.02.001.

Kennedy, G., Ballard, T., & Dop, M. (2011). *Guidelines for measuring household and individual dietary diversity*. https://www.fao.org/fileadmin/user_upload/wa_workshop/docs/FAO-guidelines-dietary-diversity2011.pdf.

Key, N., Sadoulet, E., & De de Janvry, A. (2000). Transactions costs and agricultural household supply response. *American Journal of Agricultural Economics*, *82*(2), 245–259. https://doi.org/10.1111/0002-9092.00022.

Kilimani, N., Buyinza, F., & Guloba, M. (2022). Crop commercialization and nutrient intake among farming households in Uganda. *Food Policy*, *113*. https://doi.org/10.1016/j.foodpol.2022.102328.

Koppmair, S., Kassie, M., & Qaim, M. (2017). Farm production, market access and dietary diversity in Malawi. *Public Health Nutrition*, *20*(2), 325–335. https://doi.org/10.1017/S1368980016002135.

Kuijpers, R. (2018). The effect of agricultural commercialization on farm household dietary intake: Evidence from Ethiopia, Bangladesh, and Rwanda. *Cintributed Paper at the 30th International Association of Agricultural Economists Conference, July 28-August 2, 2018, Vancouver, British Columbia*.

Kuma, T., Dereje, M., Hirvonen, K., & Minten, B. (2019). Cash crops and food security: Evidence from Ethiopian smallholder coffee producers. *Journal of Development Studies*, *55*(6), 1267–1284. https://doi.org/10.1080/00220388.2018.1425396.

Kumar, N., Harris, J., & Rawat, R. (2015). If They Grow It, Will They Eat and Grow? Evidence from Zambia on Agricultural Diversity and Child Undernutrition. *Journal of Development Studies*, *51*(8), 1060–1077. https://doi.org/10.1080/00220388.2015.1018901.

Kyaw, N. N., Ahn, S., & Lee, S. H. (2018). Analysis of the factors influencing market participation among smallholder rice farmers in Magway Region, Central Dry Zone of Myanmar. *Sustainability*, *10*(12). https://doi.org/10.3390/su10124441.

Lawal, J. O., Omonona, B. T., Ajani, O. I. Y., & Oni, O. A. (2009). Determinants of constraint to credit access among cocoa farming households in Osun State, Nigeria. *Pakistan Journal of Social Science*, *6*(3), 159–163.

Lewis, F., Butler, A., & Gilbert, L. (2011). *A unified approach to model selection using the likelihood ratio test*. *2*, 155–162. https://doi.org/10.1111/j.2041-210X.2010.00063.x.

Linderhof, V., Janssen, V., & Achterbosch, T. (2019). Does agricultural commercialization affect food security: The case of crop-producing households in the regions of Post-Reform Vietnam? *Sustainability*, *11*(5). https://doi.org/10.3390/su11051263.

Lovon, M., & Mathiassen, A. (2014). Are the world food programme's food consumption groups a good proxy for energy deficiency? *Food Security*, *6*(4), 461–470. https://doi.org/10.1007/s12571-014-0367-z.

M'Kaibi, F. K., Steyn, N. P., Ochola, S. A., & Du Plessis, L. (2017). The relationship between agricultural biodiversity, dietary diversity, household food security, and stunting of children in rural Kenya. *Food Science and Nutrition*, *5*(2), 243–254. https://doi.org/10.1002/fsn3.387.

Magnan, N., Spielman, D. J., Lybbert, T. J., & Gulati, K. (2015). Leveling with friends: Social networks and Indian farmers' demand for a technology with heterogeneous benefits. *Journal of Development Economics*, *116*, 223–251. https://doi.org/10.1016/j.jdeveco.2015.05.003.

Maluccio, J. A., Hoddinott, J., Behrman, J. R., Martorell, R., Quisumbing, A. R., & Stein, A. D. (2009). The impact of improving nutrition during early childhood on education among Guatemalan adults. *Economic Journal*, *119*(537), 734–763. https://doi.org/10.1111/j.1468-0297.2009.02220.x.

Manda, J., Azzarri, C., Feleke, S., Kotu, B., Claessens, L., & Bekunda, M. (2021). Welfare impacts of smallholder farmers' participation in multiple output markets: Empirical evidence from Tanzania. *PLoS ONE*, *16*(5). https://doi.org/10.1371/journal.pone.0250848.

Mariyono, J. (2018). Profitability and determinants of smallholder commercial vegetable production. *International Journal of Vegetable Science*, *24*(3), 274–288. https://doi.org/10.1080/19315260.2017.1413698.

Martey, E., Al-Hassan, R. M., & Kuwornu, J. K. M. (2012). Commercialization of smallholder agriculture in Ghana: A Tobit regression analysis. *African Journal of Agricultural Research*, *7*(14), 2131–2141. https://doi.org/10.5897/AJAR11.1743.

Matita, M., Chiwaula, L., Chirwa, E. W., Mazalale, J., & Walls, H. (2022). Subsidizing improved legume seeds for increased household dietary diversity: Evidence from Malawi's farm input subsidy programme with implications for addressing malnutrition in all its forms. *Food Policy*, *113*. https://doi.org/10.1016/j.foodpol.2022.102309.

Megerssa, G. R., Negash, R., Bekele, A. E., & Nemera, D. B. (2020). Smallholder market participation and its associated factors: Evidence from Ethiopian vegetable producers. *Cogent Food and Agriculture*, *6*(1). https://doi.org/10.1080/23311932.2020.1783173.

Ministry of Food and Agriculture-International Food Policy Research Institute. (2020). *Ghana's maize market*. https://www.ifpri.org/publication/ghanas-maize-market.

Ministry of Food and Agriculture. (2009). *Agriculture Sector Plan 2009 – 2015*. Ministry of Food and Agriculture, Accra, Ghana.

Ministry of Food and Agriculture. (2017). *Planting for Food and Jobs: Strategic Plan for Implementation (2017–2020)*. Accra, Ghana.

Ministry of Food and Agriculture. (2021). *Facts and figures: Agriculture in Ghana, 2020*. Ministry of Food and Agriculture, Accra, Ghana.

Minten, B., Randrianarison, L., & Swinnen, J. F. M. (2009). Global Retail Chains and Poor Farmers: Evidence from Madagascar. *World Development*, *37*(11), 1728–1741. https://doi.org/10.1016/j.worlddev.2008.08.024.

Misra, R., Chavan, P., & Verma, R. (2016). Agricultural credit in India in the 2000s: Growth, distribution and linkages with productivity. *Margin—The Journal of Applied Economic Research*, *10*(2), 169–197. https://doi.org/10.1177/0973801015625378.

Mmbando, F. E., Wale, E. Z., & Baiyegunhi, L. J. S. (2015). Welfare impacts of smallholder farmers' participation in maize and pigeonpea markets in Tanzania. *Food Security*, *7*, 1211–1224. https://doi.org/10.1007/s12571-015-0519-9.

Montalbano, P., Pietrelli, R., & Salvatici, L. (2018). Participation in the market chain and food security: The case of the Ugandan maize farmers. *Food Policy*, *76*, 81–98. https://doi.org/10.1016/j.foodpol.2018.03.008.

Muamba, F. M. (2011). Selling at the farmgate or traveling to the market: A conditional farm-level model. *The Journal of Developing Areas*, *44*(2), 95–107. https://www.jstor.org/stable/23215242.

Muriithi, B. W., & Matz, J. A. (2015). Welfare effects of vegetable commercialization: Evidence from smallholder producers in Kenya. *Food Policy*, *50*, 80–91. https://doi.org/10.1016/j.foodpol.2014.11.001.

Narayanan, S. (2016). The productivity of agricultural credit in India. *Agricultural Economics*, *47*(4), 399–409. https://doi.org/10.1111/agec.12239.

Navarro, S. (2010). Control functions. In S. N. Durlauf & L. E. Blume (Eds.), *Microeconometrics* (1st ed.). Palgrave Macmillan. https://doi.org/10.1057/9780230280816_4.

Nkegbe, P. K., & Abdul Mumin, Y. (2022). Impact of community development initiatives and access to community markets on household food security and nutrition in Ghana.

Food Policy, *113*. https://doi.org/10.1016/j.foodpol.2022.102282.

Nkegbe, P. K., Araar, A., Abu, B. M., Alhassan, H., Ustarz, Y., Setsoafia, E. D., & Abdul-Wahab, S. (2022). Nonfarm activity and market participation by farmers in Ghana. *Agricultural and Food Economics*, *10*(4). https://doi.org/10.1186/s40100-022-00210-1.

Nxumalo, K. K. S., Oduniyi, O. S., Antwi, M. A., & Tekana, S. S. (2019). Determinants of market channel choice utilised by maize and sunflower farmers in the North West province, South Africa. *Cogent Social Sciences*, *5*(1). https://doi.org/10.1080/23311886.2019.1678451.

Ochieng, J., Knerr, B., Owuor, G., & Ouma, E. (2015). Agricultural commercialization and household food security: The case of smallholders in Great Lakes Region of Central Africa. *Contributed Paper at the International Conference of Agricultural Economists (ICAE), Milan, Italy, August 8-14, 2015*.

Ochieng, J., Knerr, B., Owuor, G., & Ouma, E. (2019). Food crops commercialization and household livelihoods: Evidence from rural regions in Central Africa. *Agribusiness*, *36*(2), 318–338. https://doi.org/10.1002/agr.21619.

Ogutu, S. O., Gödecke, T., & Qaim, M. (2020). Agricultural Commercialisation and Nutrition in Smallholder Farm Households. *Journal of Agricultural Economics*, *71*(2), 534–555. https://doi.org/10.1111/1477-9552.12359.

Ogutu, S. O., & Qaim, M. (2019). Commercialization of the small farm sector and multidimensional poverty. *World Development*, *114*, 281–293. https://doi.org/10.1016/j.worlddev.2018.10.012.

Olwande, J., & Mathenge, M. (2012). Market participation among poor rural households in Kenya. *Contributed Paper at the International Association of Agricultural Economists Triennial Conference, Brazil. 18-24 August 2012*.

Olwande, J., Smale, M., Mathenge, M. K., Place, F., & Mithöfer, D. (2015). Agricultural marketing by smallholders in Kenya: A comparison of maize, kale and dairy. *Food Policy*, *52*, 22–32. https://doi.org/10.1016/j.foodpol.2015.02.002.

Omamo, S. W. (1998). Farm-to-market transaction costs and specialisation in small-scale agriculture: Explorations with a non-separable household model. *Journal of Development Studies*, *35*(2), 152–163. https://doi.org/10.1080/00220389808422568.

Omiti, J. M., Otieno, D. J., Nyanamba, T. O., & McCullough, E. (2009). Factors influencing the intensity of market participation by smallholder farmers: A case study of rural and peri-urban areas of Kenya. *African Journal of Agricultural and Resource Economics*, *3*(1), 57–82.

Ouedraogo, S. A. (2018). Agricultural commercialisation and food crop productivity as pathways to poverty reduction among smallholder farmers in rural Burkina Faso [University of Ghana]. In *Thesis*. https://ugspace.ug.edu.gh/handle/123456789/23180.

Owusu, O., & İşcan, T. B. (2021). Drivers of farm commercialization in Nigeria and Tanzania. *Agricultural Economics*, *52*(2), 265–299. https://doi.org/10.1111/agec.12618.

Papke, L. E., & Wooldridge, J. M. (1996). Econometric methods for fractional response variables with an application to 401(k) plan participation rates. *Journal of Applied Econometrics*, *11*(6), 619–632. https://doi.org/10.1002/(SICI)1099-1255(199611)11:6<619::AID-JAE418>3.0.CO;2-1.

Papke, L. E., & Wooldridge, J. M. (2008). Panel data methods for fractional response variables with an application to test pass rates. *Journal of Econometrics*, *145*(1–2), 121–133. https://doi.org/10.1016/j.jeconom.2008.05.009.

Parappurathu, S., Kumar, A., Bantilan, M. C. S., & Joshi, P. K. (2015). Food consumption patterns and dietary diversity in eastern India: evidence from village level studies (VLS). *Food Security*, *7*(5), 1031–1042. https://doi.org/10.1007/s12571-015-0493-2.

Peasant Farmers Association of Ghana. (2019). *An assessment of the planting for food and*

jobs programme. Peasant Farmers Association of Ghana (PFAG), Accra, Ghana.

Pingali, P. L. (1997). From subsistence to commercial production systems: The transformation of Asian agriculture. *American Journal of Agricultural Economics*, *79*(2), 628–634. https://doi.org/10.2307/1244162.

Pingali, P. L., Aiyar, A., Abraham, M., & Rahman, A. (2019). Linking farms to markets: Reducing transaction costs and enhancing bargaining power. In P. Pingali, A. Aiyar, M. Abraham, & A. Rahman (Eds.), *Transforming Food Systems for a Rising India. Palgrave Studies in Agricultural Economics and Food Policy* (pp. 193–214). Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-030-14409-8_8.

Pingali, P. L., Khwaja, Y., & Meijer, M. (2005). *Commercializing small farms: Reducing transaction costs* (ESA Working Paper No. 05-08; FAO). http://www.fao.org/3/a-af144t.pdf.

Pingali, P. L., & Rosegrant, M. W. (1995). Agricultural commercialization and diversification: processes and policies. *Food Policy*, *20*(3), 171–185. https://doi.org/10.1016/0306-9192(95)00012-4.

Pradhan, K., Dewina, R., & Minsten, B. (2010). *Agricultural commercialisation and diversification in Bhutan*. International Food Policy Research Institute, Washington DC.

Radchenko, N., & Corral, P. (2018). Agricultural commercialisation and food security in rural economies: Malawian experience. *Journal of Development Studies*, *54*(2), 256–270. https://doi.org/10.1080/00220388.2017.1283014.

Rashid, S., Winter-nelson, A., & Garcia, P. (2010). *Purpose and potential for commodity exchanges in African economies* (Discussion Paper No. 01035). International Food Policy Research Institute, Washington DC.

Remans, R., DeClerck, F. A. J., Kennedy, G., & Fanzo, J. (2015). Expanding the view on the production and dietary diversity link: Scale, function, and change over time. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(45), e6082. https://doi.org/10.1073/pnas.1518531112.

Reyes, B., Donovan, C., Bernsten, R., & Maredia, M. (2012). Market participation and sale of potatoes by smallholder farmers in the central highlands of Angola: A double hurdle approach. *Contributed Paper at the International Association of Agricultural Economists (IAAE) Triennial Conference*. International Association of Agricultural Economists.

Ricardo, D. (1817). *On the principles of political economy and taxation* (First Edit). John Murray.

Ricker-Gilbert, J., & Jayne, T. S. (2009). Do fertilizer subsidies affect the demand for commercial fertilizer? An example from Malawi. *Contributed Paper at the International Association of Agricultural Economists Triennial Conference, Beijing, China*. International Association of Agricultural Economists.

Ricker-Gilbert, J., Jayne, T. S., & Chirwa, E. (2011). Subsidies and crowding out: A double-hurdle model of fertilizer demand in Malawi. *American Journal of Agricultural Economics*, *93*(1), 26–42. https://doi.org/10.1093/ajae/aaq122.

Rios, A. R., Masters, W. A., & Shively, G. E. (2008). Linkages between market participation and productivity: results from a multi-country farm household sample. *Contributed Paper at the American Agricultural Economics Association Annual Meeting, Orlando, FL, July 27-29, 2008*. American Agricultural Economics Association.

Rios, A. R., Shively, G. E., & Masters, W. (2009). Farm productivity and household market participation: Evidence from LSMS Data. *Contributed Paper at the International Association of Agricultural Economists Conference, Beijing, China*. International Association of Agricultural Economists.

Robinson, L., & Flintan, F. (2022). Can formalisation of pastoral land tenure overcome its

paradoxes? Reflections from East Africa. *Pastoralism*. https://doi.org/10.1186/s13570-022-00250-8.

Roodman, D. (2011). Fitting fully observed recursive mixed-process models with cmp. *The Stata Journal*, *11*(2), 159–206. https://doi.org/10.1177/1536867x1101100202.

Seini, A. W. (2002). Political instability and agricultural policy dynamics in Ghana. *Verfassung Und Recht in Übersee*, *35*(3), 414–430. https://www.jstor.org/stable/43239049.

Sekyi, S., Abu, B. M., & Nkegbe, P. K. (2017). Farm credit access, credit constraint and productivity in Ghana: Empirical evidence from Northern Savannah ecological zone. *Agricultural Finance Review*, *77*(4), 446–462. https://doi.org/10.1108/AFR-10-2016-0078.

Sekyi, S., Abu, B. M., & Nkegbe, P. K. (2020). Effects of farm credit access on agricultural commercialization in Ghana: Empirical evidence from the northern Savannah ecological zone. *African Development Review*, *32*(2), 150–162. https://doi.org/10.1111/1467-8268.12424.

Seng, K. (2016). *The effects of market participation on farm households' food security in Cambodia: An endogenous switching approach* (Paper No. 69669; Munich Personal RePEc Archive (MPRA)). https://mpra.ub.uni-muenchen.de/69669/1/MPRA_paper_69669.pdf.

Sheahan, M., & Barrett, C. B. (2017). Ten striking facts about agricultural input use in Sub-Saharan Africa. *Food Policy*, *67*, 12–25. https://doi.org/10.1016/j.foodpol.2016.09.010.

Shilpi, F., & Umali-deininger, D. (2007). *Where to sell? Market facilities and agricultural marketing* (Paper No. WPS4455; Policy Research Working Papers). World Bank, Washington DC.

Sibhatu, K. T., Arslan, A., & Zucchini, E. (2022). The effect of agricultural programs on dietary diversity and food security: Insights from the smallholder productivity promotion program in Zambia. *Food Policy*, *113*. https://doi.org/10.1016/j.foodpol.2022.102268.

Singh, I., Squire, L., & Strauss, J. (1986). *Agricultural household models: Extensions, applications, and policy*. Johns Hopkins University Press.

Southgate, D., Graham, D., & Tweeten, L. (2007). *The world food economy*. Blackwell Publishing Ltd.

Steiner-Asiedu, M., Dittoh, S., Newton, S. K., & Akotia, C. (2017). *Addressing Sustainable Development Goal 2: The Ghana zero hunder strategic review*. World Food Programme. Accra, Ghana.

Stifel, D., & Minten, B. (2017). Market access, well-being, and nutrition: Evidence from Ethiopia. *World Development*, *90*, 229–241. https://doi.org/10.1016/j.worlddev.2016.09.009.

Stifel, D., Minten, B., & Koru, B. (2016). Economic benefits of rural feeder roads: Evidence from Ethiopia. *Journal of Development Studies*, *52*(9), 1335–1356. https://doi.org/10.1080/00220388.2016.1175555.

Strasberg, P. J., Jayne, T. S., Yamano, T., Nyoro, J., Karanja, D., & Strauss, J. (1999). *Effects of agricultural commercialisation on food crop input use and productivity in Kenya* (Working Paper No. 71; International Development Working Papers). Michigan State University (MSU).

Tafesse, A., Megerssa, G. R., & Gebeyehu, B. (2020). Determinants of agricultural commercialization in Offa District, Ethiopia. *Cogent Food and Agriculture*, *6*(1). https://doi.org/10.1080/23311932.2020.1816253.

Tesfay, M. G. (2020). Does fertilizer adoption enhance smallholders' commercialization? An endogenous switching regression model from northern Ethiopia. *Agriculture and Food Security*, *9*, 1–18. https://doi.org/10.1186/s40066-020-0256-y.

Tesfaye, W. (2022). Crop diversification and child malnutrition in rural Ethiopia: Impacts and Pathways. *Food Policy*, *113*(August), 102336. https://doi.org/10.1016/j.foodpol.2022.102336.

Thurow, R., & Kilman, S. (2009). *Enough: Why the world's poorest starve in an age of plenty*. New York: Public Affairs.

Touch, V., Tan, D. K. Y., Cook, B. R., Liu, D. L., Cross, R., Tran, T. A., Utomo, A., Yous, S., Grunbuhel, C., & Cowie, A. (2024). Smallholder farmers' challenges and opportunities: Implications for agricultural production, environment and food security. *Journal of Environmental Management*, *370*. https://doi.org/10.1016/j.jenvman.2024.122536.

UN. (2010). *Fact Sheet No. 34: The Right to Adequate Food*. https://digitallibrary.un.org/record/681497?ln=en.

UNICEF, WHO, & World Bank. (2020). *Levels and trends in child malnutrition: Key findings of the 2020 Edition of the Joint Child Malnutrition Estimates*. https://apps.who.int/iris/rest/bitstreams/1344826/retrieve.

Upton, M. (2004). *The role of livestock in economic development and poverty reduction* (Working Paper No. 10; Pro-Poor Livestock Policy Initiative). https://www.fao.org/3/bp224e/bp224e.pdf.

Usman, M. A., & Haile, M. G. (2022). Market access, household dietary diversity and food security: Evidence from Eastern Africa. *Food Policy*, *113*. https://doi.org/10.1016/j.foodpol.2022.102374.

van Asselt, J., & Useche, P. (2022). Agricultural commercialization and nutrition; evidence from smallholder coffee farmers. *World Development*, *159*. https://doi.org/10.1016/j.worlddev.2022.106021.

Vandercasteelen, J., Dereje, M., Minten, B., & Taffesse, A. S. (2020). From agricultural experiment station to farm: The impact of the promotion of a new technology on farmers' yields in Ethiopia. *Economic Development and Cultural Change*, *68*(3), 965–1007. https://doi.org/10.1086/701234.

Villacis, A. H., Mayorga, J., & Mishra, A. K. (2022). Experience-based food insecurity and agricultural productivity in Nigeria. *Food Policy*, *113*. https://doi.org/10.1016/j.foodpol.2022.102286.

von Braun, J. (1995). Agricultural commercialization: Impacts on income and nutrition and implications for policy. *Food Policy*, *20*(3), 187–202. https://doi.org/10.1016/0306-9192(95)00013-5.

von Braun, J., & Kennedy, E. (1994). *Commercialisation of agriculture, economic development and nutrition* (J. von Braun & E. Kennedy (eds.)). Johns Hopkins Press.

Wagner, N., & Tasciotti, L. (2018). Urban agriculture, dietary diversity and child health in a sample of Tanzanian town folk. *Canadian Journal of Development Studies*, *39*(2), 234–251. https://doi.org/10.1080/02255189.2017.1375902.

Wambogo, E. A., Ghattas, H., Leonard, K. L., & Sahyoun, N. R. (2018). Validity of the food insecurity experience scale for use in sub-Saharan Africa and characteristics of food-insecure individuals. *Current Developments in Nutrition*, *2*(9). https://doi.org/10.1093/cdn/nzy062.

Wedig, K., & Wiegratz, J. (2018). Neoliberalism and the revival of agricultural cooperatives: The case of the coffee sector in Uganda. *Journal of Agrarian Change*, *18*(2), 348–369. https://doi.org/10.1111/joac.12221.

WFP. (2008). *Food consumption analysis: Calculation and use of the food consumption score in food security analysis*. https://documents.wfp.org/stellent/groups/public/documents/manual_guide_proced/wfp197216.pdf.

WFP. (2015). *Food consumption score nutritional quality analysis (FCS-N) guidelines*. https://docs.wfp.org/api/documents/WFP-0000007074/download/.

WHO. (2011). *WHO Anthro for personal computers* (version 3.2.2). World Health Organisation (WHO).

Woldehanna, T., & Oskam, A. (2001). Off-farm employment and income inequality: The implication for poverty reduction strategy. *Ethiopian Journal of Economics*, *9*(1), 40–57.

Wooldridge, J. M. (2002). *Econometric analysis of cross section and panel data*. Massachusetts Institute of Technology.

Wooldridge, J. M. (2015). Control function methods in applied econometrics. *The Journal of Human Resources*, *50*(2), 420–445.

World Bank. (2008). *World Development Report: Agriculture for Development*. Washington DC.

World Bank. (2017). *Ghana: Agriculture sector policy note: Transforming Agriculture for Economic Growth, Job Creation and Food Security*. http://hdl.handle.net/10986/28394

World Bank. (2024). *World Development Indicators*. World Bank. https://databank.worldbank.org/source/world-development-indicators#.

Yamane, T. (1967). *Statistics, an introductory analysis* (2nd ed.). Harper and Row.

Yaro, J. A., Teye, J. K., & Nyaaba, C. K. (2018). *The smallholder farmers in Ghana's food systems*. Peasant Farmers Association of Ghana. Accra, Ghana.

Ziska, L., Crimmins, A., Auclair, A., DeGrasse, S., Garofalo, J. F., Khan, A. S., Loladze, I., Pérez de León, A. A., Showler, A., Thurston, J., & Walls, I. (2016). Food safety, nutrition, and distribution. In *The impacts of climate change on human health in the United States: A Scientific Assessment* (pp. 190–216). https://doi.org/10.7930/J0ZP4417.

APPENDICES

Appendix 1A: Household questionnaire (for primary data)

DEPARTMENT OF AGRICULTURAL ECONOMICS AND AGRIBUSINESS
COLLEGE OF BASIC AND APPLIED SCIENCES
UNIVERSITY OF GHANA, LEGON

HOUSEHOLD QUESTIONNAIRE ON THE STUDY "FARM HOUSEHOLDS' AGRICULTURAL COMMERCIALISATION AND FOOD AND NUTRITION SECURITY IN GHANA

2021/2022 PRODUCTION SEASON

PRELIMINARY INFORMATION

REGION: ……. DISTRICT……

COMMUNITY NAME……. COMMUNITY ID: …….

HOUSEHOLD ID: ……

HOUSEHOLD UNIQUE SERIAL NUMBER: ……

GPS COORDINATES: …….

SUPERVISOR: ……..

ENUMERATOR: ……...

TEAM: ……..……...

HOUSEHOLD CONTACT(S): 1…….. 2……

DATE OF INTERVIEW: ……...

SECTION A: Socio-demographic Information

A01 What is the family type of the household? 1 Nuclear 2 Extended 3 Other (specify)	A02 What type of marriage is the household head practicing? 1 Polygamous 2 Monogamous 3 Other (specify)

A03 Number of people in household:

MEMBER ID	A04 Sex 0=Female 1=Male	A05 What is the relationship of (NAME) to head? **Code A**	A06 How old is (NAME)? [Years and months if < 5 years, otherwise years only]		ONLY 12 YEARS OR OLDER		A09 What is your religious denomination? **Code C**	A10 To which ethnic group do you belong? **Code D**	A11 What is your settlement status? 0=Settler 1=Native	A12 What is your highest level of education attained? **Code E**	A13 What is the highest grade completed at that level? **Code F**	A14 What was the highest educational qualification attained? **Code G**
			Yrs	Mth.	A07 What is (NAME'S) present marital status? **Code B**	A08 At what age did (NAME) first get married or start living with a partner?						
01												
02												
03												
04												
05												
06												
07												
08												
09												
10												
11												
12												
13												
14												
15												

Code A	**Code B**	**Code C**	**Codes D**		**Code E**		**Code F**	
1 Head	1 Married	1 No religion	1 Ahafo	12 Grunsi	0 None	8 Polytechnic	00 None	21 M2
2 Spouse (wife/husband)	2 Consen. union	2 Christianity	2 Akan	13 Hausa	1 Kindergarten	9 Univ.(bach.)	33 L6	
3 Child (son/daughter)	3 Separated	3 Islam	3 Bimoba	14 Kassena	2 Primary	10 Uni. (postgrad.)	01 Pre-school	22 M3
4 Grandchild	4 Divorced	4 Trad./Spiritualist	4 Bono	15 Konkomba	3 JSS/JHS	11 Professional	34 U6	
5 Parent/parent-in-law	5 Widowed	5 Atheist	5 Chekosi	16 Kusasi	4 Middle	12 Don't know	11 P1	23 M4
6 Son/daughter-in-law	6 Never married	6 Other (specify)	6 Dagaaba	17 Mamprusi	5 SSS/SHS	13 Other (spec.)	41 Year 1	
7 Other relative			7 Dagomba	18 Nankan	6 Voc/Tech/Comm		12 P2	24 SSS1/SHS1

8 Adopted/foster/stepchild 9 House help (other relative) 10 House help (non-relative) 11 Non-relative 12 Other (specify)			8 Ewe 19 Nanumba 9 Frafra 20 Sissala 10 Ga-Adangbe 21 Wala 11 Gonja 22 Other (spe.)	7 Teacher, Agric/Nursing Training	42 Year 2 13 P3 25 SSS2/SHS2 43 Year 3 14 P4 26 SSS3/SHS3 44 Year 4 15 P5 27 SHS4 45 Year 5 16 P6 28 S1 46 Year 6, above 17 JSS1/JHS1 29 S2 61 Other (specify) 18 JSS2/JHS2 30 S3 98 Don't know 19 JSS3/JHS3 31 S4 20 M1 32 S5

Code G

0 None
1 BECE 5 'A' Level 9 Bachelor's degree
2 MSLC 6 Certificate 10 Master's degree
3 SSCE/WASSCE 7 Diploma 11 PHD
4 'O' Level 8 HND 12 Other professional (ACCA, ICA, CIMA, CIB, etc)

SECTION A: Socio-demographic Information (continued)

A15 Can you read a phrase/ sentence in English? 0=No 1=Yes	A16 Can you write a sentence in English? 0=No 1=Yes	A17 Can you do written calculations? 0=No 1=Yes	A18 In what Ghanaian language can you read a phrase or sentence? **Code H**	A19 In what Ghanaian language can you write a sentence? **Code H**	A20 Have you ever attended an adult literacy course? 0=No 1=Yes	A21 What is your main secondary occupation? **Code I**	A22 During the 2021/22 season did you suffer from either an illness or injury? 1=Neither (>> A26) 2=Illness 3=Injury 4=Both	A23 How many times during the season did you suffer from this condition?	A24 Did you have to stop the farm activities because of this condition? 0=No >> A26 1=Yes	A25 For how many days did you stop operation on the farm in the season?	A26 Have you ever been registered with a health insurance scheme? **Code J**	A27 Are you currently covered? 0=No 1=Yes

Code H			Code I				Code J	
0 None	3 Ga-Dangme	6 Nzema	0 None	3 Agric. trader	6 Store operator	9 Don't know	0 No	2 Yes, registered private
1 Twi/Fanti	4 Dagbani	7 Wali/Dagari	1 Casual farm lab.	4 Artisan	7 Housekeeping		1 Yes, registered NHIS	3 Yes, NHIS and priv.
2 Ewe	5 Frafra/Grusi	8 Other (spec.)	2 Casual nonfarm lab.	5 Security service	8 Other (specify)			

SECTION B: Production, Harvest, Sales and Purchases of Crops

Part 1: Production

B101 How much agriculture land does your household have access to (or under your control) now?		B102 What is the number of years engaged in farming (in general up to 2021/22 farming season)?	B103 How many years have you been farming maize on your own (up to the 2021/22 season)?	B104 What type of maize variety did you plant? **Code L**	B105 What quantity of seed did you plant?		B106 What proportion of farm was under the dominant variety? >> B107 if response in B104 is 1-4	B107 Where did you get this maize variety? **Code N**	B108 If you planted improved seeds, how many years have you been cultivating it?	B109 Have you been consistent in your use of improved seeds since you started using them? 0=No 1=Yes
Area	Unit **Code K**				Q'ty	Unit **Code M**				

Code K	Code L	Code M		Code N	
1 Acre	1 Local, same variety	1 Mini bag (50kg)	5 Bowl (2.5kg)	0 Own storage	3 Purchased from input dealer
2 Hectare	2 Local, different varieties	2 Maxi bag (100kg)	6 American tin (2.5kg)	1 Purchased from open market	4 Gift
3 Plot	3 Improved, same variety	3 Maxi bag (150kg)	7 Margarine tin (0.5kg)	2 Purchased from gov't agency	5 Pre-contract arrangement
4 Pole	4 Improved, different varieties	4 Kilogram	8 Other (spec.)	6 Other (specify)	
5 Rope	5 Local and improved, more improved				
6 Other (spec)	6 Local and improved, more local				

B110 Why did you not cultivate improved seeds? **Code O**	B111 Did you apply fertiliser on your maize farmland(s)? 0= No >> B113 1= Yes	B112 What was the total cost incurred on fertiliser? (GHS)	B113 Did you apply pesticides? 0=No >> B115 1=Yes	B114 What was the total expenditure on pesticides? (GHS)	B115 Did you apply weedicides? 0=No >> B118 1=Yes	B116 What was the total expenditure on weedicides? (GHS)	B117 Did you apply green manure? 0=No 1=Yes	B118 Did you apply animal manure? 0=No 1=Yes	B119 Did you apply composted manure? 0=No 1=Yes	B120 What was the dominant type of cropping you adopted in the 2021/2022 cropping season? 0=Mono cropping 1=Multi cropping 2=Both, more mono cropping 3=Both, more multi cropping

B121 What is your perception about the natural fertility of the land cultivated? **Code P**	B122 What is the dominant texture of soils on this farm? **Code Q**	B123 How wet were your maize land(s) compared to other lands in your community? 1=less wet 2=same as others 3=more wet	B124 What is the slope of this land? 1=Plain 2=Gentle 3=Hilly	B125 Is the land watered from a source other than rain? 0=No >> B127 1=Yes	B126 What is your primary source of watering? **Code R**	B127 How long have you been farming this land in years?	B128 Do you practice soil and water conservation? 0=No >> B131 1=Yes	B129 Which type(s) do you practice? *[Multiple responses*] **Code S**	B130 What is the dominant practice? **Code S**

Code O	**Code P**	**Code Q**	**Code R**	**Code S**
1 Cannot get seed at all 6 Requires more 11 Requires skills 2 Lack of cash to buy seed 7 Don't know how to use it 12 Expensive 3 Susceptible to pests/diseases 8 Low yielding 13 Can't get credit 4 Susceptible to storage pests 9 Poor market price 14 Need for other crops 5 Poor taste 10 No market 15 Other specify)	1 Fertile 2 Moderately fertile 3 Less fertile 4 Infertile	1 Sandy 2 Rocky/gravely 3 Clay filled 4 Silty 5 Loamy 6 Other (spec.)	1 Well 2 Borehole 3 Pond/tank 4 Weir 5 River/stream 6 Other (spec.)	1 Crop rotation 5 Minimal tillage 2 Land enriching cover crops 6 Composting 3 Legumes 7 Agroforestry 4 Zero tillage 8 Other (specify)

Did you use items on plot in the 2021/22 farming season?						B137	B138		B139	B140	B141	B142	B143
B131 Tractor 0=No >> B133 1=Yes	B132 Cost (give money value if in kind) (GHS)	B133 Drought animal 0=No >> B135 1=Yes	B134 Cost (give money value if in kind) (GHS)	B135 Hand 0=No >> B137 1=Yes	B136 Cost (give money value if in kind) (GHS)	Location of majority of farm(s) **Code T** If 1 >> B139	How far is this farm from your home?		Did you have any contact with extension agent in the 2021/22 season? 0=No >> B142 1=Yes	How many working visits did you have with the extension officer (s)?	Which type(s) of services did you receive from the extension officer **Code V**	What is your orientation towards farming in general? **Code W**	What is your orientation towards maize farming? **Code W**
							Dist.	Unit **Code U**					

Code T	**Code U**	**Code V**	**Code W**
1 Within the homestead 2 Outside the homestead, same village 3 Outside the homestead,	1 Mile 2 Kilometre 3 Metre 4 Other (spec.)	1 Use of seeds 4 Mechanisation 7 Animal husbandry 10 Other 2 Planting 5 Credit facilities 8 Use of chemicals 3 Use of fertiliser 6 Irrigation 9 Post harvest services	1 Primarily for consumption 4 Both, but more market 2 Primarily for market 5 Other (specify) 3 Both, but more consumption

different village 4 Other (specify)			

Activity	Family						Hired					
	B144 Did you use family labour? 0=No >> B145 1=Yes						B145 Did you use hired labour? 0=No >> B146 1=Yes					
	Man		Woman		Children (<18 years)		Man			Woman		
	Num.	Days	Num.	Days	Num.	Days	Num.	Days	Rate/day (GHS)	Num.	Days	Rate/day (GHS)
Clearing												
Ploughing												
Planting												
Chem. application												
Weeding/weed control												
Harvesting												
B146 Did you use communal labour for any activity in the 2021/22 season? 0=No 1=Yes												

Part 2: Harvest, sales and purchases of crops

B201 Did you produce/harvest any other crop(s) apart from maize? 0=No >> B208 1=Yes	B202 Please identify all the major crops that were produced/harvested in the 2021/22 production season apart from maize. [*This is a multiple response question*]	B203 What was the farm size of the harvest?		B204 What quantity was harvested of crop?		B205 Did you sell crop? 0=No >> Next crop in B202/B208 1=Yes	B206 What quantity was sold within the season?		B207 What was the total value of sale in the season? (GHS)
		Size	Unit **Code K**	Q'ty	Unit **Code X**		Q'ty	Unit **Code X**	

B208 What quantity of maize did the household harvest from all farm areas in the 2021/22 season?	B209 Which month did you harvest all or most of the maize produce?	B210 Size of all farm areas cultivated?	B211 Was any quantity lost during harvest?	B212 What quantity of maize was lost during harvest?	B213 How was the maize harvested? 0= By hand 1=By machine	B214 How did you store the harvest? **Code Z** If 0 (not stored)	B215 Did you treat harvest under storage with chemicals/l	B216 Did you sell maize? 0=No >> B292	B217 Which specific month did you sell most of the	B218 Did you find out about market conditions before sale?	B219 What was/were the infor. source? [*Multiple*	B220 What was the dominant source of market information?	B221 What was your pattern of sale of maize?

Q't y	Unit **Code X**	**Code Y**	Are a	Unit **Code K**	0=No >> B213 1=Yes	Q't y	Unit **Code X**	2=Both 3=Other	>> B216	ocal concoctions? 0=No 1=Yes	1=Yes	produce? **Code Y**	0=No >> B221 1=Yes	*response*] **Code AA**	**Code AA**	0=Single outlet 1=Multiple outlets >> B254

Code X		**Code Y**		**Code Z**	**Code AA**	
1 Mini bag (50kg)	9 Basket	1 May 2021	7 November 2021	0 Not stored	1 Telephone/cell phone	8 GOs
2 Maxi bag (100kg)	10 Box/carton	2 June 2021	8 December 2021	1 Local silo at home/farm	2 Friends/relatives	9 NGOs
3 Maxi bag (150kg)	11 Bunch	3 July 2021	9 January 2022	2 In bags at home/farm	3 Radio	10 FBO
4 Kilogram	12 Fingers	4 August 2021	10 February 2022	3 With private aggregator	4 TV (ESOKO, e AGRI)	11 ICT platform
5 Bowl (2.5kg)	13 Bundle	5 September 2021	11 March 2022	4 Cooperative/FBO facility	5 Traders	12 Other (specify)
6 American tin (2.5kg)	14 Dozen	6 October 2021	12 April 2022	5 Communal storage unit	6 Newspaper	
7 Margarin tin (0.5kg)	15 Other (specify)		13 May 2022	6 Other (specify)	7 Extension officer	
8 Tubers						

B222 What was the single outlet? **Code AB**	B223 How many times did you sell through this outlet up till now in the season?	B224 First quantity sold during and since harvest(s) in 2021/22		B225 What unit price did you sell first quantity? (GHS)	B226 Who did you specifically sell to? **Code AC**	B227 What was the principal reason for this sale? **Code AD**	**Skip B228-B231 if response to B222 is 1, 2 or 3**				B232 Did buyer provide you with any services? 0=No >> B234 1=Yes	B233 Which service(s) were you provided with? Multiple responses possible **Code AF**
		Q'ty	Unit **Code X**				B228 Distance to market for maize transported to the market for sale? Dist.	Unit of dist. **Code U**	B229 What was the transport cost to the market? (GHS)	B230 What other marketing costs did you incur? **Code AE**	B231 How much was spent on these costs? (GHS)	

Code AB	**Code AC**			**Code AD**	**Codes AE**	**Code AF**	
1 On the farm	1 Pre-harvest contractor dealer	5 Consumer outside c'ty	9 Input	1 Meeting household basic needs/necessities	0 None	1 Plough/tractor	6 Inorg. fert./chem.
2 In my house	2 Farm gate buyer aggregator	6 State trading organ.	10 Private	2 Had some surplus left	1 Market toll	2 Seeds	7 Organic fertiliser
3 Market in my c'ty	3 Market trader vendor	7 Cooperative/FBO	11 Food	3 Took advantage of favourable market con.	2 Loading/offloading	3 Weedicides/herbicides	8 Extension
4 Market outside my c'ty				4 To make profit	3 Comm.: search & neg.		
5 Other (specify)							

	4 Consumer in c'ty 8 Outgrower 12 Other (specify) 13 Don't know	5 When household was cash constrained 6 Anticipate a price decrease soon 7 Other (specify)	4 Packaging 5 Other (specify)	4 Post harvest chemicals 9 Transportation 5 Post harvest processing 10 Other (specify)

Skip B238-B241 if response to B222 is 1, 2 or 3

B234 Second quantity sold during and since harvest(s) in 2021/22		B235 What unit price did you sell second quantity? (GHS)	B236 Who did you specifically sell to? **Code AC**	B237 What was the principal reason for this sale? **Code AD**	B238 Distance to market for maize transported to the market for sale?		B239 What was the transport cost to the market? (GHS)	B240 What other marketing costs did you incur? **Code AE**	B241 How much was spent on these costs? (GHS)	B242 Did buyer provide you with any services? 0=No >> B244 1=Yes	B243 Which service(s) were you provided with? Multiple responses possible **Code AF**
Q'TY	UNIT **Code X**				Dist.	Unit of dist. **Code U**					

Skip B248-B251 if response to B222 is 1, 2 or 3

B244 All other quantity sold during and since harvest(s) in 2021/22		B245 What unit price did you sell all other quantity? (GHS)	B246 Who did you specifically sell most to? **Code AC**	B247 What was the principal reason for these sales? **Code AD**	B248 Distance to market for maize transported to the market for sale?		B249 What was the transport cost to the market? (GHS)	B250 What other marketing costs did you incur? **Code AE**	B251 How much was spent on these costs? (GHS)	B252 Did buyer provide you with any services? 0=No >> B288 1=Yes	B253 Which service(s) were you provided with? Multiple responses possible **Code AF**
Q'TY	UNIT **Code X**				Dist.	Unit of dist. **Code U**					

Skip B261-B264 if response to B255 is 1, 2 or 3

B254 If multiple outlets, how many times did you sell	B255 What was the main outlet in terms of frequency?	B256 What proportion was sold through the main	B257 Quantity sold during and since harvest(s) through the	B258 What was the total value of sale in the 2021/22 season through the main outlet?	B259 Who did you specifically sell most of the	B260 What was the principal reason for this	B261 Distance to market for maize transported to the market for	B262 What was the transport cost to the	B263 What other marketing costs did you	B264 How much was spent on	B265 Did buyer provide you with any	B266 Which service(s) were you provided with?

through multiple outlets in the entire season?	**Code AB**	outlet	main outlet in 2021/22?		(GHS)	harvest to through the main outlet? **Code AC**	sale? **Code AD**	sale?		market? (GHS)	incur? **Code AE**	these costs? (GHS)	services? 0=No >> B267 1=Yes	Multiple responses possible **Code AF**
			Q'TY	UNIT **Code X**				Dist.	Unit of dist. **Code U**					

Skip B272-B275 if response to B255 is 1, 2 or 3

B267 What proportion was sold through the main outlet	B268 Quantity sold during and since harvest(s) through the main outlet in 2021/22?		B269 What was the total value of sale in the 2021/22 season through the main outlet? (GHS)	B270 Who did you specifically sell most of the harvest to through the main outlet? **Code AC**	B271 What was the principal reason for this sale? **Code AD**	B272 Distance to market for maize transported to the market for sale?		B273 What was the transport cost to the market? (GHS)	B274 What other marketing costs did you incur? **Code AE**	B275 How much was spent on these costs? (GHS)	B276 Did buyer provide you with any services? 0=No >> B278 1=Yes	B277 Which service(s) were you provided with? Multiple responses possible **Code AF**
	Q'TY	UNIT **Code X**				Dist.	Unit of dist. **Code U**					

Skip B282-B285 if response to B255 is 1, 2 or 3

B278 Quantity sold during and since harvest(s) through the rest of the outlets in 2021/22?		B279 What was the total value of sale in the 2021/22 season through the rest of the outlets? (GHS)	B280 Who mainly did you specifically sell the rest to? **Code AC**	B281 What was the principal reason for this sale? **Code AD**	B282 Distance to market for maize transported to the market for sale?		B283 What was the transport cost to the market? (GHS)	B284 What other marketing costs did you incur? **Code AE**	B285 How much was spent on these costs? (GHS)	B286 Did buyer provide you with any services? 0=No >> B288 1=Yes	B287 Which services were you provided with? **Code AF**	B288 What do you consider maize primarily ? 0=Food 1=Cash	B289 When you sold most output, did you negotiate and/or bargain with buyer(s)? 0=No 1=Yes
Q'TY	UNIT **Code X**				Dist.	Unit of dist. **Code U**							

B290 Do you still have some produce left purposely for sale? 0=No >> B295 1=Yes	B291 What quantity is left purposely for sale?		B292 Why did you not sell maize in reference to B216? If not 1 (still waiting) >> B295 **Code AG**	B293 What quantity out of the total harvest would you sell?		B294 What specific month are you going to sell? **Code Y**	B295 What is the main use of income from crop sales? **Code AH**	B296 What proportion is used for this?	B297 What is the next main use of income? **Code AH**	B298 What proportion is used for this?	B299 What is the next main use of income? **Code AH**	B2100 What proportion is used for this?	B2101 Have you ever had contract with an entity/individual in your farming in the past 5 years prior to the 2021/22 farming season? 0=No >> B2103 1=Yes	B2102 When were prices determined between you and the contractor(s)? 0 =Before cultivation 1 =After harvest
	Q't y	Unit **Code X**		Q't y	Unit **Code X**									

Code AG			**Code AH**		
1 Still waiting to sell	3 For hh. Consumption	5 Price not good for me 7 Other (specify)	1 More for next year's agric. investments	3 More for household needs	5 Other (spec.)
2 Low output sell	4 Used as input in nonfarm bus.	6 Could not access market to	2 More for nonfarm investments	4 More for paying debts/loan	

B2103 Did you buy maize for household consumption in the 2021/22 season? 0=No >> B2104 1=Yes								
B2103a Quantity of maize purchased in 2021/22?	B2103b Unit of purchases **Code X**	B2103c What was the total value of maize purchases? (GHS)	B2103d Did you find out about market before buying? 0=No >> B2106f 1=Yes	B2103e What was the dominant source of information? **Code AA**	B2103f Where did you buy most of these? **Code AB**	B2103g If in the market, distance to purchase point?		B2103h Transport cost from the market? GHS
						Distance	Unit of distance **Code U**	

B2104 Income from aid (from NGO/Gov't) (GHS)	B2105 What amount of other non-classified income did you receive in the 2021/22? (GHS)	B2106 How much did you spend on other regular non-food items (e.g., electricity, utilities) in a regular	B2107 How much did you spend on other non-regular non-food items (e.g., funerals, remittance, gifts, weddings etc.) in the 2021/2022 season? (GHS)

		month? (GHS)	

SECTION C: Livestock and other Assets

Animal	C01 Do you own any animal prior to the 2021/22 season? 0=No >> next animal/C06 1=Yes	C02 How many is owned currently?	C03 Did you sell any …. in the 2021/22 season? 0=No >> C06 1=Yes	C04 How many?	C05 What was the total value of sale? (GHS)	C06 Did you buy any …. in the 2021/22 season? 0=No >> next animal/C09 1=Yes	C07 How many?	C08 What was the total value of purchase? (GHS)
Cattle								
Sheep								
Goat								
Pig								
Rabbit								
Chicken								
Guinea fowl								
Turkey								
Duck								
Grass cutter								
Guinea pig								
Dove								
Donkey								
Other								

Item	C09 Do you own any functional ….....? 0=No >> next asset/Section D 1=Yes	C10 How many functional items in all?	C11 Did you sell any item? 0=No >> next animal/Section D 1=Yes	C12 Value of sale (GHS)
Radio				
Computer (desk/laptop)				
Television				
Bicycle				
Motor cycle				

Tricycle				
Car				
Mobile phone				
Tractor				
Combine harvester				
Bullock				
Donkey & cart				
Cutlass				
Hoe				
Knapsack				
Manual thresher				
Mechanised sheller				
Other				

SECTION D: Expenditure on Inputs

Input	D01 Did you spend anything in cash and/or in kind on … in the 2021/22 season? 0=No >> D05/Section E 1=Yes	D02 What was the total amount spent in cash & in kind on …. in the 2021/22 season?	D03 Of the total amount spent, what amount was spent on buying from the market?	D04 What proportion of the total amount spent was on maize?	D05 Was … obtainable in this community any time during the year when you needed it? 0=No >> next input/Section E 1=Yes
Inorganic fertiliser					
Organic fertiliser					
Insecticides/Pesticides					
Herbicides/Weedicides					
Seed/seedlings					
Hired labour					
Equipment rental					
Crop storage					
Irrigation					
Animal rental					
Other input					

SECTION E: Financial Assets and Inclusion

E01 Do you have a bank account? 0=No 1=Yes >> E03	E02 What is the main reason why you do not have a bank account? **Code AI**	E03 What is the main type of financial institution is your account being held? **Code AJ**	E04 What type of account is being held in the financial institution? **Code AK**	E05 Have you registered for mobile money with any network provider? 0=No >> E10 1=Yes	E06 How many network providers have you registered momo with?	E07 Have you ever made a momo transaction to a different subscriber using interoperability? 0=No 1=Yes	E08 What was the main purpose for the interoperable transaction? **Code AL**	E09 How many times do you typically use interoperable transactions in a month?	E10 During the cropping season, did you have liquidity constraints in financing production? 0=No 1=Yes	E11 Did you apply for a loan to finance production? 0=No >> E22 1=Yes	E12 How much did you apply for? (GHS)	E13 Was the loan granted? 0=No >> E21 1=Yes	E14 What was the source of this loan? **Code AM**	E15 What was the total amount of the loan given? (GHS)

Code AI	**Code AJ**	**Code AK**	**Code AL**	**Code AM**
1 Not necessary/interested	1 Commercial bank	1 Current or cheque a/c	1 To purchase input	1 State bank 10 Trader
2 Not aware of one	2 Investment/mortgage	2 Investment account	2 Pay for labour	2 Private bank 11 Input dealer
3 Process cumbersome	3 Community/rural bank	3 Savings account	3 Send remittance	3 Rural bank 12 Aggregator
4 Financial institutions far away	4 Savings and loans scheme	4 Susu account	4 Buy household consumer goods	4 Cooperative 13 Farmer
5 Don't have enough money or income	5 Cooperative/credit union	5 Fixed deposit a/c	5 Buy nonfarm business goods	5 Gov't agency 14 Relative/friend
6 Don't have regular income	6 Susu scheme	6 Other (specify)	6 Other (specify)	6 NGOs 15 Outgrower
7 Other (specify)	7 Other (specify)			7 Money lender 16 Other (specify)
				8 Savings/loans
				9 Susu scheme

E16 If more credit had been available from this source, would you have used it? 0=No 1=Yes	E17 What was the specific purpose of the loan? **Code AN**	E18 What kind of guarantee/ collateral was required by the lender? **Code AO**	E19 Did you actually use loan for the intended purpose? 0=No 1=Yes	E20 Have you defaulted in paying the loan? 0=No 1=Yes	E21 Why was the loan not granted? **Code AP**	E22 Why did you not apply for loan? **Code AQ**	E23 Did you acquire another loan for a different purpose outside agriculture? 0=No >> E26 1=Yes	E24 What was the specific purpose of the loan? **Code AR**	E25 Have you defaulted in paying the loan? 0=No 1=Yes	E26 If you have a savings account, what is its current balance? (GHS) If no savings account >> E29	E27 How much has been added to the savings in the past 12 months? (GHS)	E28 How much has been withdrawn from the savings in the past 12 months? (GHS)

Code AN	**Code AO**	**Code AP**	**Code AR**
1 Farm preparation and planting 2 Agricultural input 3 Hiring of labour 4 Harvesting 5 Agricultural improvements (e.g., irrigation/fencing) 6 Agricultural implements 7 Purchasing livestock	0 None 1 Land 2 Cattle 3 House/building guarantee fund 4 Form a group 5 Third party security/guarantor 6 Land title (with or without a house) 7 Salary channeled through lending institution 8 Vehicle documents 9 Cash or bank account/loan 10 Other (specify)	1 Could not provide collateral 2 Income too low 3 Could not get a guarantor 4 Amount applied for too high 5 Previous debt problems 6 Inappropriate purpose of loan 7 Other (specify) 8 Don't know	1 Household needs 2 Buying assets 3 Starting/expanding nonfarm business 4 Social function 5 Unforeseen contingencies 6 Other (specify)

Code AQ		
1 No need	4 Demand for collateral	7 Cumbersome/expensive procedure
2 Interest rate too high	5 Already has too much debt	8 Lenders far away
3 Don't want to pay interest	6 Cannot obtain the amount needed	9 Other (specify)

E29 Do you have an insurance policy for any of your agricultural activities? 0=No >> E31 1=Yes	E30 What type of agric. insurance policy do you have? **Code AS**	E31 Do you have any other insurance policy? 0=No >> E33 1=Yes	E32 What type of insurance policy do you have? **Code AT**	E33 Have you heard of weather index insurance? 0=No >> E35 1=Yes	E34 What was the major source of information? **Code AU**	E35 Are you willing to acquire weather insurance if you have access? 0=No 1=Yes

Code AS	**Code AT**	**Code AU**
1 Protection against crop failure 2 Protection against fire burning produce 3 Protection against price fluctuation 4 Other (specify)	1 Vehicle/motor 2 Medical 3 Funeral 4 Property 5 Commercial or business 6 Travel 7 Other (specify)	1 Financial institution 2 Friends/relatives 3 Radio 4 TV 5 Traders 6 Newspaper 7 Extension officer 8 GOs 9 NGOs 10 FBO 11 ICT platform (ESOKO, e AGRI) 12 Other (specify)

SECTION F: Nonfarm Participation, Associations and Remittances

F01 Did any member of the household engage in any activity outside agriculture in the 2021/2022 season? 0=No >> F06 1=Yes	F02 How many members were engaged?	F03 How many nonfarm activities were you engaged in during the season?	F04 In which specific nonfarm activity were you engaged in? **Code AV**	F05 How much in total was gained in the engagement in the nonfarm activity? (GHS)

Code AV		**Code AW**		**Code AX**		**Code AY**	
1 Casual farm labourer	5 Security service	1 Weekly	4 Quarterly	0 No	3 Yes, Quarterly	1 Daily consumption	6 Education
2 Casual nonfarm labourer	6 Store operator	2 Fortnightly	5 Annually	1 Yes, Weekly	4 Yes, Annually	2 Agric investment	7 Health
3 Agricultural trader	7 Mining	3 Monthly	6 Other (spec.)	2 Yes, Monthly	5 Yes, other (specify)	3 Housing	8 Funerals
4 Artisan	8 Other (spec.)					4 Nonfarm business	9 Other ceremonies
						5 Savings	10 Other (specify)

Group	F06 Is there a [GROUP] in your community? 0=No >> next group/F11 1=Yes	F07 Are you an active member of this [GROUP]? 0=No >> next group/F11 1=Yes	F08 Do you hold any leadership position in this group? 0=No 1=Yes	F09 How often did your association meet to discuss issues related to your farm activities in the 2021/22 season? **Code AW**	F10 How many times did you attend meeting in the season?
Agricultural/livestock producers' group/FBO					
Credit or microfinance group (including SACCOs/merry-go-rounds/VSLAs)					
Mutual help or insurance group					
Trade and business association					
Civic groups (improving community) or charitable group (helping others)					
Other (specify)					

F11 Did you receive cash remittance in the 2021/22 season? 0=No >> section G 1=Yes	F12 Were these remittances made on a regular basis? **Code AX**	F13 What was the total amount of cash sent?	F14 What was the main use of cash sent? **Code AY**	F15 What was the proportion of cash remittance invested in your farm operations?

SECTION G: Risk Profile

G01 Imagine you have a choice between the following two options: OPTION 1: You receive 16 Ghana Cedis today. OPTION 2: You receive 32 Ghana Cedis in 1 month. Which option do you prefer?	G02 Imagine you have a choice between the following two options. OPTION 1: You receive 16 Ghana Cedis today. OPTION 2: You receive 40 Ghana Cedis in 1 month. Which option do you prefer?	G03 Imagine you have a choice between the following two options. OPTION 1: You receive 16 Ghana Cedis today. OPTION 2: You receive 24 Ghana Cedis in 1 month. Which option do you prefer?	G04 Imagine you have a choice between the following two options. OPTION 1: You receive 4 Ghana Cedis for sure. OPTION 2: I flip a 1 Cedi Coin. If it shows the Shell, you get 12 Ghana Cedis. If it's the coat of arms, you get 1 Ghana Cedi. Which option do you prefer?	G05 Imagine you have a choice between the following two options. OPTION 1: You receive 4 Ghana Cedis for sure. OPTION 2: I flip a 1 GH Cedi Coin. If it shows the Shell, you get 16 Ghana Cedis. If it's the coat of arms, you get 1 Ghana Cedi. Which option do you prefer?	G06 Suppose you want to invest some money. OPTION 1: Investing in a business where I can't lose money but has low profits. OPTION 2: Investing in a business where there is a small chance I can lose money but potentially brings high profits. Which option do you prefer?

SECTION H: Food Security

Part 1: Food Insecurity Experience Scale (FIES) Module

During **the last 12 MONTHS:**		**Code** 0=No 1=Yes 8=Don't know 9=Refused
H101	Was there a time when you or others in your household worried about not having enough food to eat because of a lack of money or other resources?	
H102	Still thinking about the last 12 MONTHS, was there a time when you or others in your household were unable to eat healthy and nutritious food	

	because of a lack of money or other resources?	
H103	Was there a time when you or others in your household ate only a few kinds of foods because of a lack of money or other resources?	
H104	Was there a time when you or others in your household had to skip a meal because there was not enough money or other resources to get food?	
H105	Still thinking about the last 12 MONTHS, was there a time when you or others in your household ate less than you thought you should because of a lack of money or other resources?	
H106	Was there a time when your household ran out of food because of a lack of money or other resources?	
H107	Was there a time when you or others in your household were hungry but did not eat because there was not enough money or other resources for food?	
H108	Was there a time when you or others in your household went without eating for a whole day because of a lack of money or other resources?	

Part 2: Household Hunger Scale (HHS) Module

Q No.	Question	**Response Code**
H201	In the past [4 weeks/30 days], was there ever no food to eat of any kind in your house because of lack of resources to get food?	0 = No (Skip to H202) 1 = Yes
H201a	How often did this happen in the past [4 weeks/30 days]?	1 = Rarely (1-2 times) 2 = Sometimes (3-10 times) 3 = Often (more than 10 times)
H202	In the past [4 weeks/30 days], did you or any household member go to sleep at night hungry because there was not enough food?	0 = No (Skip to H203) 1 = Yes
H202a	How often did this happen in the past [4 weeks/30 days]?	1 = Rarely (1-2 times) 2 = Sometimes (3-10 times) 3 = Often (more than 10 times)
H203	In the past [4 weeks/30 days], did you or any household member go a whole day and night without eating anything at all because there was not enough food?	0 = No (Skip to Part 3) 1 = Yes
H203a	How often did this happen in the past [4 weeks/30 days]?	1 = Rarely (1-2 times) 2 = Sometimes (3-10 times) 3 = Often (more than 10 times)

Part 3: Household Food Insecurity Access Scale (HFIAS) Module

Q No.	Question	**Response Code**
H301	In the past 4 weeks (30 days), did you worry that your household would not have enough food?	0 = No (Skip to H302) 1 = Yes
H301a	How often did this happen?	1 = Rarely (1-2 times) 2 = Sometimes (3-10 times) 3 = Often (more than 10 times)

H302	In the past 4 weeks (30 days), were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	0 = No (Skip to H303) 1 = Yes
H302a	How often did this happen?	1 = Rarely (1-2 times) 2 = Sometimes (3-10 times) 3 = Often (more than 10 times)
H303	In the past 4 weeks (30 days), did you or any household member have to eat a limited variety of foods due to a lack of resources?	0 = No (Skip to H304) 1 = Yes
H303a	How often did this happen?	1 = Rarely (1-2 times) 2 = Sometimes (3-10 times) 3 = Often (more than 10 times)
H304	In the past 4 weeks (30 days), did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?	0 = No (Skip to H305) 1 = Yes
H304a	How often did this happen?	1 = Rarely (1-2 times) 2 = Sometimes (3-10 times) 3 = Often (more than 10 times)
H305	In the past 4 weeks (30 days), did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	0 = No (Skip to H306) 1 = Yes
H305a	How often did this happen?	1 = Rarely (1-2 times) 2 = Sometimes (3-10 times) 3 = Often (more than 10 times)
H306	In the past 4 weeks (30 days), did you or any household member have to eat fewer meals in a day because there was not enough food?	0 = No (Skip to H307) 1 = Yes
H306a	How often did this happen?	1 = Rarely (1-2 times) 2 = Sometimes (3-10 times) 3 = Often (more than 10 times)
H307	In the past 4 weeks (30 days), was there ever no food to eat of any kind in your house because of lack of resources to get food?	0 = No (Skip to H308) 1 = Yes
H307a	How often did this happen?	1 = Rarely (1-2 times) 2 = Sometimes (3-10 times) 3 = Often (more than 10 times)
H308	In the past 4 weeks (30 days), did you or any household member go to sleep at night hungry because there was not enough food?	0 = No (Skip to H309) 1 = Yes
H308a	How often did this happen?	1 = Rarely (1-2 times) 2 = Sometimes (3-10 times) 3 = Often (more than 10 times)
H309	In the past 4 weeks (30 days), did you or any household member go a whole day and night without eating anything because there was not enough food?	0 = No (Skip to Part 4) 1 = Yes

H309a	How often did this happen?	1 = Rarely (1-2 times) 2 = Sometimes (3-10 times) 3 = Often (more than 10 times)

Part 4: Consumption of food groups

No.	Food item	H401 Did your household consume this in the last 7 days? 0=No>> H404 1=Yes	H402 How many times in the last 7 days?	H403 How much do you spend on this in a regular month? (GHS)	H404 Why did you not consume this in the last 7 days? **Code AZ**
1	Cereals and grains				
2	Roots and tubers				
3	Legumes and nuts				
4	Vitamin A-rich vegetables				
5	Green leafy vegetables				
6	Other vegetables				
7	Vitamin A-rich fruits				
8	Other fruits				
9	Organ meat				
10	Meat				
11	Fish/shellfish and seafood				
12	Eggs				
13	Milk and milk products				
14	Oil, fat and butter				
15	Sugar and sweet				
16	Condiments and spices				

Code AZ
1 Run out of money
2 It was too expensive
3 It wasn't physically available
4 Don't like it
5 Not our delicacy
6 Medical advice
7 Other (specify)

END OF QUESTIONNAIRE

Appendix 1B: Community questionnaire (for primary data)

DEPARTMENT OF AGRICULTURAL ECONOMICS AND AGRIBUSINESS
COLLEGE OF BASIC AND APPLIED SCIENCES
UNIVERSITY OF GHANA, LEGON

COMMUNITY FOCUSED GROUP INTERVIEW GUIDE ON THE STUDY "FARM HOUSEHOLDS' AGRICULTURAL COMMERCIALISATION AND FOOD AND NUTRITION SECURITY IN GHANA

2021/2022 PRODUCTION SEASON

REGION: …… DISTRICT: ……

COMMUNITY NAME: ……. COMMUNITY UNIQUE ID: ……

SUPERVISOR: ……

GPS COORDINATES: ……

DATE OF INTERVIEW: ……

LIST OF PEOPLE IN FOCUSED GROUP INTERVIEW

Name	Sex 0=Female 1=Male	Age (yrs)	Position in community	Primary occupation **Code A**	Secondary occupation **Code A**
1.					
2.					
3.					
4.					
5.					

Code A

1 Farming/livestock/fishing/hunting	4 Technician/artisan	7 Dressmaking
2 Trading/selling	5 Construction work	8 Housewife
3 Civil/public servant	6 Wage labour	9 Other (specify)

SECTION 1: DEMOGRAPHIC INFORMATION

S101. What is the estimated number of people living in this community?

S102. How many years has this community existed? 1 Less than 100 years [ ] 2 100 – 200 years [ ] 3 201 – 300 years [ ] 4 301 – 400 years 5 Above 400 years [ ]

S103. What are the principal ethnic groups in this community? 1st ranked group …… 2nd ranked group …… 3rd ranked group …… 4th ranked group …….

[**Groups**: 1=Akan 2=Ewe 3=Ga-Dangme 4=Mole-Dagbani 5=Guan 6=Gruma 7=Grusi 8=Mande 9=Other (specify)]

S104. What are the major religious affiliations by persons living in this community? 1st ranked …… 2nd ranked …… 3rd ranked …… 4th ranked …….

[**Groups**: 1=Christianity 2=Islam 3=Traditional/Spiritualism 4=No religion 5= Atheist 6=Other (specify)]

S105. In the last five years (since 2016/2017), what has been the movement of people in this community? 1 More arrival of people [ ] 2 More departure of people [ ] 3 Arrival and departure about the same [ ] 4 Neither arrival or departure of people [ ]

SECTION 2: ECONOMY AND INFRASTRUCTURE

S201. What is the distance of this community to the district/municipal capital? …….. 1 Mile [ ] 2 Kilometre [ ] 3 Metre [ ] 4 Other (specify) [ ]

S202. What are the major economic activities of the people of this community? 1st ranked …… 2nd ranked …… 3rd ranked …… 4th ranked …….

[**Activities**: 1=Farming 2=Fishing 3=Trading 4=Handicraft 5=Mining 6=Quarrying 7=Sand winning 8=Other (specify)]

S203. Do you think that living conditions of the people in this community is better or worse than it was five years ago (since 2016/2017)? 1 Better [ ] 2 Slightly better [ ] 3 No change [ ] 4 Slightly worse [ ] 5 Worse [ ]

S204. What are the main reasons for this response?1st ranked …… 2nd ranked …… 3rd ranked ……..

[**Better and slightly better reasons**: 1=Provision of electricity 2=Provision of drinking water 3=Improvement in roads 4=More job opportunities 5=Improvement/availability of other social amenities 6=Construction/improvement in drainage systems 7=Peaceful environment 8=Improvement in business 9=Good prices for produce 10=Other]

[**Slightly worse and worse reasons**: 1=Unemployment 2=Poverty 3=Deterioration in social amenities 4=Natural disasters/famine 5=Wars/conflicts 6=Out-migration 7=High prices of consumer goods 8=Diseases 9=Social vices 10=Other]

S205. Does a motorable road extend to this community? 0 No [ ] >> 10 1 Yes [ ]

S206. What is the specific nature of the road? 1 Tarred, in excellent condition [ ] 2 Tarred, with minor potholes [ ] 3 Tarred, with severe potholes [ ] 4 Not tarred, but in good condition [ ] 5 Not tarred, in very bad condition [ ] 6 Other (specify) [ ]

S207. Is the road to the community impassable during certain times of the year? 0 No [ ] >> 10 1 Yes [ ]

S208. For how many months is the road usually impassable during the year? …… months

S209. How far is this community from the nearest tarred-in-good condition motorable road? …… 1 Mile [ ] 2 Kilometre [ ] 3 Metre [ ] 4 Other (specify) [ ]

S210. How far is this community from the nearest any motorable road (i.e., either tarred or untarred)? …… 1 Mile [ ] 2 Kilometre [ ] 3 Metre [ ] 4 Other (specify) [ ]

S211. Does this community have electricity or generators/solar power? 0 No [ ] 1 Yes, electricity from national grid 2 Yes, electricity from generator [ ] 3 Yes, electricity from solar energy [ ] 4 Yes, electricity from all these sources [ ]

S212. What is the main source of drinking water in this community? 1 Pipe-borne [ ] 2 Borehole/pump/tube Well [ ] 3 Protected well [ ] 4 Harvested rain water [ ] 5 Protected spring [ ] 6 Bottled water [ ] 7

Sachet water [ ] 8 Tanker supply/vendor provided [ ] 9 Unprotected well [ ] 10 Unprotected spring [ ] 11 River/stream [ ] 12 Dug out/pond/lake/dam/canal [ ] 13 Other (Specify) [ ]

S213. Is there a mobile phone network in this community? 0 No [ ] 1 Yes [ ] >> 17

S214. Which networks are here? 1 MTN [ ] 2 Vodaphone [ ] 3 AirtelTigo [ ] 4 All these networks [ ] 5 Other (specify) [ ]

S215. What is the strength of the mobile network(s)? 1 Strong [ ] 2 Moderately strong [ ] 3 Weak [ ] 4 Very weak [ ]

S216. How far is the nearest mobile phone network signal from this community? …… 1 Mile [ ] 2 Kilometre [ ] 3 Metre [ ] 4 Other (specify) [ ]

S217. Is there a financial institution (bank, micro-finance, etc.) in this community? 0 No [ ] 1 Yes [ ] >> 17

S218. How far is the nearest financial institution (bank, micro-finance, etc.) from this community? …… 1 Mile [ ] 2 Kilometre [ ] 3 Metre [ ] 4 Other (specify) [ ]

S219. Is there a permanent (daily) market in this community? 0 No [ ] 1 Yes [ ]

S220. Is there a periodic market in this community? 0 No [ ] >> 22 1 Yes [ ]

S221. How often is this market? 1 Weekly [ ] 2 Fortnightly [ ] 3 Monthly [ ] 4 Other (specify) [ ]

S222. How far away is the nearest periodic or daily market? …… 1 Mile [ ] 2 Kilometre [ ] 3 Metre [ ] 4 Other (specify) [ ]

S223. Does public transport pass through or by this community? 0 No [ ] >> 30 1 Yes [ ]

S224. Do people have access to the public transport 0 No [ ] 1 Yes [ ] >>26

S225. What is the main internal means of transport in this community? 0 None 1 Bus (Metro, STC, VIP, OA, etc.) [ ] 2 Mini bus/trotro [ ] 3 Articulator truck [ ] 4 Car (taxi) [ ] 5 Tricycle [ ] 6 Tractor [ ] 7 Other (specify) [ ]

S226. What are the various means of public transport? Multiply responses allowed. 1 Bus (Metro, STC, VIP, OA, etc.) [ ] 2 Mini bus/trotro [ ] 3 Articulator truck [ ] 4 Car (taxi) [ ] 5 Tricycle [ ] 6 Tractor [ ] 7 Other (specify) [ ]

S227. What is the main means of public transport? 1 Bus (Metro, STC, VIP, OA, etc.) [ ] 2 Mini bus/trotro [ ] 3 Articulator truck [ ] 4 Car (taxi) [ ] 5 Tricycle [ ] 6 Tractor [ ] 7 Other (specify) [ ]

S228. How often does public transport pass through or by this community? 1 Daily [ ] 2 Every other day [ ] 3 Weekly [ ] 4 Monthly [ ] 5 Other (specify) [ ]

S229. What is the frequency of passage within the chosen time period? ……

S230. How far away from this community must you go to board a public transport? …….. 1 Mile [ ] 2 Kilometre [ ] 3 Metre [ ] 4 Other (specify) [ ]

S231. Do any of the people in this community leave temporarily during certain times of the year to look for work elsewhere? 0 No [ ] >> 30 1 Yes [ ]

S232. What type of work do they look for during these times of the year? 1 Private employment [ ] 2 Public/government employment [ ] 3 Self-employment (agric.) [ ] 4 Self-employment (non-agric.) [ ] 5 Other (specify) [ ]

S233. Do people come to this community temporarily during certain times of the year to look for work? 0 No [ ] >> 32 1 Yes [ ]

S234. What major type of work do they do in this community? [**Activities**: 1=Farming 2=Fishing 3=Trading 4=Handicraft 5=Mining 6=Quarrying 7=Sand winning 8=Other (specify)]

S235. Is it easier or more difficult to find work in this community compared to five years ago? 1 Easier [ ] 2 More difficult [ ] 3 No change [ ]

S236. What major agricultural development projects are in this community? 1 Irrigation fields [ ] 2 Community farm [ ] 3 Silo [ ] 4 Input delivery centre [ ] 5 Mechanisation centre [ ] 6 Other (specify) [ ]

SECTION 3: AGRICULTURE

S301. What are the major varieties of maize cultivated in this community?

S302. What are the basic orientation towards farming in this community? 1 Primarily for consumption [ ] 2 Primarily for market [ ] 3 Consumption and market, but more consumption [ ] 4 Consumption and market, but more market [ ] 5 Other (specify) [ ]

S303. Do people generally store their produce after harvest with chemicals? 0 No [ ] 1 Yes [ ]

S304. What are the major sources of market information for people in this community? 1st ranked …….. 2nd ranked ……. 3rd ranked ……. 4th ranked ……

S305. What is the average number of times people sell their produce (especially maize)? ……

S306. What are the principal reasons for the sale of agricultural produce in this community? 1st ranked …….. 2nd ranked ……. 3rd ranked ……. 4th ranked ……

S307. How many times in a year is maize planted in general in this community?

S308. What is the usual planting month of maize?

S309. What is the main period (i.e., month) of sale of maize?

S310. What are the three main channels of maize sales? 1 At the farm [ ] 2 At the house [ ] 3 At the local market [ ] 4 At the market of another place [ ] 5 To middlemen [ ] 6 To public agencies [ ] 7 To a cooperative [ ] 8 Other (specify) [ ]

S311. What is the typical transportation cost for 50kg bag of produce to the major/popular market centre?

S312. What is the distance to the major/popular market? …….. 1 Mile [ ] 2 Kilometre [ ] 3 Metre [ ] 4 Other (specify) [ ]

S313. Does this community have an agricultural extension office? 0 No [ ] 1 Yes [ ] >> 15

S314. How far is the agricultural extension office from this community? ……. 1 Mile [ ] 2 Kilometre [ ] 3 Metre [ ] 4 Other (specify) [ ]

S315. Is there an agricultural extension officer stationed in this community? 0 No [ ] 1 Yes [ ]

S316. Does an agricultural extension officer or agent visit farmers of this community? 0 No [ ] >> 18 1 Yes [ ]

S317. What are the four main services they provide? 1st ranked …… 2nd ranked …… 3rd ranked ……. 4th ranked …….

[1=Use of improved seeds 2=Appropriate planting 3=Use of fertiliser 4=Mechanisation 5=Credit facilities 6=Irrigation 7=Animal husbandry 8=Use of chemicals (herbicides, weedicides insecticides, spraying, etc.) 9=Post harvest services (eg. marketing, storage) 10=Other (specify)]

S318. Is there an agricultural association in this community? 0 No [ ] >> 20 1 Yes [ ]

S319. How effective is this association? 1 Very effective [ ] 2 Moderately effective [ ] 3 Not effective [ ]

S320. What three major services does it provide? 1st ranked …… 2nd ranked …… 3rd ranked …….

[**Services**: 1=Provision of employment 2=Provision of credit facilities 3=Provision of agricultural equipment 4=Provision of agric. inputs (seeds, fertiliser, fishing net, etc.) 5= Marketing 6=Records/Book-keeping 7=Provision of communal labour 8=Other (specify)]

S321. Is there an agricultural cooperative in this community? 0 No [ ] >> 23 1 Yes [ ]

S322. How effective is this cooperative? 1 Very effective [ ] 2 Moderately effective [ ] 3 Not effective [ ]

S323. What three major services does it provide? 1st ranked …… 2nd ranked …… 3rd ranked …….

[**Services**: 1=Provision of employment 2=Provision of credit facilities 3=Provision of agricultural equipment 4=Provision of agric. inputs (seeds, fertiliser, fishing net, etc.) 5= Marketing 6=Records/Book-keeping 7=Provision of communal labour 8=Other (specify)]

S324. How many tractors are used for agricultural purposes in this community? …….

S325. Is there a maize processing machine in this community? 0 No [ ] 1 Yes [ ]

S326. Do any of the farmers in this community use chemical fertilisers? 0 No [ ] 1 Yes [ ]

S327. Do any of the farmers in this community use insecticides/pesticides? 0 No [ ] 1 Yes [ ]

S328. Do any of the farmers in this community use herbicides? 0 No [ ] 1 Yes [ ]

S329. Are there any irrigated fields in this community? 0 No [ ] 1 Yes [ ]

S330. During the 2021/22 season, have you received more or less rain than during the 2020/21 season? 1 More [ ] 2 Less [ ] 3 No change [ ]

S331. Are there any sharecroppers in this community? 0 No [ ] 1 Yes [ ]

S332. How much money does an agricultural labourer charge for the following activities per day in the 2021/22 season?

	Clearing	Planting	Weeding	Harvesting	Other major activity (spec.)
Man					
Woman					
Child					

S333. How are land usually measured in this community?

	Acre	Plot	Pole	Rope	Other (specify)
Length (m)					
Width (m)					

S334. Is there a system of mutual aid among the farmers of this community for fieldwork? 0 No [ ] 1 Yes [ ]

S335. What are the average prices for the following in the community in the 2021/22 season?

	Price	
Crop	Bowl	50kg bag
Maize		
Rice		
Beans		
Millet		

Sorghum/guinea corn		
Groundnut		
Soybean		
Cotton		
Yam ('calabash')		
Cassava (tubers)		

S336. What are the average quarterly prices of maize in the 2021/22 season?

	Oct-Dec 2021	Jan-March 2022
50kg		

S337. What is your estimate of the average quarterly prices of maize for the following quarters?

	April-June 2022	Jul-Sept 2022
50kg bag		

[TO BE WRITTEN IN NOTEPAD AND NOT IN CAPI]

S338. What are the major challenges to crop production in general?

S339. What the major challenges specific to the production of maize?

S340. What are the major challenges to livestock production?

S341. What are the major challenges to the marketing of crop produce?

S342. What are the major challenges specific to the marketing of maize?

S343. What are the major challenges to the marketing of livestock produce?

SECTION 4: FOOD SECURITY [to be written in notepad and not in capi]

S401. Does food generally get short within a season in some households?

S402. Did this situation happen in the 2021/22 season?

S403. How severe was it this season?

S404. How do you compare this season's situation to the past 5 seasons?

S405. What periods within the season does food usually get short?

S406. Which period is the situation more severe?

S407. What are the main reasons for food shortages?

S408. What are the main coping strategies of households to food shortages?

S409. Does the community generally receive food aid?

S410. Which sources do these aid come from?

END OF DISCUSSION

Appendix 2: Tables

Table A1: Crop and livestock commercialisation indices

Crop	GLSS7				Primary data			
	% producing	% selling among producers	CCI among producers	CCI conditional on producing and selling	% producing	% selling among producers	CCI among producers	CCI conditional on producing and selling
All crops	90.52	62.95	35.20	55.91	100.0	74.13	38.24	51.59
Food	82.73	54.88	31.60	50.03	100.0	74.13	38.24	51.59
Non-food	14.76	92.05	73.10	79.05	0.12	100.0	85.11	85.11
Cereals	70.38	41.45	29.70	52.05	83.45	62.15	36.00	52.32
Maize	62.82	35.52	20.19	56.84	74.59	58.59	29.65	50.61
Millet	18.93	17.44	11.00	63.07	11.66	49.00	33.85	69.09
Rice	16.97	37.22	20.10	54.00	10.96	68.09	44.54	65.42
Sorghum	17.57	17.47	10.77	61.64	2.21	52.63	32.43	61.62
Legumes	35.42	50.13	24.82	43.27	57.11	78.98	44.41	53.67
Groundnut	26.24	52.34	33.08	63.21	25.06	73.49	50.25	68.38
Beans	20.42	31.53	17.80	56.46	9.91	70.59	44.38	62.87
Soya bean					30.54	84.35	63.27	75.01
Bambara beans					1.52	46.15	21.28	46.11
Cowpea					1.28	54.55	44.59	81.75
Roots and tubers	27.50	59.52	42.76	57.94	8.86	85.53	45.60	51.87
Yam	9.48	54.24	32.13	59.23	8.04	85.51	55.89	65.37
Cassava	18.02	51.32	33.28	64.84	2.21	78.95	43.25	54.78
Cocoyam	2.17	33.33	22.01	66.04				
Plantain	9.30	60.26	37.15	61.64				
Potato	0.57	54.76	43.09	78.69	0.12	100.0	25.00	25.00
Vegetables	9.68	55.77	39.68	56.35	0.70	100.0	55.04	55.04
Tomato	1.76	63.57	48.37	76.09				
Pepper	4.96	51.92	36.18	69.68	0.12	100.0	25.00	25.00
Okro	4.16	52.79	38.30	72.56	0.23	100.0	100.0	100.0
Garden egg	0.89	61.54	53.91	87.61				
Ginger	0.33	75.00	48.21	64.28				
Onion	0.87	53.13	42.04	79.14	0.35	100.0	83.33	83.33
Leafy veg.	0.30	36.36	27.57	75.81				
Moringa	0.01	100.0	75.00	75.00				
Kenef	0.03	100.0	87.50	87.50				
Fruits	1.77	86.15	67.02	70.48	0.35	100.0	93.33	93.33
Avocado pear	0.07	100.0	87.00	87.00				
Banana	0.23	52.94	44.21	83.51				
Coconut	0.18	100.0	79.76	79.76				
Lemon	0.01	100.0	50.00	50.00				
Mango	0.07	100.0	79.23	79.23				
Orange	0.61	88.89	82.57	92.90				
Pawpaw	0.03	50.00	50.00	100.0				
Pineapple	0.10	85.71	62.78	73.24				
Tigernut	0.07	60.00	45.56	75.93				
Watermelon	0.49	94.44	79.80	84.49	0.35	100.0	93.33	93.33
Industrial	16.58	89.06	69.85	77.60	0.12	100.0	100.0	100.0
Cashew	1.69	97.58	96.33	98.72				
Cocoa	13.27	91.47	82.20	89.87				
Coffee	0.04	66.67	66.67	100.0				
Colanut	0.07	100.0	93.33	93.33				
Cotton	0.08	100.0	94.44	94.44	0.12	100.0	100.0	100.0
Oilpalm	2.66	70.26	52.27	74.40				
Rubber	0.01	100.0	100.0	100.0				

Sugarcane	0.46	50.00	39.99	79.97				
Tobacco	0.04	66.67	50.00	75.00				
Woodlot	0.04	100.0	76.01	76.01				
Livestock								
All	99.02	38.25	10.94	28.56	83.22	44.96	8.10	18.01
Large	9.96	25.34	8.06	31.82	27.51	16.10	5.04	31.29
Cattle	9.96	25.34	8.06	31.82	27.51	16.10	5.04	31.29
Small	56.71	36.05	10.59	27.03	66.40	26.49	7.76	21.63
Sheep	23.00	32.03	11.82	36.91	31.59	23.25	7.70	33.13
Goat	41.48	29.76	10.07	33.82	57.69	15.96	5.40	33.82
Pig	9.67	35.40	13.31	37.59	4.43	52.63	17.00	32.31
Rabbit	0.82	33.33	17.99	53.96	0.47	0.00	0.00	0.00
Grasscutter	0.07	60.00	18.33	30.56	0.00	0.00	0.00	0.00
Guinea pig					0.23	50.0	30.00	60.0
Poultry	69.05	33.46	10.93	28.24	65.97	30.92	8.21	15.41
Chicken	64.32	30.39	11.48	37.71	64.10	16.00	6.12	38.22
Guinea fowl	13.12	39.92	23.23	58.20	16.90	44.14	19.00	43.04
Turkey	0.57	26.19	14.73	56.25	1.63	71.43	20.34	28.47
Duck	2.63	23.32	7.76	33.28	4.90	54.76	20.45	37.32
Dove	1.87	37.23	13.58	36.48	2.56	13.64	6.35	46.59

Table A2: Probit model for estimating inverse mills ratio (IMR)

	GLSS7		Primary
	(1)	(2)	(3)
Variable	All sample	Subsample	Subsample
Sex of head	0.319***	0.117*	0.035
	(0.080)	(0.071)	(0.186)
Age of head	0.005***	-0.002	-0.008*
	(0.002)	(0.002)	(0.005)
Household size	0.023*	-0.028***	0.020
	(0.012)	(0.009)	(0.028)
Locality of household	0.778***	0.716***	
	(0.104)	(0.108)	
Marital status of head	-0.092	-0.070	-0.157
	(0.071)	(0.060)	(0.187)
Years of education of head	-0.016**	0.003	0.007
	(0.006)	(0.006)	(0.010)
Received cash remittance	-0.006	-0.016	0.132
	(0.069)	(0.058)	(0.193)
No. of days stop work due to ill-health	-0.000	0.004	0.003*
	(0.013)	(0.009)	(0.002)
Ownership of nonfarm enterprise	-0.196***	-0.165**	-0.264
	(0.065)	(0.064)	(0.163)
Agric cooperative in community	-1.247***	0.344***	0.602***
	(0.271)	(0.123)	(0.193)
Bank in community	0.733***	0.897***	-0.122
	(0.106)	(0.118)	(0.247)
Mobile phone network in community	0.287*	0.060	-0.906***
	(0.166)	(0.095)	(0.263)
Agric extension office in community	0.666***	0.193**	0.086
	(0.098)	(0.098)	(0.140)
Irrigated fields in community	-1.471***	0.010	-0.306**
	(0.297)	(0.119)	(0.151)
Perceived rain pattern in community	-0.070	-0.143*	-0.090
	(0.099)	(0.076)	(0.202)
Log of amount agrochemicals	0.150***	0.012	-0.004
	(0.022)	(0.012)	(0.025)

Log of expenditure on hired labour	0.044**	0.024**	0.002
	(0.021)	(0.011)	(0.024)
No. of crops produced	0.608***	0.112***	0.124
	(0.056)	(0.024)	(0.080)
Log of total value of household assets	-0.018	-0.014	-0.140***
	(0.013)	(0.009)	(0.033)
Log of agric land endowment	0.063	0.079**	0.151**
	(0.098)	(0.037)	(0.073)
Market in community	-1.053***	0.663***	0.780***
	(0.227)	(0.089)	(0.148)
Navigable road to community	2.643***	0.817***	1.124***
	(0.261)	(0.186)	(0.174)
Access to public transport	1.439***	0.431***	0.550***
	(0.347)	(0.152)	(0.183)
Household in southern Ghana	-0.149	-0.178*	-1.202***
	(0.183)	(0.095)	(0.273)
Household in coastal zone	0.401**	-0.539**	-1.899***
	(0.180)	(0.257)	(0.235)
Household in forest zone	0.824***	-0.339	-1.153***
	(0.139)	(0.250)	(0.323)
Household in savannah zone	0.630***	-0.859***	-1.548***
	(0.226)	(0.269)	(0.315)
Constant	-4.547***	-1.414***	1.922***
	(0.337)	(0.286)	(0.511)
Observations	14009	7332	858
F-statistic	44.855***	32.619***	384.678***

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; All sample is the decision to sell crop and livestock in the entire sample; Subsample is decision to sell crop and livestock between those selling at least 25 percent and those selling below 25 percent; Standard errors in parentheses; Source: Produced by the author using the GLSS7 and Primary Data

Table A3: Tobit determinants of extended metric of agricultural commercialisation

	Dependent variable: HCLCI	
Variable	GLSS7	Primary
Sex of head	0.013	0.018
	(0.012)	(0.024)
Age of head	-0.000*	-0.002***
	(0.000)	(0.001)
Household size	-0.005***	0.003
	(0.001)	(0.003)
Locality of household	0.131***	
	(0.022)	
Marital status of head	-0.008	-0.057**
	(0.010)	(0.028)
Years of education	0.000	0.002
	(0.001)	(0.001)
Received cash remittance	0.006	0.000
	(0.009)	(0.024)
No. of days stop work due to ill-health	-0.001	0.000
	(0.001)	(0.000)
Ownership of nonfarm enterprise	-0.023**	-0.041**
	(0.010)	(0.020)
Agric cooperative in community	0.106***	0.096***
	(0.022)	(0.025)
Bank in community	0.153***	0.112***
	(0.017)	(0.036)
Mobile phone network in community	0.018	-0.271***
	(0.016)	(0.039)

Agric extension office in community	0.022	0.062***
	(0.017)	(0.018)
Irrigated fields in community	0.139***	-0.042**
	(0.027)	(0.018)
Perceived rain pattern in community	-0.020	0.008
	(0.013)	(0.025)
Log of expenditure on agrochemicals	-0.001	-0.001
	(0.002)	(0.003)
Log of expenditure on hired labour	0.002	-0.002
	(0.002)	(0.003)
No. of crops produced	0.007*	0.032***
	(0.004)	(0.009)
Log of total value of household assets	-0.001	-0.017***
	(0.002)	(0.003)
Log of agric land endowment	0.022***	0.048***
	(0.006)	(0.009)
Market in community	0.241***	0.103***
	(0.016)	(0.018)
Navigable road to community	0.161***	0.161***
	(0.043)	(0.023)
Access to public transport	0.056***	0.158***
	(0.021)	(0.024)
Household in southern Ghana/NR	-0.039**	-0.217***
	(0.018)	(0.032)
Household in coastal zone/UER	-0.039	-0.241***
	(0.036)	(0.029)
Household in forest zone/UWR	0.005	-0.271***
	(0.034)	(0.040)
Household in savannah zone/SR	-0.094**	-0.233***
	(0.039)	(0.037)
Inverse mills ratio	-0.104***	
	(0.020)	
Constant	0.003	0.580***
	(0.066)	(0.067)
Observations	7332	858
Wald chi-square	173.884***	53.931***

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; HCLCI is the household crop-livestock commercialisation index; Standard errors in parentheses; Source: Produced by the author using GLSS7 and Primary Data

Table A4: Determinants of extended metric of agricultural commercialisation (25-100%)

	Dependent variable: HCLCI	
	GLSS7	Primary
	(1)	(2)
Variable	Fractional regression	Fractional regression
Sex of head	0.026	0.105
	(0.027)	(0.087)
Age of head	-0.001*	-0.002
	(0.001)	(0.002)
Household size	-0.025***	0.002
	(0.004)	(0.009)
Locality of household	0.450***	
	(0.071)	
Marital status of head	-0.020	-0.324***
	(0.028)	(0.077)
Years of education	0.002	0.003
	(0.002)	(0.004)
Received cash remittance	0.028	-0.006
	(0.023)	(0.064)

No. of days stop work due to ill-health	-0.003	0.001
	(0.004)	(0.001)
Ownership of nonfarm enterprise	-0.114***	-0.079
	(0.034)	(0.064)
Agric cooperative in community	0.226***	-0.019
	(0.055)	(0.082)
Bank in community	0.467***	0.662***
	(0.069)	(0.091)
Mobile phone network in community	-0.013	-0.511***
	(0.028)	(0.145)
Agric extension office in community	0.082**	0.021
	(0.037)	(0.057)
Irrigated fields in community	0.443***	-0.106
	(0.069)	(0.070)
Perceived rain pattern in community	-0.064**	0.084
	(0.029)	(0.066)
Log of expenditure on agrochemicals	0.011**	0.006
	(0.005)	(0.009)
Log of expenditure on hired labour	0.015***	-0.005
	(0.005)	(0.009)
No. of crops produced	0.047***	0.017
	(0.012)	(0.028)
Log of total value of household assets	-0.003	-0.065***
	(0.004)	(0.015)
Log of agric land endowment	0.086***	0.117***
	(0.011)	(0.028)
Market in community	0.865***	0.194**
	(0.047)	(0.094)
Navigable road to community	0.591***	-0.010
	(0.080)	(0.133)
Access to public transport	0.248***	0.214**
	(0.050)	(0.088)
Household in southern Ghana/NR	-0.136***	-0.249*
	(0.043)	(0.130)
Household in coastal zone/UER	-0.064	-0.631***
	(0.104)	(0.226)
Household in forest zone/UWR	0.115	-0.571***
	(0.100)	(0.148)
Household in savannah zone/SR	-0.256**	-0.474***
	(0.124)	(0.170)
Inverse mills ratio	0.850***	0.484**
	(0.139)	(0.239)
Constant	-2.077***	0.768***
	(0.249)	(0.169)
Observations	3005	448
F-statistic/Wald chi-square	84.980***	284.77***

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; HCLCI is the household crop-livestock commercialisation index; Standard errors in parentheses; Source: Produced by the author using the GLSS7 and Primary Data

Table A5: Comparison of determinants of HCLCI, HCCI and HLCI

	GLSS7			Primary		
Variable	HCLCI	HCCI	HLCI	HCLCI	HCCI	HLCI
Sex of head	0.029	0.092*	-0.252***	0.056	0.100	0.405
	(0.035)	(0.047)	(0.095)	(0.070)	(0.088)	(0.356)
Age of head	-0.001	0.002	0.002	-0.005***	-0.004*	0.008
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.006)
Household size	-0.019***	-0.021***	-0.054***	0.006	0.018	0.015
	(0.004)	(0.005)	(0.016)	(0.010)	(0.011)	(0.021)
Locality of household	0.395***	0.290***	-0.477***			
	(0.067)	(0.089)	(0.176)			
Marital status of head	-0.015	-0.069*	0.044	-0.199**	-0.154	-0.060
	(0.030)	(0.041)	(0.065)	(0.078)	(0.094)	(0.165)
Years of education of head	0.001	0.004	-0.005	0.005	0.003	0.018
	(0.003)	(0.004)	(0.005)	(0.004)	(0.005)	(0.014)
Received cash remittance	0.016	-0.008	-0.045	0.020	-0.077	0.176
	(0.026)	(0.036)	(0.057)	(0.069)	(0.087)	(0.136)
No. of days stop work due to ill-health	-0.002	-0.010*	0.008	0.001	0.000	0.002
	(0.004)	(0.005)	(0.008)	(0.001)	(0.001)	(0.001)
Ownership of nonfarm enterprise	-0.078**	-0.100**	-0.182*	-0.121**	-0.247***	0.348*
	(0.032)	(0.046)	(0.097)	(0.060)	(0.076)	(0.202)
Agric cooperative in community	0.311***	0.157**	0.168**	0.292***	0.401***	0.110*
	(0.065)	(0.077)	(0.083)	(0.073)	(0.091)	(0.064)
Bank in community	0.447***	0.329***	0.259***	0.255**	0.132*	0.208**
	(0.048)	(0.066)	(0.095)	(0.102)	(0.075)	(0.101)
Mobile phone network in community	0.027	-0.061	-0.648***	-0.825***	-0.859***	-0.300
	(0.048)	(0.064)	(0.213)	(0.116)	(0.138)	(0.264)
Agric extension office in community	0.068	0.007	0.038	0.169***	0.188***	0.062
	(0.048)	(0.069)	(0.063)	(0.055)	(0.068)	(0.122)
Irrigated fields in community	0.456***	0.266***	-0.181*	-0.124**	-0.126*	0.271
	(0.078)	(0.087)	(0.109)	(0.056)	(0.066)	(0.187)
Perceived rain pattern in community	-0.054	-0.017	0.125*	0.001	0.008	0.402*
	(0.040)	(0.050)	(0.065)	(0.078)	(0.089)	(0.243)
Log of expenditure on agrochemicals	-0.001	-0.006	-0.030***	-0.002	-0.003	0.020
	(0.007)	(0.009)	(0.011)	(0.009)	(0.011)	(0.020)
Log of expenditure on hired labour	0.007	0.016**	0.042***	-0.007	-0.008	0.033
	(0.006)	(0.008)	(0.015)	(0.009)	(0.012)	(0.020)
No. of crops produced	0.024**	0.059***	0.037*	0.078***	0.029	-0.013

	(0.011)	(0.017)	(0.019)	(0.028)	(0.033)	(0.051)
Log of total value of household assets	-0.004	0.004	-0.028***	-0.055***	-0.027**	-0.044**
	(0.005)	(0.007)	(0.007)	(0.010)	(0.013)	(0.022)
Log of agric land endowment	0.064***	0.041	-0.113***	0.139***	0.127***	0.114
	(0.020)	(0.026)	(0.031)	(0.028)	(0.034)	(0.180)
Market in community	0.652***	0.485***	0.650***	0.310***	0.305***	0.256**
	(0.044)	(0.055)	(0.154)	(0.051)	(0.066)	(0.119)
Navigable road to community	0.398***	0.146***	0.283***	0.504***	0.447***	0.429*
	(0.132)	(0.013)	(0.037)	(0.075)	(0.090)	(0.251)
Access to public transport	0.139**	0.161***	0.025**	0.433***	0.455***	0.346**
	(0.059)	(0.052)	(0.012)	(0.080)	(0.094)	(0.155)
Household in southern Ghana/NR	-0.115**	-0.158**	0.078	-0.640***	-0.720***	-1.097**
	(0.053)	(0.075)	(0.073)	(0.090)	(0.111)	(0.495)
Household in coastal zone/UER	-0.117	-0.235	0.556**	-0.767***	-0.730***	0.133
	(0.112)	(0.234)	(0.245)	(0.084)	(0.101)	(0.325)
Household in forest zone/UWR	0.014	-0.097	0.193	-0.795***	-0.858***	-0.747**
	(0.108)	(0.230)	(0.207)	(0.116)	(0.141)	(0.357)
Household in savannah zone/SR	-0.297**	-0.425*	-0.320	-0.695***	-0.543***	-0.669***
	(0.121)	(0.246)	(0.250)	(0.108)	(0.132)	(0.258)
Inverse mills ratio	-0.305***	-0.984***	-3.357***			1.183
	(0.060)	(0.156)	(0.819)			(1.055)
Constant	-1.322***	0.202	4.804***	0.438**	0.278	-3.556
	(0.203)	(0.336)	(1.682)	(0.194)	(0.232)	(2.208)
Observations	7332	6637	7260	858	858	714
F-statistic	96.612***	48.360***	12.253***	1194.111***	850.445***	69.099***

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; Standard errors in parentheses; HCLCI is the household crop-livestock commercialisation index; HCCI is household crop commercialisation index; HLCI is household livestock commercialisation index; Source: Produced by the author using GLSS7 and Primary Data

Table A6: Relevance of instruments to commercialisation

	Secondary		Primary	
Variable	Continuous	Ordered	Continuous	Ordered
Market in community	0.455***	0.937***	0.199***	0.334**
	(0.042)	(0.047)	(0.059)	(0.130)
Average hclci in community	0.014***	0.030***	0.028***	0.052***
	(0.001)	(0.002)	(0.007)	(0.016)
Average moi in community	0.002**	0.005***	0.010**	0.085***
	(0.001)	(0.001)	(0.005)	(0.031)
Sex of head	0.075**	0.143***	0.133**	0.195
	(0.030)	(0.050)	(0.067)	(0.167)
Age of head	-0.001	-0.002*	-0.003*	-0.004
	(0.001)	(0.001)	(0.002)	(0.004)
Household size	-0.014***	-0.029***	-0.004	-0.020
	(0.004)	(0.006)	(0.009)	(0.021)
Locality of household	0.334***	0.443***		
	(0.052)	(0.058)		
Marital status of head	-0.029	-0.046	-0.246***	-0.527***
	(0.025)	(0.047)	(0.078)	(0.186)
Years of education of head	0.000	-0.002	0.001	0.003
	(0.003)	(0.004)	(0.004)	(0.008)
Received cash remittance	0.016	-0.036	-0.044	-0.157
	(0.023)	(0.035)	(0.067)	(0.146)
No. of days stop work due to ill-health	-0.001	0.002	0.001	0.002
	(0.004)	(0.007)	(0.001)	(0.002)
Ownership of nonfarm enterprise	-0.056*	-0.160***	-0.117*	-0.235*
	(0.029)	(0.047)	(0.061)	(0.135)
Agric cooperative in community	0.225***	0.419***	0.035	-0.022
	(0.060)	(0.057)	(0.099)	(0.193)
Bank in community	0.419***	0.774***	0.186*	0.796***
	(0.046)	(0.057)	(0.100)	(0.225)
Mobile phone network in community	0.122***	0.148***	-0.754***	-1.273***
	(0.046)	(0.040)	(0.112)	(0.245)
Agric extension office in community	0.053	-0.057	0.251***	0.371***
	(0.044)	(0.050)	(0.053)	(0.123)
Irrigated fields in community	0.246***	0.289***	-0.023	-0.076
	(0.074)	(0.054)	(0.056)	(0.128)
Perceived rain pattern in community	-0.053	-0.024	0.001	-0.058
	(0.035)	(0.033)	(0.065)	(0.160)
Log of expenditure on agrochemicals	0.017***	0.015*	0.007	0.018
	(0.006)	(0.008)	(0.009)	(0.021)
Log of expenditure on hired labour	0.003	0.014**	-0.007	-0.014
	(0.005)	(0.007)	(0.009)	(0.020)
No. of crops produced	0.044***	0.045***	0.049*	0.031
	(0.010)	(0.011)	(0.026)	(0.060)
Log of total value of household assets	-0.001	-0.004	-0.050***	-0.127***
	(0.004)	(0.006)	(0.009)	(0.023)
Log of agric land endowment	0.056***	0.073***	0.078***	0.113*
	(0.017)	(0.018)	(0.026)	(0.058)
Navigable road to community	0.649***	0.709***	0.453***	0.665***
	(0.092)	(0.059)	(0.063)	(0.140)
Access to public transport	0.212***	0.196***	0.488***	0.701***
	(0.066)	(0.046)	(0.072)	(0.163)
Household in southern Ghana/NR	-0.025	0.096*	-0.305***	-0.430**
	(0.041)	(0.056)	(0.078)	(0.180)

Household in coastal zone/UER	0.033	0.351	0.191	0.127
	(0.115)	(0.366)	(0.132)	(0.273)
Household in forest zone/UWR	0.076	0.491	-0.531***	-1.023***
	(0.110)	(0.364)	(0.113)	(0.245)
Household in savannah zone/SR	0.001	0.422	-0.432***	-0.796***
	(0.119)	(0.370)	(0.103)	(0.240)
Constant	-2.524***		-1.223***	
	(0.137)		(0.269)	
Cut1		3.063***		0.233
		(0.381)		(0.568)
Cut2		4.125***		1.443**
		(0.381)		(0.578)
Cut3		5.449***		2.827***
		(0.383)		(0.582)
Observations	7332	7332	858	858
F-statistic/Wald chi-square	87.701***	3975.165***	1382.043***	520.493***
Log pseudolikelihood		-5032.150	-427.300	-699.961

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; Continuous is where the household crop-livestock commercialisation index (HCLCI) is continuous; Ordered is where HCLCI is categorised into 4 quadrants (0-<25%, 25-<50, 50-<75, 75-100); Standard errors in parentheses; Fractional regression used for the continuous models and ordered probit used for the ordered models; (Source: Produced by the author using the GLSS7 and Primary Data.

Table A7: Exogeneity test for instruments (GLSS7 data)

Variable	PCFEXP	PAEEXP	HDDS	FCS	Vit. A	Protein	H. iron	Stunting	Wasting	Underweight	FIES
Market in community	198.376*	139.426	0.889***	3.108***	2.321***	1.457***	0.655***	-0.562***	-0.533***	-0.409**	0.004
	(108.230)	(87.193)	(0.123)	(0.287)	(0.372)	(0.239)	(0.097)	(0.140)	(0.173)	(0.203)	(0.075)
Average hclci in community	9.297**	7.626**	0.007	0.018	0.002	0.008	0.004	-0.005	0.001	-0.000	0.011***
	(4.149)	(3.458)	(0.006)	(0.014)	(0.014)	(0.009)	(0.004)	(0.005)	(0.006)	(0.005)	(0.003)
Average moi in community	-2.191	-1.960	0.010*	0.026**	0.021	0.007	0.002	0.004	-0.017***	-0.010**	-0.005
	(3.809)	(3.197)	(0.005)	(0.012)	(0.014)	(0.008)	(0.003)	(0.004)	(0.005)	(0.004)	(0.003)
Sex of head	519.120***	92.561	-0.181*	-0.390**	-0.893***	-0.261*	-0.011	-0.207	-0.106	0.021	0.134**
	(87.984)	(73.055)	(0.103)	(0.189)	(0.234)	(0.135)	(0.061)	(0.137)	(0.159)	(0.158)	(0.066)
Age of head	6.988***	9.550***	0.001	0.004	0.014**	0.001	0.001	0.002	-0.002	-0.006*	0.004***
	(1.890)	(1.700)	(0.002)	(0.006)	(0.006)	(0.004)	(0.002)	(0.004)	(0.004)	(0.004)	(0.001)
Household size	-267.444***	-213.559***	0.057***	0.160***	0.160***	0.191***	0.053***	0.039***	-0.014	0.022	-0.040***
	(19.111)	(14.944)	(0.011)	(0.021)	(0.029)	(0.023)	(0.009)	(0.014)	(0.018)	(0.018)	(0.008)
Locality of household	-121.578	-166.251*	0.116	0.351	-0.811**	-0.021	0.054	-0.649***	-0.411***	-0.567***	-0.109
	(109.319)	(91.414)	(0.108)	(0.244)	(0.338)	(0.233)	(0.106)	(0.125)	(0.116)	(0.145)	(0.100)
Marital status of head	-558.637***	-231.473***	0.336***	0.699***	1.226***	0.772***	0.347***	0.180	-0.328*	-0.372**	0.146***
	(92.171)	(72.109)	(0.103)	(0.207)	(0.244)	(0.140)	(0.060)	(0.163)	(0.196)	(0.172)	(0.049)
Years of education of head	17.507**	12.796**	0.002	-0.020	-0.013	-0.027**	-0.006	-0.007	0.011	-0.004	0.037***
	(7.282)	(5.876)	(0.006)	(0.014)	(0.019)	(0.013)	(0.006)	(0.009)	(0.011)	(0.010)	(0.005)
Received cash remittance	326.987***	228.667***	0.254***	0.429**	0.459**	0.660***	0.234***	-0.147*	0.025	-0.205**	0.137***
	(67.818)	(56.343)	(0.073)	(0.166)	(0.221)	(0.141)	(0.061)	(0.082)	(0.096)	(0.092)	(0.044)
No. of days stop work due to health	-8.220	-5.651	0.019*	0.019	-0.009	0.030	0.008	0.043***	-0.026**	0.024	-0.021***
	(10.835)	(9.527)	(0.011)	(0.021)	(0.027)	(0.021)	(0.009)	(0.015)	(0.012)	(0.020)	(0.007)
Ownership of nonfarm enterprise	160.694**	147.093**	0.027	0.127	0.021	0.386**	0.086	0.153	-0.064	0.082	0.271***
	(77.455)	(62.206)	(0.068)	(0.165)	(0.210)	(0.156)	(0.066)	(0.106)	(0.135)	(0.131)	(0.055)
Agric cooperative in community	-162.568	-149.737	0.065	0.367	-1.029**	0.072	0.156	-0.022	-0.256	-0.221	-0.158
	(180.696)	(150.194)	(0.130)	(0.318)	(0.449)	(0.324)	(0.149)	(0.195)	(0.244)	(0.223)	(0.129)
Bank in community	37.479	14.027	-0.003	0.037	0.209	0.177	-0.024	-0.490***	-0.307	-0.326	0.004
	(121.473)	(98.344)	(0.155)	(0.271)	(0.378)	(0.253)	(0.100)	(0.170)	(0.221)	(0.250)	(0.078)
Mobile phone network in community	92.524	83.183	-0.099	-0.434	-0.295	-0.413	-0.158	-0.337***	-0.416***	-0.551***	-0.161*
	(131.795)	(97.934)	(0.118)	(0.284)	(0.428)	(0.329)	(0.142)	(0.120)	(0.133)	(0.126)	(0.086)
Extension office in community	321.566**	248.295**	0.114	0.185	0.225	-0.318	-0.149	-0.165	-0.210	-0.084	0.151
	(155.789)	(120.568)	(0.119)	(0.292)	(0.463)	(0.326)	(0.135)	(0.159)	(0.220)	(0.198)	(0.108)
Irrigated fields in community	28.435	-62.562	0.055	0.806**	0.587	0.186	-0.248*	-0.214	-0.250	-0.212	0.166
	(148.297)	(109.355)	(0.130)	(0.330)	(0.367)	(0.257)	(0.135)	(0.186)	(0.240)	(0.204)	(0.105)
Perceived rain pattern	94.769	54.044	0.271***	0.494**	0.630*	0.487**	0.022	0.208**	0.076	0.217**	0.059
	(91.955)	(76.079)	(0.096)	(0.217)	(0.329)	(0.223)	(0.091)	(0.095)	(0.115)	(0.109)	(0.071)
Log of expenditure on agrochemicals	28.092*	16.844	0.034**	0.150***	0.171***	0.077***	0.036***	-0.035**	-0.008	-0.037**	-0.004
	(15.533)	(12.959)	(0.015)	(0.030)	(0.048)	(0.029)	(0.013)	(0.018)	(0.019)	(0.018)	(0.010)
Log of expenditure on hired labour	50.508***	41.869***	0.026*	0.048	0.090**	0.061**	0.020	-0.030*	0.036	0.010	0.030***
	(13.593)	(10.970)	(0.014)	(0.031)	(0.040)	(0.028)	(0.013)	(0.016)	(0.022)	(0.019)	(0.010)
No. of crops produced	56.757	26.159	0.104***	0.229***	0.283***	0.333***	0.015	-0.008	-0.062*	-0.038	-0.017
	(38.813)	(27.683)	(0.029)	(0.058)	(0.094)	(0.063)	(0.029)	(0.035)	(0.034)	(0.037)	(0.022)
Log of total value of hh assets	15.324	15.246	0.072***	0.116***	0.200***	0.188***	0.075***	-0.021	-0.005	-0.009	0.049***
	(11.522)	(9.568)	(0.011)	(0.024)	(0.038)	(0.031)	(0.013)	(0.014)	(0.017)	(0.016)	(0.010)
Log of agric land endowment	150.259***	127.061***	0.032	0.210***	0.222**	0.220**	0.130***	-0.049	-0.117**	-0.043	0.002
	(43.317)	(36.224)	(0.035)	(0.067)	(0.100)	(0.095)	(0.042)	(0.041)	(0.054)	(0.050)	(0.025)
Navigable road to community	933.989***	483.330***	0.774***	1.582***	1.445***	1.740***	0.494***	-0.958***	-1.326***	-1.298***	0.055
	(140.964)	(110.954)	(0.234)	(0.442)	(0.544)	(0.411)	(0.158)	(0.157)	(0.145)	(0.153)	(0.113)

Access to public transport	60.599	-74.229	-0.294	-0.841*	-0.520	-1.230***	-0.245	-0.504***	-0.595***	-0.552***	0.160*
	(139.322)	(118.031)	(0.232)	(0.432)	(0.587)	(0.414)	(0.157)	(0.141)	(0.163)	(0.150)	(0.096)
Household in southern Ghana	65.597	71.678	0.301***	0.197	1.189**	-0.486	-0.031	0.364**	0.272	0.219	0.036
	(169.965)	(150.407)	(0.109)	(0.284)	(0.478)	(0.310)	(0.118)	(0.180)	(0.191)	(0.207)	(0.140)
Household in coastal zone	-840.396**	-716.794**	-0.149	0.066	-1.554	-0.576	-0.381	0.443	0.315	0.160	0.089
	(377.747)	(334.274)	(0.405)	(0.554)	(1.216)	(0.620)	(0.328)	(0.363)	(0.243)	(0.303)	(0.285)
Household in forest zone	-705.528*	-581.310*	-0.254	-0.022	-1.022	-0.494	-0.170	0.188	0.207	0.072	0.260
	(369.673)	(329.197)	(0.406)	(0.539)	(1.202)	(0.588)	(0.324)	(0.360)	(0.247)	(0.306)	(0.273)
Household in savannah zone	-1252.826***	-1054.60***	-0.472	-0.676	-2.318*	-1.452**	-0.718**	0.542	0.367	0.249	-0.061
	(392.216)	(349.653)	(0.421)	(0.611)	(1.289)	(0.647)	(0.337)	(0.385)	(0.285)	(0.369)	(0.304)
Constant	2293.587***	2278.542***	4.067***	4.798***	3.604***	1.607**	0.990***	0.992**	1.834***	2.018***	
	(422.881)	(376.134)	(0.437)	(0.651)	(1.307)	(0.693)	(0.343)	(0.457)	(0.422)	(0.424)	
Cut1											0.329
											(0.312)
Cut2											1.112***
											(0.316)
Observations	7332	7332	7332	7332	7332	7332	7332	2452	2452	2452	7332
F-statistic	32.775***	25.255***	34.288***	44.996***	20.843***	20.614***	15.869***	18.522***	23.924***	19.529***	10.840***

Note: * p<0.1; ** p<0.05; *** p<0.01; Standard errors in parentheses; PCFEXP is real per capita annual food expenditure; PAEEXP is real per adult equivalent annual food expenditure; HDDS is household dietary diversity; Vit. A is consumption of vitamin A rich foods; Proteins is consumption of protein rich foods; H. iron is consumption of hem iron rich foods; FIES is food insecurity experience scale; Ordinary least squares is used for the continuous outcomes, probit is used for dummy outcomes and ordered probit is used for ordered outcomes; Source: Produced by the author using the GLSS7 Data.

Table A8: Exogeneity test for instruments (primary data)

Variable	PCFEXP	FEXP	HDDS	FCS	Vit. A	Protein	H. iron	FIES	HHS	HFIAS
Market in community	84.743	-75.605	-0.810***	5.414**	-1.204**	-1.544**	-1.249**	0.587***	0.629***	0.232*
	(106.263)	(465.948)	(0.292)	(2.193)	(0.612)	(0.706)	(0.490)	(0.119)	(0.137)	(0.124)
Average hclci in community	59.756***	331.347***	0.162***	0.981	0.229***	0.937	0.691	0.028*	0.037**	0.026*
	(18.009)	(82.043)	(0.034)	(0.796)	(0.077)	(0.899)	(0.942)	(0.015)	(0.017)	(0.015)
Average moi in community	-9.605	-61.355	-0.184	-0.442**	-0.086	-0.195***	-0.108**	0.002	0.005	0.005
	(11.003)	(44.441)	(0.185)	(0.197)	(0.059)	(0.070)	(0.050)	(0.012)	(0.013)	(0.012)
Sex of head	170.056	-111.980	-0.630**	-2.816	-1.269*	-3.029***	-1.401**	-0.203	0.275*	0.117
	(156.846)	(462.647)	(0.321)	(2.347)	(0.712)	(0.868)	(0.573)	(0.158)	(0.162)	(0.148)
Age of head	-6.055	-4.301	-0.017**	-0.035	-0.027	-0.026	-0.022	-0.002	0.004	-0.005
	(3.952)	(17.649)	(0.008)	(0.063)	(0.018)	(0.021)	(0.014)	(0.004)	(0.004)	(0.004)
Household size	-230.770***	-124.282	0.035	0.251	0.197*	-0.026	-0.111	-0.016	-0.055**	-0.054**
	(22.489)	(110.052)	(0.046)	(0.324)	(0.104)	(0.113)	(0.085)	(0.020)	(0.021)	(0.021)
Marital status of head	-643.420**	-1034.369	-0.392	-0.257	-0.320	0.362	0.104	-0.160	-0.186	0.068
	(268.010)	(675.548)	(0.345)	(2.633)	(0.752)	(1.037)	(0.703)	(0.160)	(0.167)	(0.153)
Years of education of head	12.829	34.421	0.003	0.184	0.058	0.088*	0.058*	0.007	0.004	0.005
	(9.008)	(39.473)	(0.018)	(0.123)	(0.038)	(0.045)	(0.033)	(0.008)	(0.009)	(0.008)
Received cash remittance	-67.865	-115.188	-0.542	0.030	-0.471	-1.111	-0.326	0.055	-0.071	0.093
	(153.633)	(750.973)	(0.336)	(2.608)	(0.758)	(0.874)	(0.629)	(0.149)	(0.179)	(0.164)
No. of days stop work due to health	-0.716	-0.949	0.001	-0.018	-0.011***	-0.020***	-0.013***	-0.001	0.001	-0.001
	(0.884)	(4.215)	(0.002)	(0.011)	(0.004)	(0.005)	(0.004)	(0.002)	(0.001)	(0.002)
Ownership of nonfarm enterprise	-46.735	-293.557	0.303	2.581	2.210***	1.901***	1.152**	-0.206*	-0.021	-0.415***
	(106.982)	(499.630)	(0.278)	(1.993)	(0.614)	(0.721)	(0.487)	(0.121)	(0.136)	(0.124)

Agric cooperative in community	-91.894	-86.975	0.603*	0.560	-0.293	0.327	0.630	0.241	0.426**	0.198
	(185.918)	(760.434)	(0.358)	(2.952)	(0.797)	(0.958)	(0.687)	(0.171)	(0.200)	(0.189)
Bank in community	703.862**	2921.362***	-0.715*	-2.748	0.670	1.471	0.868	0.191	-0.546**	-0.466**
	(285.688)	(1035.737)	(0.426)	(2.871)	(1.066)	(1.128)	(0.855)	(0.210)	(0.242)	(0.197)
Mobile phone network in community	-582.585**	-1356.671	-0.470	-4.780	-0.282	-1.820	-0.512	-0.584**	-0.731***	-0.459*
	(277.836)	(1118.440)	(0.514)	(2.953)	(0.994)	(1.313)	(0.973)	(0.243)	(0.263)	(0.241)
Extension office in community	317.525***	1547.610***	0.274	3.511*	-0.617	0.270	0.971*	0.226*	0.442***	0.495***
	(120.534)	(529.503)	(0.279)	(2.104)	(0.562)	(0.731)	(0.498)	(0.118)	(0.133)	(0.118)
Irrigated fields in community	136.489	268.026	0.537**	0.175	0.553	0.554	0.286	-0.111	0.203	0.109
	(123.989)	(503.520)	(0.241)	(1.678)	(0.514)	(0.645)	(0.455)	(0.113)	(0.129)	(0.111)
Perceived rain pattern	-12.256	-726.041	-0.138	-0.673	0.461	0.955	0.992	-0.158	-0.665***	-0.053
	(151.945)	(713.857)	(0.332)	(2.287)	(0.744)	(0.870)	(0.613)	(0.147)	(0.159)	(0.140)
Log of expenditure on agrochemicals	22.622	18.906	0.146***	0.015	0.154*	0.248**	0.160**	-0.015	-0.004	-0.023
	(19.001)	(81.793)	(0.043)	(0.308)	(0.089)	(0.111)	(0.075)	(0.019)	(0.021)	(0.021)
Log of expenditure on hired labour	-14.011	70.795	0.121***	0.639**	0.414***	0.441***	0.238***	0.004	-0.021	-0.013
	(18.488)	(86.237)	(0.039)	(0.254)	(0.088)	(0.111)	(0.079)	(0.019)	(0.021)	(0.020)
No. of crops produced	-85.132	84.545	0.263*	0.545	-0.874***	-0.647*	-0.272	0.076	0.150**	0.151**
	(71.063)	(346.882)	(0.136)	(0.989)	(0.297)	(0.356)	(0.250)	(0.058)	(0.066)	(0.062)
Log of total value of hh assets	22.296	-64.684	0.193***	-1.416***	0.562***	0.850***	0.414***	0.014	-0.027	0.045**
	(23.391)	(151.143)	(0.062)	(0.533)	(0.144)	(0.170)	(0.122)	(0.022)	(0.026)	(0.022)
Log of agric land endowment	188.000**	825.395***	0.112	2.805***	0.543*	0.411	0.326	0.079	0.074	-0.031
	(88.931)	(318.648)	(0.123)	(0.870)	(0.295)	(0.352)	(0.295)	(0.060)	(0.068)	(0.061)
Navigable road to community	39.953	242.414	2.822***	1.776	-0.370	-0.825	-0.430	0.796***	0.885***	0.853***
	(140.744)	(664.284)	(0.298)	(2.005)	(0.633)	(0.745)	(0.530)	(0.141)	(0.148)	(0.140)
Access to public transport	462.289***	1360.518**	1.082***	2.073	0.940	0.077	-0.281	0.273*	0.421***	0.383**
	(147.323)	(660.662)	(0.308)	(2.172)	(0.649)	(0.748)	(0.539)	(0.145)	(0.151)	(0.150)
Household in NR	-1616.942***	-9744.220***	-0.420	-5.171*	-1.028	-3.859***	-4.266***	-0.344*	-0.068	-0.440**
	(293.459)	(1409.086)	(0.417)	(3.116)	(1.072)	(1.177)	(0.774)	(0.198)	(0.203)	(0.199)
Household in UER	-1075.202***	-7032.673***	-1.164**	-12.958***	-2.754**	-6.974***	-5.114***	-0.107	0.208	0.060
	(362.118)	(1691.978)	(0.456)	(4.006)	(1.170)	(1.352)	(0.965)	(0.252)	(0.251)	(0.273)
Household in UWR	-1639.397***	-8854.204***	-1.373***	-12.597***	-5.234***	-10.25***	-7.617***	-0.218	0.069	0.001
	(336.799)	(1562.649)	(0.501)	(3.613)	(1.182)	(1.320)	(0.936)	(0.245)	(0.276)	(0.258)
Household in SR	-1624.966***	-9470.613***	0.179	7.848**	1.410	-0.125	-2.450**	-0.165	0.034	-0.447
	(318.791)	(1549.578)	(0.549)	(3.866)	(1.359)	(1.502)	(0.986)	(0.258)	(0.270)	(0.272)
Constant	2990.349***	8066.686***	0.071	33.642***	1.749	9.282***	6.969***			
	(676.432)	(2984.623)	(1.033)	(8.285)	(2.334)	(2.845)	(2.099)			
Cut1								0.210	0.902*	1.003*
								(0.505)	(0.546)	(0.533)
Cut2								1.323***	1.471***	1.370**
								(0.505)	(0.548)	(0.534)
Cut3										1.670***
										(0.536)
Observations	858	858	858	858	858	858	858	858	858	858
F-statistic/Wald chi-square	16.283***	22.505***	45.270***	14.676***	12.901***	20.928***	17.653***	411.732***	416.92***	338.52***

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; Standard errors in parentheses; PCFEXP is per capita annual food expenditure; Vit. A is consumption of vitamin A rich foods; Proteins is consumption of protein rich foods; H. iron is consumption of hem iron rich foods; FEXP is total annual food expenditure; HDDS is household dietary diversity; FCS is food consumption score; FIES is food insecurity experience scale; HHS is household hunger scale; HFIAS is household food insecurity access scale; Ordinary least squares is used for the continuous outcomes, probit is used for dummy outcomes and ordered probit is used for ordered outcomes; Source: Produced by the author using Primary Data 2022.

Table A9: First-stage estimates of agricultural commercialisation for ordered outcomes

	GLSS7	Primary data		
	FIES	FIES	HHS	HFIAS
Variable	HCLCI	HCLCI	HCLCI	HCLCI
Market in community	21.237***			
	(0.591)			
Average moi in community	0.359***	0.746***	0.746***	0.746***
	(0.011)	(0.075)	(0.075)	(0.075)
Sex of head	1.926***	2.105	2.105	2.105
	(0.562)	(1.812)	(1.812)	(1.812)
Age of head	-0.007	-0.072	-0.072	-0.072
	(0.013)	(0.050)	(0.050)	(0.050)
Household size	-0.399***	0.040	0.040	0.040
	(0.069)	(0.265)	(0.265)	(0.265)
Locality of household	3.158***			
	(0.554)			
Marital status of head	-0.192	-6.892***	-6.892***	-6.892***
	(0.540)	(2.219)	(2.219)	(2.219)
Years of education of head	-0.009	0.071	0.071	0.071
	(0.044)	(0.105)	(0.105)	(0.105)
Received cash remittance	0.124	-1.556	-1.556	-1.556
	(0.412)	(1.912)	(1.912)	(1.912)
No. of days stop work due to health	0.013	0.013	0.013	0.013
	(0.079)	(0.023)	(0.023)	(0.023)
Ownership of nonfarm enterprise	-1.273**	-2.006	-2.006	-2.006
	(0.526)	(1.692)	(1.692)	(1.692)
Agric cooperative in community	8.845***	2.057	2.057	2.057
	(0.716)	(2.594)	(2.594)	(2.594)
Bank in community	13.545***	16.925***	16.925***	16.925***
	(0.703)	(3.043)	(3.043)	(3.043)
Mobile phone network in community	3.165***	-18.028***	-18.028***	-18.028***
	(0.491)	(3.228)	(3.228)	(3.228)
Extension office in community	1.117*	7.758***	7.758***	7.758***
	(0.631)	(1.698)	(1.698)	(1.698)
Irrigated fields in community	5.394***	-0.654	-0.654	-0.654
	(0.636)	(1.414)	(1.414)	(1.414)
Perceived rain pattern	-0.161	-1.811	-1.811	-1.811
	(0.376)	(1.865)	(1.865)	(1.865)
Log of expenditure on agrochemicals	0.060	0.037	0.037	0.037
	(0.082)	(0.226)	(0.226)	(0.226)
Log of expenditure on hired labour	0.233***	0.099	0.099	0.099
	(0.082)	(0.238)	(0.238)	(0.238)
No. of crops produced	0.708***	1.055	1.055	1.055
	(0.132)	(0.789)	(0.789)	(0.789)
Log of total value of hh assets	-0.112	-1.727***	-1.727***	-1.727***
	(0.070)	(0.299)	(0.299)	(0.299)
Log of agric land endowment	0.904***	2.117***	2.117***	2.117***
	(0.196)	(0.805)	(0.805)	(0.805)
Navigable road to community	9.954***	12.789***	12.789***	12.789***
	(0.621)	(1.658)	(1.658)	(1.658)
Access to public transport	2.875***	10.313***	10.313***	10.313***
	(0.576)	(1.912)	(1.912)	(1.912)
Household in southern Ghana/NR	-1.415**	-8.135***	-8.135***	-8.135***
	(0.702)	(2.529)	(2.529)	(2.529)
Household in coastal zone zone/UER	-0.716	-2.548	-2.548	-2.548

	(2.703)	(2.821)	(2.821)	(2.821)
Household in forest/UWR	1.039	-18.362***	-18.362***	-18.362***
	(2.671)	(3.204)	(3.204)	(3.204)
Household in savannah/SR	-3.098	-18.192***	-18.192***	-18.192***
	(2.760)	(2.988)	(2.988)	(2.988)
Constant	-2.443	126.978***	26.978***	26.978***
	(2.894)	(6.145)	(6.145)	(6.145)
Cut1		1.065	1.944***	1.838***
		(0.661)	(0.634)	(0.638)
Cut2		2.392***	2.564***	2.240***
		(0.681)	(0.623)	(0.634)
Cut3				2.558***
				(0.633)
Corr(hclci & outcomes)		0.141	-0.217	-0.131
		(0.130)	(0.136)	(0.132)
Observations	7332	858	858	858
Wald Chi-square	1455.347***	405.054***	583.594***	447.409***
Log likelihood		-4212.516	-4153.193	-4365.064

Notes: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; Standard errors in parentheses; HCLCI is the household crop-livestock commercialisation index; FIES, HHS and HFIAS are estimated using eoprobit; Source: Produced by the author using GLSS7 and Primary Data 2022.

Table A10: Impact of agricultural commercialisation on food and nutrition security outcomes (GLSS7 robustness)

Variable	PCFEXP	HCLCI	PAEFEXP	HCLCI	HDDS	HCLCI	FCS	HCLCI
HCLCI	8.519***		7.751***		0.038***		0.091***	
	(2.713)		(1.745)		(0.002)		(0.004)	
Sex of head	441.128***	2.328***	71.241	1.926***	-0.249***	2.513***	-0.380***	2.513***
	(65.636)	(0.607)	(53.469)	(0.569)	(0.058)	(0.587)	(0.110)	(0.587)
Age of head	2.651**	-0.002	4.276***	-0.007	-0.001	-0.009	-0.002	-0.009
	(1.282)	(0.014)	(1.073)	(0.012)	(0.001)	(0.013)	(0.003)	(0.013)
Household size	-206.249***	-0.479***	-165.912***	-0.399***	0.083***	-0.377***	0.183***	-0.377***
	(8.501)	(0.074)	(6.769)	(0.071)	(0.007)	(0.072)	(0.014)	(0.072)
Locality of household	-314.956***	1.317**	-326.302***	3.156***	-0.164***	3.708***	-0.213*	3.708***
	(60.429)	(0.598)	(48.203)	(0.594)	(0.056)	(0.566)	(0.109)	(0.566)
Marital status of head	-502.581***	-0.409	-217.042***	-0.192	0.281***	-0.744	0.526***	-0.744
	(66.813)	(0.597)	(50.579)	(0.554)	(0.059)	(0.578)	(0.109)	(0.578)
Years of education of head	12.625***	0.032	12.032***	-0.009	0.006	-0.015	-0.014	-0.015
	(4.511)	(0.048)	(3.747)	(0.044)	(0.004)	(0.046)	(0.009)	(0.046)
Received cash remittance	357.522***	0.138	275.156***	0.124	0.240***	-0.296	0.401***	-0.296
	(46.299)	(0.459)	(37.588)	(0.420)	(0.042)	(0.440)	(0.086)	(0.440)
No. of days stop work due to health	-4.414	-0.008	-4.431	0.013	0.010	0.020	0.022	0.020
	(7.367)	(0.087)	(6.370)	(0.082)	(0.008)	(0.081)	(0.016)	(0.081)
Ownership of nonfarm enterprise	105.299*	-1.555***	98.381**	-1.273**	0.057	-1.577***	0.071	-1.577***
	(56.531)	(0.557)	(46.796)	(0.521)	(0.052)	(0.542)	(0.104)	(0.542)
Agric cooperative in community	-229.654**	9.411***	-211.842***	8.845***	-0.080	9.148***	-0.143	9.148***
	(97.798)	(0.906)	(78.461)	(0.841)	(0.082)	(0.846)	(0.170)	(0.846)
Bank in community	-26.614	23.009***	-74.893	13.546***	-0.464***	19.234***	-0.440**	19.234***
	(109.658)	(0.860)	(79.082)	(0.866)	(0.091)	(0.835)	(0.190)	(0.835)
Mobile phone network in community	101.633*	2.340***	54.058	3.165***	-0.187***	1.505***	-0.587***	1.505***
	(53.527)	(0.581)	(42.314)	(0.536)	(0.050)	(0.556)	(0.104)	(0.556)
Extension office in community	190.683**	2.197***	133.456**	1.117	-0.128*	1.587**	-0.308**	1.587**
	(83.067)	(0.793)	(64.624)	(0.720)	(0.071)	(0.750)	(0.143)	(0.750)
Irrigated fields in community	-37.767	6.800***	-55.297	5.395***	-0.302***	4.649***	-0.089	4.649***
	(72.258)	(0.718)	(57.867)	(0.685)	(0.066)	(0.691)	(0.135)	(0.691)
Perceived rain pattern	50.068	0.560	17.095	-0.160	0.109***	0.687*	0.314***	0.687*
	(38.456)	(0.405)	(31.734)	(0.374)	(0.038)	(0.387)	(0.075)	(0.387)
Log of expenditure on agrochemicals	32.795***	0.052	24.102***	0.060	0.031***	0.197**	0.126***	0.197**
	(9.351)	(0.086)	(7.761)	(0.081)	(0.008)	(0.083)	(0.016)	(0.083)
Log of expenditure on hired labour	44.825***	0.296***	35.296***	0.233***	0.036***	0.200**	0.059***	0.200**
	(9.700)	(0.093)	(7.937)	(0.087)	(0.008)	(0.089)	(0.017)	(0.089)
No. of crops produced	-5.495	0.696***	-17.537	0.708***	0.072***	0.693***	0.137***	0.693***
	(15.623)	(0.142)	(11.962)	(0.131)	(0.013)	(0.137)	(0.027)	(0.137)

Log of total value of hh assets	8.963	-0.178**	10.758*	-0.112	0.074***	-0.177**	0.126***	-0.177**
	(6.826)	(0.075)	(5.653)	(0.069)	(0.007)	(0.073)	(0.014)	(0.073)
Log of agric land endowment	200.960***	1.022***	167.558***	0.904***	0.084***	1.094***	0.237***	1.094***
	(24.807)	(0.224)	(19.887)	(0.209)	(0.020)	(0.214)	(0.040)	(0.214)
Navigable road to community	596.209***	11.644***	248.759***	9.953***	0.071	10.448***	0.139	10.448***
	(71.622)	(0.631)	(53.568)	(0.632)	(0.070)	(0.611)	(0.137)	(0.611)
Access to public transport	206.268***	6.792***	72.603	2.875***	-0.061	6.401***	-0.140	6.401***
	(62.396)	(0.604)	(48.425)	(0.582)	(0.060)	(0.579)	(0.120)	(0.579)
Household in southern Ghana	-36.633	-3.088***	0.659	-1.415*	0.324***	-0.759	0.240	-0.759
	(90.856)	(0.862)	(73.547)	(0.777)	(0.071)	(0.827)	(0.156)	(0.827)
Household in coastal zone	-384.651	-1.510	-325.985	-0.716	0.108	0.435	0.487	0.435
	(308.538)	(3.247)	(254.126)	(3.207)	(0.297)	(3.095)	(0.463)	(3.095)
Household in forest zone	-291.121	0.206	-249.766	1.038	0.065	1.607	0.624	1.607
	(302.461)	(3.213)	(249.911)	(3.180)	(0.295)	(3.064)	(0.456)	(3.064)
Household in savannah zone	-981.333***	-5.756*	-823.627***	-3.098	-0.207	-0.572	0.009	-0.572
	(313.141)	(3.312)	(258.505)	(3.259)	(0.303)	(3.165)	(0.480)	(3.165)
Market in community				21.232***				
				(0.798)				
Average hclci in community						0.581***		0.581***
						(0.014)		(0.014)
Average moi in community		0.421***		0.359***				
		(0.012)		(0.012)				
Constant	2397.139***	0.007	2336.162***	-2.443	4.344***	-9.775***	5.674***	
	(325.967)	(3.409)	(270.726)	(3.325)	(0.315)	(3.261)	(0.508)	
Corr(e.hclci, e.outcomes)	0.040		0.011		-0.100***		0.035	
	(0.032)		(0.026)		(0.027)		(0.026)	
Observations	7332		7332		7332		7332	
Wald Chi-square	2325.837***		2080.587***		2873.416***		3938.187***	
Log likelihood	-95755.106		-93711.949		-44504.383		-49597.129	

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; Standard errors in parentheses; HCLCI is the household crop-livestock commercialisation index; PCFEXP, PAEFEXP, HDDS, Vit. A, Protein and H. iron are estimated using eregress; Source: Produced by the author using the GLSS7 Data

Table A10: continued

Variable	Vit. A	HCLCI	Proteins	HCLCI	H. iron	HCLCI
HCLCI	0.063***		0.033***		0.018***	
	(0.006)		(0.004)		(0.002)	
Sex of head	-0.903***	2.498***	-0.257**	2.498***	0.030	2.498***
	(0.147)	(0.585)	(0.103)	(0.585)	(0.043)	(0.585)
Age of head	0.005*	-0.007	-0.003	-0.007	-0.001	-0.007

	(0.003)	(0.013)	(0.003)	(0.013)	(0.001)	(0.013)
Household size	0.169***	-0.386***	0.176***	-0.386***	0.060***	-0.386***
	(0.018)	(0.072)	(0.017)	(0.072)	(0.007)	(0.072)
Locality of household	-1.247***	3.137***	-0.138	3.158***	-0.097**	3.137***
	(0.146)	(0.576)	(0.107)	(0.576)	(0.047)	(0.576)
Marital status of head	1.061***	-0.684	0.590***	-0.686	0.243***	-0.683
	(0.142)	(0.577)	(0.102)	(0.577)	(0.043)	(0.577)
Years of education of head	0.009	-0.007	-0.018**	-0.007	-0.003	-0.007
	(0.012)	(0.046)	(0.009)	(0.046)	(0.004)	(0.046)
Received cash remittance	0.382***	-0.252	0.619***	-0.254	0.222***	-0.252
	(0.113)	(0.440)	(0.090)	(0.440)	(0.039)	(0.440)
No. of days stop work due to health	-0.012	0.017	0.035**	0.017	0.012	0.017
	(0.020)	(0.081)	(0.017)	(0.081)	(0.007)	(0.081)
Ownership of nonfarm enterprise	0.032	-1.508***	0.229**	-1.510***	0.097**	-1.508***
	(0.137)	(0.541)	(0.112)	(0.541)	(0.048)	(0.541)
Agric cooperative in community	-1.235***	9.096***	-0.039	9.097***	0.006	9.096***
	(0.225)	(0.847)	(0.176)	(0.847)	(0.076)	(0.847)
Bank in community	-0.356	19.464***	0.046	19.453***	-0.136*	19.464***
	(0.258)	(0.837)	(0.185)	(0.837)	(0.079)	(0.837)
Mobile phone network in community	-0.663***	1.733***	-0.496***	1.725***	-0.305***	1.733***
	(0.139)	(0.558)	(0.119)	(0.558)	(0.050)	(0.558)
Extension office in community	0.103	1.573**	-0.431***	1.573**	-0.064	1.573**
	(0.211)	(0.749)	(0.152)	(0.749)	(0.065)	(0.749)
Irrigated fields in community	0.032	4.920***	-0.245*	4.909***	-0.198***	4.920***
	(0.173)	(0.691)	(0.125)	(0.691)	(0.055)	(0.691)
Perceived rain pattern	0.322***	0.674*	0.340***	0.675*	0.037	0.674*
	(0.098)	(0.387)	(0.078)	(0.387)	(0.033)	(0.387)
Log of expenditure on agrochemicals	0.125***	0.177**	0.070***	0.178**	0.032***	0.177**
	(0.021)	(0.083)	(0.015)	(0.083)	(0.007)	(0.083)
Log of expenditure on hired labour	0.130***	0.201**	0.077***	0.201**	0.033***	0.201**
	(0.023)	(0.089)	(0.018)	(0.089)	(0.008)	(0.089)
No. of crops produced	0.322***	0.696***	0.328***	0.696***	-0.018	0.696***
	(0.037)	(0.136)	(0.029)	(0.136)	(0.013)	(0.136)
Log of total value of hh assets	0.163***	-0.173**	0.169***	-0.173**	0.070***	-0.173**
	(0.019)	(0.072)	(0.016)	(0.072)	(0.007)	(0.072)
Log of agric land endowment	0.149***	1.037***	0.357***	1.039***	0.156***	1.037***
	(0.054)	(0.214)	(0.050)	(0.214)	(0.022)	(0.214)
Navigable road to community	0.273	10.336***	0.948***	10.339***	0.231***	10.336***
	(0.173)	(0.610)	(0.149)	(0.610)	(0.064)	(0.610)
Access to public transport	0.240	6.310***	-0.677***	6.313***	-0.104*	6.310***

	(0.150)	(0.579)	(0.132)	(0.579)	(0.055)	(0.579)
Household in southern Ghana	1.470***	-0.956	-0.478***	-0.948	0.048	-0.956
	(0.210)	(0.830)	(0.155)	(0.830)	(0.067)	(0.830)
Household in coastal zone	-1.493*	0.178	-0.293	0.188	-0.187	0.178
	(0.779)	(3.086)	(0.471)	(3.087)	(0.212)	(3.086)
Household in forest zone	-0.468	1.236	-0.037	1.249	0.082	1.236
	(0.770)	(3.056)	(0.464)	(3.057)	(0.210)	(3.056)
Household in savannah zone	-1.562*	-1.011	-0.983**	-0.992	-0.463**	-1.011
	(0.797)	(3.158)	(0.483)	(3.159)	(0.218)	(3.158)
Average hclci in community		0.516***		0.519***		0.516***
		(0.021)		(0.021)		(0.021)
Average moi in community		0.073***		0.071***		0.073***
		(0.018)		(0.018)		(0.018)
Constant	4.234***	-8.930***	2.016***	-8.965***	0.958***	
	(0.825)	(3.260)	(0.512)	(3.261)	(0.228)	
Corr(e.hclci,e.outcomes)		0.104***		0.096***		0.048**
		(0.026)		(0.023)		(0.025)
Observations		7332		7332		7332
Wald Chi-square		2211.802***		1591.525***		1596.763***
Log likelihood		-51575.984		-49969.171		-43690.677

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; Standard errors in parentheses; HCLCI is the household crop-livestock commercialisation index; PCFEXP, PAEFEXP, HDDS, Vit. A, Protein and H. iron are estimated using eregress; Source: Produced by the author using the GLSS7 Data

Table A10 continued

Variable	Stunting	HCLCI	Wasting	HCLCI	Underweight	HCLCI	FIES	HCLCI
HCLCI	-0.008**		-0.039***		-0.021***		0.004***	
	(0.004)		(0.004)		(0.004)		(0.001)	
Sex of head	-0.106	2.848**	-0.024	2.927**	0.177	2.927**	0.098**	1.926***
	(0.118)	(1.323)	(0.131)	(1.323)	(0.129)	(1.323)	(0.042)	(0.563)
Age of head	0.000	0.014	0.003	0.012	-0.004	0.012	0.004***	-0.007
	(0.003)	(0.027)	(0.003)	(0.027)	(0.003)	(0.027)	(0.001)	(0.013)
Household size	0.023*	-0.415***	-0.038***	-0.405***	0.001	-0.405***	-0.036***	-0.399***
	(0.012)	(0.120)	(0.014)	(0.120)	(0.015)	(0.120)	(0.005)	(0.069)
Locality of household	-0.377***	3.120***	-0.171*	3.711***	-0.363***	3.711***	-0.167***	3.158***
	(0.099)	(1.034)	(0.102)	(1.023)	(0.102)	(1.023)	(0.042)	(0.555)
Marital status of head	-0.001	0.647	-0.010	0.562	-0.266*	0.562	0.106***	-0.192
	(0.131)	(1.544)	(0.144)	(1.542)	(0.143)	(1.542)	(0.040)	(0.542)
Years of education of head	0.001	-0.010	0.012	-0.021	-0.003	-0.021	0.044***	-0.009
	(0.007)	(0.083)	(0.009)	(0.082)	(0.008)	(0.082)	(0.003)	(0.044)

Received cash remittance	-0.091	0.182	0.070	0.084	-0.116	0.084	0.136***	0.124
	(0.068)	(0.724)	(0.079)	(0.725)	(0.079)	(0.725)	(0.031)	(0.413)
No. of days stop work due to health	0.022	-0.124	-0.035**	-0.122	0.005	-0.122	-0.020***	0.013
	(0.015)	(0.152)	(0.014)	(0.151)	(0.017)	(0.151)	(0.006)	(0.079)
Ownership of nonfarm enterprise	0.068	-2.084**	0.011	-2.096**	0.159	-2.096**	0.309***	-1.273**
	(0.088)	(0.880)	(0.096)	(0.878)	(0.098)	(0.878)	(0.040)	(0.527)
Agric cooperative in community	-0.120	8.453***	-0.096	8.659***	-0.140	8.659***	-0.197***	8.845***
	(0.141)	(1.428)	(0.200)	(1.424)	(0.180)	(1.424)	(0.058)	(0.717)
Bank in community	-0.534***	18.989***	0.285	18.650***	-0.042	18.650***	-0.023	13.545***
	(0.169)	(1.493)	(0.211)	(1.488)	(0.211)	(1.488)	(0.061)	(0.705)
Mobile phone network in community	-0.431***	2.449***	-0.425***	2.312***	-0.568***	2.312***	-0.218***	3.165***
	(0.073)	(0.867)	(0.089)	(0.865)	(0.085)	(0.865)	(0.036)	(0.492)
Extension office in community	-0.030	2.754**	0.074	2.765**	0.050	2.765**	0.127**	1.117*
	(0.126)	(1.300)	(0.168)	(1.303)	(0.160)	(1.303)	(0.050)	(0.633)
Irrigated fields in community	-0.248**	3.792***	0.032	3.576***	-0.090	3.576***	0.202***	5.394***
	(0.118)	(1.213)	(0.147)	(1.216)	(0.142)	(1.216)	(0.049)	(0.637)
Perceived rain pattern	0.119*	0.503	-0.014	0.550	0.098	0.550	0.021	-0.161
	(0.063)	(0.667)	(0.071)	(0.669)	(0.071)	(0.669)	(0.028)	(0.377)
Log of expenditure on agrochemicals	-0.028**	0.134	-0.005	0.153	-0.036**	0.153	0.010*	0.060
	(0.014)	(0.150)	(0.016)	(0.150)	(0.015)	(0.150)	(0.006)	(0.082)
Log of expenditure on hired labour	-0.017	0.316**	0.015	0.332**	0.010	0.332**	0.028***	0.233***
	(0.014)	(0.152)	(0.016)	(0.153)	(0.015)	(0.153)	(0.006)	(0.082)
No. of crops produced	-0.020	0.880***	-0.004	0.872***	-0.021	0.872***	0.014	0.708***
	(0.022)	(0.222)	(0.024)	(0.223)	(0.026)	(0.223)	(0.010)	(0.132)
Log of total value of hh assets	-0.017	0.011	0.006	0.003	-0.014	0.003	0.054***	-0.112
	(0.011)	(0.116)	(0.012)	(0.116)	(0.012)	(0.116)	(0.005)	(0.070)
Log of agric land endowment	0.010	0.360	-0.130***	0.507	-0.041	0.507	0.002	0.904***
	(0.034)	(0.348)	(0.040)	(0.341)	(0.040)	(0.341)	(0.015)	(0.197)
Navigable road to community	-1.021***	7.905***	-1.092***	7.910***	-1.221***	7.910***	-0.017	9.954***
	(0.093)	(0.973)	(0.116)	(0.974)	(0.103)	(0.974)	(0.049)	(0.622)
Access to public transport	-0.381***	5.867***	-0.146	5.909***	-0.276***	5.909***	0.142***	2.875***
	(0.085)	(0.931)	(0.108)	(0.928)	(0.106)	(0.928)	(0.043)	(0.577)
Household in southern Ghana	0.231*	-2.297	-0.114	-1.904	-0.006	-1.904	-0.005	-1.415**
	(0.126)	(1.445)	(0.144)	(1.425)	(0.146)	(1.425)	(0.056)	(0.704)
Household in coastal zone	0.242	-6.472*	0.041	-5.656	-0.091	-5.656	-0.203	-0.716
	(0.323)	(3.632)	(0.313)	(3.695)	(0.313)	(3.695)	(0.214)	(2.708)
Household in forest zone	0.011	-6.438*	-0.286	-5.414	-0.191	-5.414	-0.085	1.039
	(0.315)	(3.542)	(0.298)	(3.596)	(0.306)	(3.596)	(0.212)	(2.676)
Household in savannah zone	0.294	-8.622**	-0.265	-7.379*	-0.189	-7.379*	-0.515**	-3.098
	(0.338)	(3.799)	(0.322)	(3.839)	(0.335)	(3.839)	(0.219)	(2.765)

								21.237***
								(0.592)
Average hclci in community		0.545***		0.622***		0.622***		
		(0.040)		(0.025)		(0.025)		
Average moi in community		0.081**						0.359***
		(0.033)						(0.011)
Commercialisation residual							-0.002	
							(0.002)	
Constant	1.230***	-3.065	1.720***	-4.945	2.002***	-4.945		-2.443
	(0.366)	(4.205)	(0.375)	(4.199)	(0.379)	(4.199)		(2.900)
Cut1							-0.108	
							(0.228)	
Cut2							0.687***	
							(0.228)	
Corr(e.hclci, e.outcomes)	-0.247***		0.225***		-0.010			
	(0.062)		(0.076)		(0.074)			
Observations	2452		2452		2452		7332	
Wald Chi-square	969.612***		837.371***		1013.137***		1439.257***	
Log likelihood	-11323.129		-11013.978		-11075.300		-7210.112	

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; HCLCI is the household crop-livestock commercialisation index; Standard errors in parentheses; Stunting. Wasting and Underweight are estimated using eprobit; FIES is estimated using control function ordered probit; Source: Produced by the author using the GLSS7 Data.

Table A11: Impact of agricultural commercialisation on food and nutrition security outcomes (primary robustness)

Variable	PCFDEXP	HCLCI	FDEXP	HCLCI	HDDS	HCLCI	FCS	HCLCI
HCLCI	39.998***		197.060***		0.086***		0.311***	
	(7.600)		(37.435)		(0.016)		(0.094)	
Sex of head	64.413	2.206	-655.269*	2.209	-0.838***	2.105	-3.510	2.433
	(132.346)	(1.764)	(377.095)	(1.764)	(0.323)	(1.812)	(2.151)	(1.729)
Age of head	-3.943	-0.074	4.855	-0.073	-0.012	-0.072	-0.010	-0.060
	(3.562)	(0.050)	(15.309)	(0.050)	(0.009)	(0.050)	(0.058)	(0.050)
Household size	-224.928***	0.063	-87.465	0.062	0.053	0.040	0.292	-0.098
	(20.335)	(0.262)	(93.388)	(0.262)	(0.045)	(0.265)	(0.307)	(0.262)
Marital status of head	-351.213	-6.710***	444.216	-6.716***	0.254	-6.892***	1.729	-7.194***
	(230.723)	(2.171)	(583.576)	(2.172)	(0.355)	(2.219)	(2.413)	(2.147)
Years of education of head	10.162	0.097	23.632	0.097	0.001	0.071	0.143	0.063
	(7.779)	(0.105)	(35.154)	(0.105)	(0.018)	(0.105)	(0.112)	(0.102)
Received cash remittance	-24.661	-1.498	110.031	-1.504	-0.471	-1.556	-0.119	-1.159
	(135.954)	(1.908)	(675.279)	(1.907)	(0.330)	(1.912)	(2.433)	(1.864)
No. of days stop work due to health	-1.228**	0.014	-3.312	0.014	-0.000	0.013	-0.023*	0.013

	(0.576)	(0.024)	(2.970)	(0.024)	(0.003)	(0.023)	(0.012)	(0.022)
Ownership of nonfarm enterprise	69.904	-2.077	287.486	-2.073	0.574**	-2.006	3.915**	-2.697
	(89.363)	(1.678)	(400.092)	(1.678)	(0.286)	(1.692)	(1.775)	(1.669)
Agric cooperative in community	-80.101	1.155	29.818	1.149	0.492	2.057	0.488	0.694
	(163.831)	(2.417)	(670.369)	(2.419)	(0.403)	(2.594)	(2.761)	(2.752)
Bank in community	256.718	14.967***	716.258	14.991***	-1.816***	16.925***	-3.876	13.079***
	(285.261)	(3.112)	(1204.408)	(3.115)	(0.526)	(3.043)	(3.034)	(3.091)
Mobile phone network in community	18.924	-18.833***	1457.682	-18.819***	0.651	-18.028***	0.022	-15.686***
	(272.143)	(3.332)	(1187.462)	(3.333)	(0.620)	(3.228)	(3.283)	(3.262)
Extension office in community	-4.928	6.508***	-158.028	6.528***	-0.582**	7.758***	1.971	8.199***
	(97.377)	(1.634)	(388.011)	(1.639)	(0.296)	(1.698)	(2.042)	(1.667)
Irrigated fields in community	170.285	-2.268	310.915	-2.245	0.396	-0.654	1.585	-0.480
	(113.160)	(1.436)	(448.897)	(1.439)	(0.250)	(1.414)	(1.472)	(1.403)
Perceived rain pattern	53.960	-2.006	-403.531	-2.007	-0.041	-1.811	-0.333	-1.613
	(136.045)	(1.809)	(613.655)	(1.809)	(0.341)	(1.865)	(2.100)	(1.826)
Log of expenditure on fertiliser	16.322	0.157	-7.739	0.155	0.148***	0.037	-0.104	0.097
	(15.840)	(0.224)	(70.004)	(0.224)	(0.046)	(0.226)	(0.284)	(0.218)
Log of expenditure on hired labour	-8.803	0.064	97.013	0.065	0.135***	0.099	0.793***	-0.071
	(15.235)	(0.236)	(72.937)	(0.237)	(0.040)	(0.238)	(0.231)	(0.227)
No. of crops produced	-121.699**	1.051	-83.752	1.049	0.180	1.055	0.139	0.976
	(59.649)	(0.780)	(296.810)	(0.780)	(0.147)	(0.789)	(0.946)	(0.768)
Log of total value of hh assets	86.508***	-1.817***	241.977	-1.816***	0.315***	-1.727***	-0.889*	-1.618***
	(25.896)	(0.292)	(157.502)	(0.292)	(0.067)	(0.299)	(0.507)	(0.277)
Log of agric land endowment	112.810	1.986**	469.585	1.983**	-0.079	2.117***	2.020**	2.021***
	(82.695)	(0.794)	(297.674)	(0.794)	(0.138)	(0.805)	(0.869)	(0.752)
Navigable road to community	-407.355**	9.205***	-2147.377**	9.239***	1.363***	12.789***	0.039	12.467***
	(180.907)	(1.847)	(907.012)	(1.852)	(0.366)	(1.658)	(2.102)	(1.607)
Access to public transport	66.839	11.724***	-486.847	11.710***	0.457	10.313***	-1.497	9.659***
	(154.917)	(1.859)	(706.173)	(1.862)	(0.355)	(1.912)	(2.042)	(1.902)
Household in southern Ghana	-1443.087***	-9.358***	-9151.745***	-9.322***	-0.230	-8.135***	-2.486	-5.294**
	(283.757)	(2.494)	(1267.188)	(2.508)	(0.450)	(2.529)	(3.034)	(2.442)
Household in coastal zone	-1442.043***	-4.066	-9438.225***	-3.996	-2.242***	-2.548	-13.932***	5.907*
	(288.576)	(2.833)	(1330.542)	(2.860)	(0.462)	(2.821)	(3.050)	(3.102)
Household in forest zone	-1162.575***	-17.625***	-6666.386***	-17.619***	-0.342	-18.362***	-9.677**	-13.902***
	(338.974)	(3.134)	(1505.394)	(3.134)	(0.621)	(3.204)	(3.918)	(3.269)
Household in savannah zone	-1383.841***	-17.952***	-8580.602***	-17.951***	0.467	-18.192***	7.275**	-9.263***
	(300.630)	(2.871)	(1396.994)	(2.872)	(0.561)	(2.988)	(3.487)	(2.850)
Market in community		7.408***		7.316***				
		(1.668)		(1.739)				
Average hclci in community								1.108***

								(0.097)
Average moi in community		0.711***		0.714***		0.746***		
		(0.075)		(0.076)		(0.075)		
Constant	2512.458***	29.715***	6643.060**	29.587***	-0.563	26.978***	25.180***	16.268**
	(649.895)	(6.209)	(2951.858)	(6.266)	(1.274)	(6.145)	(8.270)	(6.447)
Corr(e.hclci,e.outcomes)	0.015		-0.022		-0.328***		0.169*	
	(0.109)		(0.113)		(0.091)		(0.093)	
Observations	858		858		858		858	
Wald Chi-square	639.875***		890.342***		1110.919***		450.157***	
Log likelihood	-10857.077		-12126.655		-5630.835		-7237.571	

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; HCLCI is the household crop-livestock commercialisation index; Standard errors in parentheses; PCFEXP, FDEXP, HDDS and FCS are estimated using eregress; Source: Produced by the author using Primary Data 2022

Table A11 continued

Variable	Vit. A	HCLCI	Proteins	HCLCI	H. iron	HCLCI
HCLCI	0.091**		0.124***		0.082***	
	(0.036)		(0.036)		(0.025)	
Sex of head	-1.500**	2.105	-3.282***	2.433	-1.572***	2.433
	(0.696)	(1.812)	(0.817)	(1.729)	(0.533)	(1.729)
Age of head	-0.022	-0.072	-0.018	-0.060	-0.017	-0.060
	(0.018)	(0.050)	(0.021)	(0.050)	(0.014)	(0.050)
Household size	0.225**	0.040	0.010	-0.098	-0.088	-0.098
	(0.099)	(0.265)	(0.107)	(0.262)	(0.081)	(0.262)
Marital status of head	0.391	-6.892***	1.268	-7.194***	0.714	-7.194***
	(0.751)	(2.219)	(1.011)	(2.147)	(0.693)	(2.147)
Years of education of head	0.058	0.071	0.086*	0.063	0.057*	0.063
	(0.037)	(0.105)	(0.045)	(0.102)	(0.032)	(0.102)
Received cash remittance	-0.416	-1.556	-1.153	-1.159	-0.329	-1.159
	(0.715)	(1.912)	(0.819)	(1.864)	(0.578)	(1.864)
No. of days stop work due to health	-0.012***	0.013	-0.021***	0.013	-0.014***	0.013
	(0.004)	(0.023)	(0.005)	(0.022)	(0.003)	(0.022)
Ownership of nonfarm enterprise	2.533***	-2.006	2.428***	-2.697	1.477***	-2.697
	(0.593)	(1.692)	(0.708)	(1.669)	(0.470)	(1.669)
Agric cooperative in community	-0.396	2.057	-0.036	0.694	0.386	0.694
	(0.863)	(2.594)	(1.078)	(2.752)	(0.742)	(2.752)
Bank in community	-0.402	16.925***	0.261	13.079***	-0.066	13.079***
	(1.112)	(3.043)	(1.250)	(3.091)	(0.869)	(3.091)
Mobile phone network in community	0.765	-18.028***	-0.453	-15.686***	0.400	-15.686***
	(1.207)	(3.228)	(1.440)	(3.262)	(1.008)	(3.262)
Extension office in community	-1.608***	7.758***	-1.000	8.199***	0.088	8.199***

	(0.585)	(1.698)	(0.749)	(1.667)	(0.520)	(1.667)
Irrigated fields in community	0.322	-0.654	0.294	-0.480	0.061	-0.480
	(0.492)	(1.414)	(0.615)	(1.403)	(0.429)	(1.403)
Perceived rain pattern	0.543	-1.811	0.990	-1.613	1.024*	-1.613
	(0.689)	(1.865)	(0.815)	(1.826)	(0.575)	(1.826)
Log of expenditure on agrochemicals	0.159*	0.037	0.256**	0.097	0.170**	0.097
	(0.087)	(0.226)	(0.107)	(0.218)	(0.071)	(0.218)
Log of expenditure on hired labour	0.436***	0.099	0.493***	-0.071	0.266***	-0.071
	(0.084)	(0.238)	(0.105)	(0.227)	(0.073)	(0.227)
No. of crops produced	-0.961***	1.055	-0.801**	0.976	-0.369	0.976
	(0.302)	(0.789)	(0.359)	(0.768)	(0.245)	(0.768)
Log of total value of hh assets	0.683***	-1.727***	1.009***	-1.618***	0.518***	-1.618***
	(0.154)	(0.299)	(0.172)	(0.277)	(0.123)	(0.277)
Log of agric land endowment	0.335	2.117***	0.050	2.021***	0.095	2.021***
	(0.305)	(0.805)	(0.358)	(0.752)	(0.288)	(0.752)
Navigable road to community	-2.084**	12.789***	-3.264***	12.467***	-2.131***	12.467***
	(0.813)	(1.658)	(0.872)	(1.607)	(0.582)	(1.607)
Access to public transport	0.371	10.313***	-0.610	9.659***	-0.714	9.659***
	(0.688)	(1.912)	(0.800)	(1.902)	(0.553)	(1.902)
Household in southern Ghana	-1.009	-8.135***	-3.608***	-5.294**	-4.143***	-5.294**
	(1.104)	(2.529)	(1.164)	(2.442)	(0.770)	(2.442)
Household in coastal zone	-4.366***	-2.548	-8.706***	5.907*	-6.290***	5.907*
	(1.081)	(2.821)	(1.158)	(3.102)	(0.817)	(3.102)
Household in forest zone	-4.313***	-18.362***	-9.000***	-13.902***	-6.727***	-13.902***
	(1.376)	(3.204)	(1.523)	(3.269)	(1.060)	(3.269)
Household in savannah zone	1.281	-18.192***	-0.742	-9.263***	-2.690***	-9.263***
	(1.380)	(2.988)	(1.438)	(2.850)	(0.929)	(2.850)
Average hclci in community				1.108***		1.108***
				(0.097)		(0.097)
Average moi in community		0.746***				
		(0.075)				
Constant	1.670	26.978***	8.092**	16.268**	6.326***	16.268**
	(2.815)	(6.145)	(3.167)	(6.447)	(2.293)	(6.447)
Corr(e.hclci,e.outcomes)	-0.081		-0.121		-0.043	
	(0.105)		(0.093)		(0.098)	
Observations	858		858		858	
Wald Chi-square	349.808***		579.603***		503.774***	
Log likelihood	-6305.539		-6439.704		-6110.434	

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; HCLCI is the household crop-livestock commercialisation index; Standard errors in parentheses; PCFEXP, FDEXP, HDDS and FCS are estimated using eregress; Source: Produced by the author using Primary Data 2022

Table A11 continued

Variable	HCLCI	FIES	HHS	HFIAS
HCLCI		0.037***	0.046***	0.034***
		(0.008)	(0.009)	(0.008)
Sex of head	2.105	-0.355**	0.166	0.033
	(2.011)	(0.166)	(0.168)	(0.151)
Age of head	-0.072	0.000	0.006	-0.003
	(0.049)	(0.004)	(0.004)	(0.004)
Household size	0.040	-0.024	-0.065***	-0.056**
	(0.268)	(0.021)	(0.023)	(0.023)
Marital status of head	-6.892***	0.036	0.149	0.338*
	(2.155)	(0.182)	(0.201)	(0.181)
Years of education of head	0.071	0.002	-0.001	0.001
	(0.105)	(0.008)	(0.009)	(0.008)
Received cash remittance	-1.556	0.097	0.001	0.148
	(2.061)	(0.153)	(0.176)	(0.162)
No. of days stop work due to health	0.013	-0.002	0.000	-0.003
	(0.020)	(0.001)	(0.001)	(0.002)
Ownership of nonfarm enterprise	-2.006	-0.102	0.123	-0.329***
	(1.560)	(0.115)	(0.134)	(0.124)
Agric cooperative in community	2.057	0.271	0.473**	0.191
	(2.092)	(0.174)	(0.200)	(0.184)
Bank in community	16.925***	0.178	-0.978***	-0.851***
	(2.423)	(0.284)	(0.282)	(0.236)
Mobile phone network in community	-18.028***	-0.029	0.042	0.163
	(3.120)	(0.310)	(0.300)	(0.293)
Extension office in community	7.758***	0.110	0.232	0.305**
	(1.562)	(0.129)	(0.144)	(0.132)
Irrigated fields in community	-0.654	0.040	0.396***	0.175*
	(1.433)	(0.109)	(0.120)	(0.105)
Perceived rain pattern	-1.811	-0.091	-0.614***	-0.014
	(2.094)	(0.168)	(0.172)	(0.152)
Log of expenditure on agrochemicals	0.037	-0.036*	-0.022	-0.033
	(0.263)	(0.022)	(0.022)	(0.022)
Log of mount spent on hired labour	0.099	0.009	-0.013	-0.010
	(0.244)	(0.020)	(0.021)	(0.020)
No. of crops produced	1.055	0.031	0.115*	0.113*
	(0.790)	(0.063)	(0.066)	(0.065)
Log of total value of hh assets	-1.727***	0.096***	0.060*	0.109***
	(0.320)	(0.027)	(0.032)	(0.028)
Log of agric land endowment	2.117***	0.021	-0.009	-0.122*
	(0.777)	(0.070)	(0.081)	(0.070)
Navigable road to community	12.789***	0.758***	0.626***	0.578***
	(1.706)	(0.188)	(0.197)	(0.177)
Access to public transport	10.313***	-0.177	-0.108	0.029
	(1.913)	(0.172)	(0.168)	(0.164)
Household in southern Ghana	-8.135***	-0.059	0.260	-0.220
	(2.720)	(0.240)	(0.244)	(0.228)
Household in coastal zone	-2.548	-0.110	0.156	0.018
	(2.933)	(0.246)	(0.249)	(0.256)
Household in forest zone	-18.362***	0.169	0.650**	0.539*
	(3.291)	(0.313)	(0.328)	(0.312)
Household in savannah zone	-18.192***	0.211	0.523*	-0.071
	(3.146)	(0.300)	(0.305)	(0.294)
Average moi in community	0.746***			

	(0.075)			
Commercialisation residuals		0.009	-0.014	-0.008
		(0.008)	(0.009)	(0.009)
Constant	26.978***			
	(6.268)			
cut1		1.075*	1.991***	1.854***
		(0.644)	(0.690)	(0.666)
cut2		2.416***	2.626***	2.260***
		(0.646)	(0.691)	(0.667)
cut3				2.580***
				(0.670)
Observations	858	858	858	858
F-statistic/Wald Chi-square	48.474***	571.593***	544.863***	478.510***
Log likelihood	-3589.910	-622.606	-563.283	-775.154

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; HCLCI is the household crop-livestock commercialisation index; Standard errors in parentheses; all models are estimated using control function ordered probit; Source: Produced by the author using Primary Data 2022

Table A12: Impact of ordered agricultural commercialisation on continuous outcomes (GLSS7)

Variable	PCFEXP	HCLCI	PAEFEXP	HCLCI	HDDS	HCLCI	FCS	HCLCI
Ordered HCLCI	336.852***		262.669***		1.075***		3.079***	
	(39.100)		(32.495)		(0.045)		(0.080)	
Sex of head	435.768***	0.136***	69.543	0.110**	-0.242***	0.174***	-0.399***	0.169***
	(64.832)	(0.048)	(53.309)	(0.049)	(0.057)	(0.049)	(0.106)	(0.049)
Age of head	2.742**	-0.001	4.324***	-0.002*	-0.001	-0.002	-0.002	-0.002*
	(1.279)	(0.001)	(1.072)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Household size	-203.645***	-0.036***	-164.448***	-0.034***	0.086***	-0.031***	0.199***	-0.031***
	(8.338)	(0.006)	(6.684)	(0.006)	(0.007)	(0.006)	(0.014)	(0.006)
Locality of household	-331.790***	0.172***	-332.613***	0.312***	-0.151***	0.376***	-0.284***	0.377***
	(59.996)	(0.052)	(48.289)	(0.056)	(0.055)	(0.053)	(0.105)	(0.053)
Marital status of head	-497.358***	-0.040	-213.836***	-0.023	0.290***	-0.072	0.564***	-0.068
	(66.512)	(0.045)	(50.491)	(0.046)	(0.058)	(0.046)	(0.105)	(0.046)
Years of education of head	12.310***	0.003	11.769***	0.001	0.005	-0.000	-0.017*	-0.001
	(4.503)	(0.004)	(3.743)	(0.004)	(0.004)	(0.004)	(0.009)	(0.004)
Received cash remittance	358.566***	-0.012	276.198***	-0.014	0.246***	-0.051	0.414***	-0.045
	(46.312)	(0.034)	(37.591)	(0.034)	(0.042)	(0.035)	(0.084)	(0.035)
No. of days stop work due to health	-4.337	0.001	-4.392	0.002	0.010	0.000	0.022	0.000
	(7.316)	(0.007)	(6.341)	(0.007)	(0.008)	(0.007)	(0.016)	(0.007)
Ownership of nonfarm enterprise	121.398**	-0.163***	108.044**	-0.161***	0.080	-0.172***	0.183*	-0.167***
	(56.306)	(0.046)	(46.578)	(0.046)	(0.052)	(0.047)	(0.102)	(0.047)
Agric cooperative in community	-241.935**	0.406***	-209.576***	0.409***	-0.003	0.418***	-0.111	0.422***
	(95.607)	(0.055)	(76.613)	(0.057)	(0.079)	(0.056)	(0.162)	(0.056)
Bank in community	-146.589	1.187***	-139.642*	0.854***	-0.564***	1.052***	-1.185***	1.052***
	(91.258)	(0.053)	(72.492)	(0.055)	(0.083)	(0.055)	(0.166)	(0.054)
Mobile phone network in community	132.715**	0.132***	78.510*	0.175***	-0.086*	0.092**	-0.300***	0.092**
	(53.668)	(0.040)	(42.529)	(0.040)	(0.050)	(0.040)	(0.101)	(0.040)
Extension office in community	194.726**	0.012	140.481**	-0.042	-0.077	-0.007	-0.224	-0.008
	(83.411)	(0.048)	(65.105)	(0.049)	(0.071)	(0.049)	(0.139)	(0.049)
Irrigated fields in community	-44.978	0.419***	-53.951	0.353***	-0.257***	0.323***	-0.070	0.331***
	(71.603)	(0.051)	(57.830)	(0.053)	(0.065)	(0.053)	(0.132)	(0.053)
Perceived rain pattern	49.741	0.007	17.430	-0.039	0.114***	0.015	0.318***	0.017
	(38.505)	(0.032)	(31.754)	(0.032)	(0.037)	(0.032)	(0.073)	(0.032)
Log of expenditure on agrochemicals	32.183***	0.006	23.759***	0.007	0.030***	0.016**	0.122***	0.016**
	(9.319)	(0.007)	(7.738)	(0.007)	(0.008)	(0.007)	(0.015)	(0.007)
Log of expenditure on hired labour	43.448***	0.018***	34.711***	0.016**	0.036***	0.015**	0.053***	0.016**
	(9.609)	(0.007)	(7.879)	(0.007)	(0.008)	(0.007)	(0.016)	(0.007)
No. of crops produced	-4.951	0.040***	-16.392	0.042***	0.081***	0.044***	0.151***	0.044***
	(15.533)	(0.011)	(11.939)	(0.011)	(0.013)	(0.011)	(0.026)	(0.011)

Log of total value of hh assets	9.180	-0.007	10.646*	-0.004	0.072***	-0.008	0.125***	-0.008
	(6.814)	(0.006)	(5.659)	(0.006)	(0.007)	(0.006)	(0.014)	(0.006)
Log of agric land endowment	195.379***	0.080***	165.209***	0.076***	0.086***	0.080***	0.210***	0.082***
	(24.038)	(0.018)	(19.638)	(0.018)	(0.020)	(0.017)	(0.039)	(0.018)
Navigable road to community	602.827***	0.862***	271.110***	0.757***	0.261***	0.799***	0.409***	0.803***
	(57.487)	(0.058)	(46.357)	(0.059)	(0.061)	(0.058)	(0.118)	(0.058)
Access to public transport	174.243***	0.394***	57.509	0.197***	-0.066	0.373***	-0.312***	0.377***
	(58.058)	(0.043)	(47.103)	(0.045)	(0.057)	(0.044)	(0.112)	(0.044)
Household in southern Ghana	-18.494	-0.086	10.309	-0.015	0.337***	0.048	0.350**	0.054
	(90.764)	(0.056)	(73.498)	(0.057)	(0.071)	(0.057)	(0.152)	(0.057)
Household in coastal zone	-380.396	-0.015	-323.618	0.048	0.113	0.316	0.515	0.345
	(307.157)	(0.312)	(253.151)	(0.356)	(0.314)	(0.313)	(0.464)	(0.313)
Household in forest zone	-298.590	0.135	-251.582	0.218	0.080	0.452	0.605	0.476
	(300.778)	(0.310)	(248.916)	(0.354)	(0.312)	(0.310)	(0.457)	(0.311)
Household in savannah zone	-942.079***	-0.210	-801.804***	-0.060	-0.168	0.347	0.260	0.367
	(311.618)	(0.315)	(257.351)	(0.359)	(0.320)	(0.317)	(0.481)	(0.317)
Market in community				1.037***				
				(0.046)				
Average hclci in community						0.038***		0.037***
						(0.001)		(0.001)
Average moi in community		0.026***		0.023***				
		(0.001)		(0.001)				
Constant	2373.863***	2322.257**	4.311***	5.513***	4.353***		5.563***	
	(324.946)	*	(0.331)	(0.508)	(0.331)		(0.508)	
		(269.924)						
Corr(e.agcom_cat,outcomes)	-0.026		-0.034		-0.167***		-0.138***	
	(0.018)		(0.021)		(0.024)		(0.021)	
Observations	7332		7332		7332		7332	
Wald Chi-squared	2270.219***		2060.519***		3044.818***		4783.094***	
Log pseudolikelihood	-70067.802		-68338.424		-18809.721		-23751.168	

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; HCLCI is the household crop-livestock commercialisation index; Standard errors in parentheses; All equations estimated using extended regression (eregress); Source: Produced by the author using the GLSS7 Data

Table A12 continued

Variable	Vit. A	HCLCI	Proteins	HCLCI	H. iron	HCLCI
Ordered HCLCI	2.572***		1.433***		0.666***	
	(0.108)		(0.083)		(0.037)	
Sex of head	-0.949***	0.164***	-0.286***	0.168***	0.022	0.167***
	(0.144)	(0.049)	(0.102)	(0.049)	(0.042)	(0.049)
Age of head	0.006*	-0.002	-0.002	-0.002	-0.001	-0.002

	(0.003)	(0.001)	(0.003)	(0.001)	(0.001)	(0.001)
Household size	0.190***	-0.030***	0.189***	-0.031***	0.065***	-0.031***
	(0.018)	(0.006)	(0.016)	(0.006)	(0.007)	(0.006)
Locality of household	-1.391***	0.336***	-0.229**	0.336***	-0.124***	0.336***
	(0.141)	(0.055)	(0.103)	(0.055)	(0.045)	(0.055)
Marital status of head	1.103***	-0.063	0.615***	-0.064	0.253***	-0.062
	(0.141)	(0.046)	(0.101)	(0.046)	(0.042)	(0.046)
Years of education of head	0.006	-0.000	-0.019**	-0.000	-0.003	-0.000
	(0.012)	(0.004)	(0.009)	(0.004)	(0.004)	(0.004)
Received cash remittance	0.390***	-0.036	0.623***	-0.037	0.224***	-0.038
	(0.111)	(0.035)	(0.089)	(0.035)	(0.039)	(0.035)
No. of days stop work due to health	-0.011	0.001	0.035**	0.001	0.012*	0.001
	(0.020)	(0.007)	(0.017)	(0.007)	(0.007)	(0.007)
Ownership of nonfarm enterprise	0.161	-0.163***	0.305***	-0.162***	0.126***	-0.161***
	(0.136)	(0.047)	(0.110)	(0.047)	(0.048)	(0.047)
Agric cooperative in community	-1.354***	0.420***	-0.124	0.417***	-0.006	0.417***
	(0.215)	(0.056)	(0.170)	(0.055)	(0.074)	(0.056)
Bank in community	-1.334***	1.059***	-0.544***	1.058***	-0.343***	1.058***
	(0.230)	(0.054)	(0.168)	(0.054)	(0.073)	(0.054)
Mobile phone network in community	-0.426***	0.103***	-0.364***	0.107***	-0.243***	0.105***
	(0.136)	(0.040)	(0.117)	(0.040)	(0.050)	(0.040)
Extension office in community	0.125	-0.010	-0.424***	-0.011	-0.052	-0.010
	(0.206)	(0.049)	(0.150)	(0.049)	(0.064)	(0.049)
Irrigated fields in community	-0.038	0.342***	-0.294**	0.343***	-0.205***	0.344***
	(0.169)	(0.053)	(0.123)	(0.053)	(0.054)	(0.053)
Perceived rain pattern	0.319***	0.017	0.337***	0.019	0.037	0.019
	(0.097)	(0.033)	(0.077)	(0.032)	(0.033)	(0.032)
Log of expenditure on agrochemicals	0.120***	0.014*	0.067***	0.015**	0.031***	0.014*
	(0.021)	(0.007)	(0.015)	(0.007)	(0.007)	(0.007)
Log of expenditure on hired labour	0.118***	0.016**	0.069***	0.015**	0.031***	0.016**
	(0.023)	(0.007)	(0.018)	(0.007)	(0.008)	(0.007)
No. of crops produced	0.324***	0.045***	0.328***	0.044***	-0.016	0.045***
	(0.036)	(0.011)	(0.029)	(0.011)	(0.013)	(0.011)
Log of total value of hh assets	0.166***	-0.006	0.170***	-0.007	0.071***	-0.006
	(0.019)	(0.006)	(0.016)	(0.006)	(0.007)	(0.006)
Log of agric land endowment	0.102*	0.077***	0.328***	0.076***	0.147***	0.076***
	(0.053)	(0.018)	(0.049)	(0.018)	(0.022)	(0.018)
Navigable road to community	0.287*	0.804***	0.928***	0.798***	0.262***	0.799***
	(0.152)	(0.058)	(0.136)	(0.058)	(0.058)	(0.058)
Access to public transport	-0.026	0.371***	-0.841***	0.369***	-0.158***	0.370***

	(0.142)	(0.044)	(0.126)	(0.044)	(0.054)	(0.044)
Household in southern Ghana	1.618***	0.050	-0.388**	0.049	0.079	0.050
	(0.203)	(0.056)	(0.152)	(0.056)	(0.065)	(0.056)
Household in coastal zone	-1.458*	0.302	-0.272	0.325	-0.180	0.322
	(0.774)	(0.316)	(0.457)	(0.320)	(0.213)	(0.320)
Household in forest zone	-0.533	0.423	-0.080	0.445	0.072	0.441
	(0.764)	(0.314)	(0.449)	(0.318)	(0.211)	(0.318)
Household in savannah zone	-1.243	0.319	-0.792*	0.345	-0.395*	0.337
	(0.792)	(0.321)	(0.471)	(0.324)	(0.220)	(0.324)
Average hclci in community		0.034***		0.034***		0.034***
		(0.002)		(0.002)		(0.002)
Average moi in community		0.004***		0.004***		0.004***
		(0.001)		(0.001)		(0.001)
Constant	4.047***		1.905***		0.917***	
	(0.820)		(0.499)		(0.230)	
Corr(e.agcom_cat,outcomes)	-0.070***		-0.024		-0.067***	
	(0.020)		(0.019)		(0.023)	
Observations	7332		7332		7332	
Wald Chi-squared	2591.325***		1722.138***		1733.249***	
Log pseudolikelihood	-25881.672		-24313.019		-18039.865	

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; HCLCI is the household crop-livestock commercialisation index; Standard errors in parentheses; All equations estimated using extended regression (eregress); Source: Produced by the author using the GLSS7 Data

Table A12 continued

Variable	Stunting	HCLCI	Wasting	HCLCI	Underweight	HCLCI	FIES	HCLCI
Ordered HCLCI	-0.299***		-0.571***		-0.271***		0.111***	
	(0.073)		(0.112)		(0.090)		(0.034)	
Sex of head	-0.104	0.192*	-0.062	0.199*	0.149	0.199*	0.100**	0.112**
	(0.118)	(0.113)	(0.127)	(0.114)	(0.125)	(0.114)	(0.042)	(0.049)
Age of head	-0.000	-0.002	0.004	-0.002	-0.003	-0.002	0.004***	-0.002*
	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.001)	(0.001)
Household size	0.023*	-0.026**	-0.029**	-0.028**	0.006	-0.027**	-0.036***	-0.033***
	(0.012)	(0.011)	(0.014)	(0.011)	(0.015)	(0.011)	(0.005)	(0.006)
Locality of household	-0.379***	0.393***	-0.286***	0.419***	-0.420***	0.427***	-0.163***	0.314***
	(0.099)	(0.102)	(0.099)	(0.100)	(0.099)	(0.100)	(0.042)	(0.056)
Marital status of head	-0.004	0.042	0.006	0.036	-0.258*	0.035	0.106***	-0.022
	(0.131)	(0.131)	(0.143)	(0.131)	(0.138)	(0.131)	(0.040)	(0.046)
Years of education of head	-0.000	-0.003	0.011	-0.003	-0.003	-0.004	0.044***	0.001

	(0.007)	(0.007)	(0.008)	(0.007)	(0.008)	(0.007)	(0.003)	(0.004)
Received cash remittance	-0.094	-0.026	0.055	-0.031	-0.117	-0.030	0.136***	-0.015
	(0.068)	(0.058)	(0.079)	(0.058)	(0.077)	(0.058)	(0.031)	(0.034)
No. of days stop work due to health	0.022	-0.008	-0.028**	-0.009	0.008	-0.008	-0.020***	0.002
	(0.015)	(0.013)	(0.014)	(0.013)	(0.016)	(0.013)	(0.006)	(0.007)
Ownership of nonfarm enterprise	0.058	-0.181**	0.049	-0.185**	0.179*	-0.184**	0.310***	-0.158***
	(0.087)	(0.077)	(0.095)	(0.077)	(0.096)	(0.077)	(0.040)	(0.046)
Agric cooperative in community	-0.111	0.342***	-0.298	0.346***	-0.261	0.344***	-0.184***	0.408***
	(0.142)	(0.100)	(0.207)	(0.100)	(0.179)	(0.100)	(0.057)	(0.057)
Bank in community	-0.443***	1.068***	-0.098	1.054***	-0.242	1.055***	-0.021	0.853***
	(0.158)	(0.096)	(0.200)	(0.096)	(0.194)	(0.096)	(0.060)	(0.055)
Mobile phone network in community	-0.477***	0.177***	-0.571***	0.154**	-0.639***	0.164**	-0.207***	0.176***
	(0.074)	(0.065)	(0.085)	(0.066)	(0.083)	(0.065)	(0.036)	(0.040)
Extension office in community	-0.036	0.082	-0.051	0.086	-0.011	0.089	0.133***	-0.041
	(0.125)	(0.085)	(0.163)	(0.086)	(0.154)	(0.085)	(0.050)	(0.049)
Irrigated fields in community	-0.240**	0.231**	-0.043	0.217**	-0.116	0.223**	0.209***	0.351***
	(0.117)	(0.097)	(0.149)	(0.097)	(0.140)	(0.097)	(0.049)	(0.053)
Perceived rain pattern	0.126**	0.010	-0.019	0.016	0.095	0.018	0.022	-0.039
	(0.063)	(0.057)	(0.071)	(0.057)	(0.070)	(0.057)	(0.028)	(0.032)
Log of expenditure on agrochemicals	-0.028**	0.004	-0.011	0.006	-0.039**	0.006	0.010*	0.007
	(0.014)	(0.014)	(0.016)	(0.014)	(0.015)	(0.014)	(0.006)	(0.007)
Log of expenditure on hired labour	-0.016	0.027**	0.009	0.028**	0.005	0.029**	0.028***	0.016**
	(0.014)	(0.012)	(0.016)	(0.012)	(0.015)	(0.012)	(0.006)	(0.007)
No. of crops produced	-0.023	0.052***	-0.026	0.052***	-0.035	0.053***	0.015	0.042***
	(0.022)	(0.018)	(0.024)	(0.018)	(0.025)	(0.018)	(0.010)	(0.011)
Log of total value of hh assets	-0.015	0.006	0.008	0.006	-0.012	0.006	0.054***	-0.004
	(0.011)	(0.010)	(0.012)	(0.010)	(0.012)	(0.010)	(0.005)	(0.006)
Log of agric land endowment	0.009	0.050*	-0.167***	0.056*	-0.060	0.058*	0.003	0.075***
	(0.034)	(0.030)	(0.039)	(0.030)	(0.039)	(0.030)	(0.015)	(0.018)
Navigable road to community	-1.037***	0.607***	-1.380***	0.566***	-1.356***	0.590***	0.009	0.756***
	(0.090)	(0.094)	(0.097)	(0.095)	(0.093)	(0.094)	(0.047)	(0.059)
Access to public transport	-0.356***	0.409***	-0.265**	0.409***	-0.343***	0.412***	0.145***	0.197***
	(0.085)	(0.072)	(0.106)	(0.072)	(0.103)	(0.072)	(0.042)	(0.045)
Household in southern Ghana	0.219*	-0.049	-0.077	-0.033	0.022	-0.036	-0.005	-0.016
	(0.123)	(0.097)	(0.133)	(0.097)	(0.137)	(0.097)	(0.056)	(0.057)
Household in coastal zone	0.235	-0.700	0.063	-0.668	-0.024	-0.668	-0.203	0.037
	(0.331)	(0.569)	(0.303)	(0.597)	(0.312)	(0.610)	(0.217)	(0.352)
Household in forest zone	-0.000	-0.637	-0.342	-0.597	-0.178	-0.590	-0.082	0.208
	(0.324)	(0.564)	(0.291)	(0.592)	(0.306)	(0.604)	(0.214)	(0.350)
Household in savannah zone	0.246	-0.734	-0.179	-0.692	-0.087	-0.686	-0.515**	-0.070

	(0.344)	(0.571)	(0.313)	(0.599)	(0.330)	(0.611)	(0.222)	(0.355)
Market in community								1.038***
								(0.046)
Average hclci in community		0.036***		0.040***		0.040***		
		(0.003)		(0.002)		(0.002)		
Average moi in community		0.004*						0.023***
		(0.002)						(0.001)
Constant	1.285***		1.651***		1.882***			
	(0.372)		(0.363)		(0.374)			
Cut1							-0.106	2.207***
							(0.230)	(0.361)
Cut2							0.688***	3.227***
							(0.230)	(0.361)
Cut3								4.459***
								(0.362)
Corr(e.agcom_cat,e.outcomes)	-0.184***		0.019		-0.136**		-0.036	-0.053*
	(0.061)		(0.074)		(0.065)		(0.032)	(0.030)
Observations	2452		2452		2452		7332	
Wald Chi-squared	980.789***		923.240***		1026.762***		1442.109***	
Log pseudolikelihood	-2814.541		-2524.923		-2568.862		-12429.553	

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; HCLCI is the household crop-livestock commercialisation index; Standard errors in parentheses; Stunting, Wasting and Underweight are estimated using extended probit (eprobit); FIES is estimated using extended ordered probit (eoprobit); Source: Produced by the author using the GLSS7 Data

Table A13: Impact of ordered agricultural commercialisation on food and nutrition security outcomes (primary data)

Variable	PCFEXP	HCLCI	FEXP	HCLCI	HDDS	HCLCI	FCS	HCLCI
Ordered HCLCI	1132.930***		5079.102***		1.297***		10.127***	
	(92.275)		(427.237)		(0.283)		(1.301)	
Sex of head	99.122	0.187	-491.279	0.181	-0.780**	0.147	-3.221	0.191
	(134.321)	(0.169)	(387.589)	(0.169)	(0.317)	(0.174)	(2.191)	(0.168)
Age of head	-4.394	-0.005	0.408	-0.005	-0.018**	-0.005	-0.008	-0.004
	(3.285)	(0.004)	(14.058)	(0.004)	(0.008)	(0.004)	(0.056)	(0.004)
Household size	-220.896***	-0.021	-65.693	-0.017	0.066	-0.015	0.318	-0.022
	(20.304)	(0.022)	(93.424)	(0.021)	(0.045)	(0.021)	(0.312)	(0.021)
Marital status of head	-321.460	-0.504***	481.350	-0.493***	0.072	-0.481**	2.245	-0.539***
	(229.110)	(0.186)	(549.252)	(0.188)	(0.343)	(0.191)	(2.299)	(0.185)
Years of education of head	9.670	0.003	23.205	0.003	0.004	0.002	0.134	0.002
	(7.720)	(0.008)	(34.781)	(0.008)	(0.018)	(0.008)	(0.112)	(0.008)
Received cash remittance	36.502	-0.180	390.485	-0.174	-0.387	-0.169	0.411	-0.143

	(135.475)	(0.146)	(680.103)	(0.145)	(0.333)	(0.141)	(2.512)	(0.145)
No. of days stop work due to health	-1.056*	0.002	-2.223	0.002	0.001	0.001	-0.023*	0.002
	(0.561)	(0.002)	(3.066)	(0.002)	(0.002)	(0.002)	(0.012)	(0.001)
Ownership of nonfarm enterprise	68.857	-0.212	228.716	-0.210	0.451	-0.195	4.046**	-0.243*
	(87.595)	(0.134)	(388.384)	(0.134)	(0.279)	(0.132)	(1.780)	(0.134)
Agric cooperative in community	-31.548	-0.026	397.931	-0.030	0.884**	-0.052	0.531	0.028
	(152.254)	(0.184)	(570.360)	(0.184)	(0.358)	(0.197)	(2.527)	(0.203)
Bank in community	27.924	0.970***	-9.114	0.974***	-1.405***	1.155***	-6.702**	0.806***
	(265.179)	(0.215)	(1055.000)	(0.216)	(0.485)	(0.211)	(3.075)	(0.213)
Mobile phone network in community	-39.519	-1.353***	848.533	-1.347***	-0.194	-1.274***	0.401	-1.201***
	(224.614)	(0.237)	(912.221)	(0.238)	(0.551)	(0.231)	(2.931)	(0.242)
Agric extension office in community	34.147	0.308**	125.128	0.314**	-0.295	0.375***	2.040	0.448***
	(96.137)	(0.125)	(391.659)	(0.125)	(0.275)	(0.126)	(1.927)	(0.123)
Irrigated fields in community	182.853	-0.142	339.459	-0.141	0.348	-0.013	1.769	0.037
	(111.449)	(0.123)	(448.701)	(0.123)	(0.238)	(0.111)	(1.512)	(0.115)
Perceived rain pattern	97.859	-0.053	-214.216	-0.056	-0.007	-0.024	0.079	-0.049
	(139.050)	(0.157)	(620.501)	(0.157)	(0.335)	(0.154)	(2.144)	(0.160)
Log of expenditure on agrochemicals	12.787	0.016	-25.354	0.016	0.140***	0.012	-0.131	0.012
	(16.174)	(0.021)	(70.044)	(0.021)	(0.044)	(0.021)	(0.283)	(0.020)
Log of expenditure on hired labour	-7.933	-0.008	98.376	-0.007	0.130***	-0.004	0.807***	-0.016
	(15.161)	(0.020)	(73.688)	(0.020)	(0.039)	(0.020)	(0.237)	(0.020)
No. of crops produced	-84.109	0.036	118.249	0.036	0.298**	0.033	0.388	0.030
	(58.958)	(0.060)	(294.918)	(0.060)	(0.138)	(0.059)	(0.930)	(0.059)
Log of total value of hh assets	106.886***	-0.132***	302.593**	-0.131***	0.270***	-0.116***	-0.627	-0.121***
	(24.276)	(0.024)	(144.461)	(0.024)	(0.065)	(0.025)	(0.467)	(0.022)
Log of agric land endowment	132.267*	0.119**	625.700**	0.118**	0.097	0.122**	2.015**	0.121**
	(74.758)	(0.059)	(265.887)	(0.058)	(0.125)	(0.058)	(0.814)	(0.057)
Navigable road to community	-243.864**	0.634***	-1122.358*	0.632***	2.204***	0.776***	0.741	0.814***
	(119.207)	(0.137)	(581.663)	(0.137)	(0.286)	(0.124)	(1.609)	(0.125)
Access to public transport	159.747	0.752***	89.702	0.746***	0.922***	0.651***	-1.082	0.604***
	(127.092)	(0.160)	(581.212)	(0.160)	(0.319)	(0.161)	(1.978)	(0.170)
Household in NR	-1481.178***	-0.525***	-9603.594***	-0.515***	-0.903**	-0.367**	-2.096	-0.345**
	(242.404)	(0.177)	(1144.579)	(0.177)	(0.422)	(0.170)	(2.813)	(0.175)
Household in UER	-1341.122***	-0.236	-9365.709***	-0.221	-2.978***	-0.067	-12.042***	0.314
	(232.418)	(0.226)	(1121.512)	(0.228)	(0.384)	(0.216)	(2.555)	(0.256)
Household in UWR	-1117.823***	-1.165***	-6887.619***	-1.155***	-1.236**	-1.186***	-8.181**	-1.005***
	(272.691)	(0.234)	(1259.997)	(0.234)	(0.542)	(0.230)	(3.385)	(0.246)
Household in SR	-1387.305***	-1.227***	-8944.197***	-1.216***	-0.317	-1.157***	8.149**	-0.604***
	(240.954)	(0.221)	(1188.571)	(0.221)	(0.511)	(0.222)	(3.309)	(0.221)
Market in community		0.423***		0.417***				

	(0.121)	(0.123)		
Average hclci in community	0.057***	0.057***	0.062***	
	(0.007)	(0.007)	(0.007)	
Average moi in community				0.076***
				(0.009)
Constant	2320.794***	6871.389***	1.654	20.640***
	(430.300)	(2007.907)	(1.082)	(6.227)
Corr(e.hclci,e.outcomes)	-0.109**	-0.089**	-0.223***	0.006
	(0.044)	(0.043)	(0.081)	(0.053)
Observations	858	858	858	858
Wald Chi-squared	642.015***	888.401***	1201.591***	486.587***
Log pseudolikelihood	-7982.497	-9256.428	-2763.870	-4392.766

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; HCLCI is the household crop-livestock commercialisation index; Standard errors in parentheses; All equations estimated using extended regression (eregress); Source: Produced by the author using Primary Data 2022

Table A13 continued

Variable	Vit. A	HCLCI	Proteins	HCLCI	H. iron	HCLCI
Ordered HCLCI	3.258***		4.249***		2.875***	
	(0.774)		(0.835)		(0.506)	
Sex of head	-1.411**	0.163	-3.165***	0.209	-1.493***	0.199
	(0.703)	(0.175)	(0.828)	(0.173)	(0.528)	(0.170)
Age of head	-0.020	-0.006	-0.016	-0.004	-0.016	-0.004
	(0.018)	(0.004)	(0.021)	(0.004)	(0.014)	(0.004)
Household size	0.231**	-0.015	0.020	-0.018	-0.082	-0.020
	(0.100)	(0.021)	(0.109)	(0.021)	(0.081)	(0.021)
Marital status of head	0.604	-0.484**	1.521	-0.518***	0.896	-0.505***
	(0.757)	(0.190)	(0.984)	(0.191)	(0.678)	(0.192)
Years of education of head	0.054	0.000	0.081*	0.000	0.054*	0.002
	(0.037)	(0.008)	(0.045)	(0.008)	(0.032)	(0.008)
Received cash remittance	-0.248	-0.170	-0.933	-0.120	-0.181	-0.130
	(0.723)	(0.142)	(0.832)	(0.142)	(0.580)	(0.144)
No. of days stop work due to health	-0.012***	0.002	-0.021***	0.002	-0.014***	0.002
	(0.004)	(0.001)	(0.004)	(0.001)	(0.003)	(0.001)
Ownership of nonfarm enterprise	2.601***	-0.217	2.504***	-0.273**	1.534***	-0.263**
	(0.591)	(0.133)	(0.712)	(0.133)	(0.471)	(0.133)
Agric cooperative in community	-0.456	-0.012	-0.076	-0.011	0.343	-0.004
	(0.846)	(0.190)	(1.081)	(0.198)	(0.729)	(0.200)
Bank in community	-1.459	1.115***	-1.041	0.829***	-0.979	0.826***
	(1.157)	(0.208)	(1.326)	(0.213)	(0.889)	(0.213)

Mobile phone network in community	1.058	-1.307***	-0.159	-1.205***	0.636	-1.214***
	(1.158)	(0.234)	(1.406)	(0.243)	(0.941)	(0.244)
Agric extension office in community	-1.639***	0.373***	-1.014	0.429***	0.068	0.430***
	(0.585)	(0.124)	(0.759)	(0.123)	(0.512)	(0.123)
Irrigated fields in community	0.395	-0.002	0.382	0.046	0.124	0.039
	(0.496)	(0.111)	(0.631)	(0.114)	(0.435)	(0.115)
Perceived rain pattern	0.679	-0.017	1.166	-0.024	1.144**	-0.025
	(0.697)	(0.153)	(0.828)	(0.157)	(0.579)	(0.159)
Log of expenditure on agrochemicals	0.151*	0.009	0.245**	0.014	0.163**	0.014
	(0.089)	(0.020)	(0.110)	(0.020)	(0.072)	(0.020)
Log of expenditure on hired labour	0.442***	-0.003	0.500***	-0.010	0.271***	-0.012
	(0.086)	(0.020)	(0.107)	(0.019)	(0.074)	(0.020)
No. of crops produced	-0.898***	0.041	-0.710**	0.045	-0.311	0.039
	(0.300)	(0.059)	(0.353)	(0.059)	(0.239)	(0.059)
Log of total value of hh assets	0.782***	-0.123***	1.131***	-0.121***	0.604***	-0.122***
	(0.157)	(0.024)	(0.175)	(0.022)	(0.121)	(0.022)
Log of agric land endowment	0.299	0.130**	0.021	0.133**	0.068	0.131**
	(0.286)	(0.058)	(0.343)	(0.057)	(0.268)	(0.057)
Navigable road to community	-2.002***	0.821***	-3.082***	0.806***	-2.039***	0.806***
	(0.655)	(0.123)	(0.751)	(0.124)	(0.486)	(0.125)
Access to public transport	0.425	0.663***	-0.498	0.626***	-0.655	0.626***
	(0.675)	(0.162)	(0.806)	(0.165)	(0.535)	(0.167)
Household in NR	-0.746	-0.389**	-3.336***	-0.302*	-3.928***	-0.323*
	(1.051)	(0.172)	(1.114)	(0.171)	(0.723)	(0.174)
Household in UER	-3.571***	-0.077	-7.766***	0.374	-5.614***	0.358
	(1.026)	(0.217)	(1.119)	(0.246)	(0.762)	(0.251)
Household in UWR	-3.624***	-1.200***	-8.209***	-0.993***	-6.146***	-1.008***
	(1.315)	(0.230)	(1.471)	(0.241)	(0.986)	(0.245)
Household in SR	1.733	-1.238***	-0.240	-0.594***	-2.314***	-0.601***
	(1.369)	(0.227)	(1.397)	(0.223)	(0.868)	(0.223)
Average hclci in community				0.076***		0.076***
				(0.009)		(0.009)
Average moi in community		0.059***				
		(0.007)				
Constant		-0.325		5.766*		4.636**
		(2.689)		(2.993)		(1.993)
Corr(e.hclci,e.outcomes)		-0.258**		-0.308***		-0.221**
		(0.108)		(0.097)		(0.091)
Observations		858		858		858
Wald Chi-squared		346.769***		586.606***		555.716***

Log pseudolikelihood	-3424.170	-3568.945	-3240.393

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; HCLCI is the household crop-livestock commercialisation index; Standard errors in parentheses; All equations estimated using extended regression (eregress); Source: Produced by the author using Primary Data 2022

Table A13 continued

Variable	FIES	HCLCI	HHS	HCLCI	HFIAS	HCLCI
Ordered HCLCI	0.748***		0.692***		0.400***	
	(0.212)		(0.129)		(0.151)	
Sex of head	-0.279*	0.178	0.175	0.185	0.049	0.176
	(0.159)	(0.176)	(0.162)	(0.173)	(0.147)	(0.175)
Age of head	-0.001	-0.005	0.004	-0.005	-0.005	-0.005
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Household size	-0.015	-0.018	-0.050**	-0.017	-0.049**	-0.018
	(0.020)	(0.021)	(0.022)	(0.021)	(0.022)	(0.021)
Marital status of head	0.013	-0.493***	0.031	-0.495***	0.206	-0.495***
	(0.171)	(0.190)	(0.177)	(0.189)	(0.165)	(0.189)
Years of education of head	0.003	0.001	0.001	0.001	0.003	0.001
	(0.008)	(0.008)	(0.009)	(0.008)	(0.008)	(0.008)
Received cash remittance	0.131	-0.178	0.029	-0.184	0.165	-0.177
	(0.150)	(0.144)	(0.167)	(0.144)	(0.162)	(0.144)
No. of days stop work due to health	-0.001	0.002	0.000	0.002	-0.002	0.002
	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)
Ownership of nonfarm enterprise	-0.121	-0.207	0.054	-0.203	-0.365***	-0.207
	(0.113)	(0.133)	(0.127)	(0.133)	(0.122)	(0.133)
Agric cooperative in community	0.367**	0.024	0.622***	-0.020	0.348**	0.021
	(0.166)	(0.201)	(0.185)	(0.206)	(0.172)	(0.205)
Bank in community	0.001	1.107***	-0.751***	1.118***	-0.618***	1.110***
	(0.279)	(0.206)	(0.251)	(0.206)	(0.219)	(0.207)
Mobile phone network in community	-0.253	-1.313***	-0.394	-1.285***	-0.238	-1.310***
	(0.287)	(0.233)	(0.261)	(0.228)	(0.258)	(0.233)
Extension office in community	0.170	0.392***	0.344**	0.398***	0.414***	0.390***
	(0.128)	(0.125)	(0.135)	(0.124)	(0.124)	(0.125)
Irrigated fields in community	0.051	-0.011	0.329***	-0.006	0.149	-0.012
	(0.106)	(0.113)	(0.117)	(0.111)	(0.104)	(0.112)
Perceived rain pattern	-0.077	-0.042	-0.525***	-0.045	-0.013	-0.044
	(0.159)	(0.155)	(0.166)	(0.153)	(0.148)	(0.155)
Log of expenditure on agrochemicals	-0.034	0.008	-0.024	0.008	-0.034	0.008
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
Log of expenditure on hired labour	0.008	-0.006	-0.015	-0.009	-0.011	-0.006
	(0.019)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)

No. of crops produced	0.078	0.039	0.160**	0.034	0.162***	0.038
	(0.059)	(0.059)	(0.064)	(0.059)	(0.062)	(0.059)
Log of total value of hh assets	0.082***	-0.126***	0.034	-0.124***	0.077***	-0.126***
	(0.028)	(0.024)	(0.028)	(0.024)	(0.026)	(0.024)
Log of agric land endowment	0.064	0.124**	0.086	0.118**	-0.026	0.123**
	(0.065)	(0.058)	(0.069)	(0.057)	(0.063)	(0.058)
Navigable road to community	0.924***	0.807***	1.009***	0.769***	0.917***	0.807***
	(0.162)	(0.132)	(0.152)	(0.125)	(0.143)	(0.129)
Access to public transport	-0.035	0.648***	0.104	0.655***	0.204	0.648***
	(0.155)	(0.166)	(0.149)	(0.166)	(0.149)	(0.165)
Household in NR	-0.198	-0.426**	-0.089	-0.397**	-0.499**	-0.423**
	(0.220)	(0.174)	(0.211)	(0.172)	(0.204)	(0.176)
Household in UER	-0.192	-0.112	-0.187	-0.055	-0.340	-0.112
	(0.257)	(0.235)	(0.208)	(0.231)	(0.227)	(0.231)
Household in UWR	0.002	-1.218***	0.172	-1.176***	0.090	-1.217***
	(0.308)	(0.237)	(0.284)	(0.233)	(0.278)	(0.237)
Household in SR	0.037	-1.202***	0.091	-1.195***	-0.432	-1.202***
	(0.282)	(0.224)	(0.265)	(0.223)	(0.265)	(0.224)
Average moi in community		0.058***		0.060***		0.058***
		(0.008)		(0.008)		(0.008)
Cut1	0.681	0.065	0.831	0.189	0.713	0.064
	(0.657)	(0.557)	(0.535)	(0.551)	(0.544)	(0.550)
Cut2	1.856***	1.240**	1.386***	1.368**	1.087**	1.239**
	(0.656)	(0.569)	(0.533)	(0.562)	(0.544)	(0.562)
Cut3		2.612***		2.747***	1.389**	2.613***
		(0.565)		(0.566)	(0.544)	(0.563)
Corr(e.agcom_cat,e.outcomes)		-0.040		-0.213*		-0.035
		(0.181)		(0.109)		(0.126)
Observations	858		858		858	
Wald Chi-squared	457.068***		504.862***		362.491***	
Log pseudolikelihood	-1404.543		-1320.538		-1520.863	

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; HCLCI is the household crop-livestock commercialisation index; Standard errors in parentheses; All outcomes are estimated using extended ordered probit (eoprobit); Source: Produced by the author using Primary Data 2022

Table A14: Impact of agricultural commercialisation on food and nutrition security outcomes (GLSS7 25-100%)

Variable	PCFEXP	PAEFEXP	HDDS	FCS	Vit. A	Proteins	H. iron
Commercialisation (25-100%)	6.804*	6.149**	0.050***	0.126***	0.079***	0.038***	0.026***
	(3.856)	(3.131)	(0.005)	(0.011)	(0.015)	(0.011)	(0.005)
Sex of head	355.158***	-90.483	-0.295***	-0.797***	-1.522***	-0.506***	-0.102
	(123.606)	(103.208)	(0.100)	(0.207)	(0.281)	(0.196)	(0.080)

Age of head	6.886**	9.624***	0.000	-0.004	0.005	0.000	0.001
	(2.708)	(2.214)	(0.002)	(0.005)	(0.007)	(0.005)	(0.002)
Household size	-344.140***	-257.023***	0.043***	0.177***	0.238***	0.195***	0.057***
	(18.949)	(14.702)	(0.013)	(0.026)	(0.038)	(0.031)	(0.012)
Locality of household	-565.770***	-470.174***	-0.205*	-0.283	-1.385***	-0.449*	-0.236**
	(129.770)	(104.741)	(0.107)	(0.230)	(0.319)	(0.232)	(0.097)
Marital status of head	-534.256***	-174.962*	0.249**	0.800***	1.524***	1.078***	0.456***
	(123.256)	(92.172)	(0.100)	(0.201)	(0.264)	(0.189)	(0.075)
Years of education of head	26.128***	22.033***	0.009	-0.022	0.005	-0.035**	-0.005
	(8.934)	(7.174)	(0.008)	(0.017)	(0.024)	(0.017)	(0.007)
Received cash remittance	380.684***	265.811***	0.007	0.228	0.459**	0.623***	0.174***
	(86.635)	(69.229)	(0.070)	(0.156)	(0.211)	(0.161)	(0.067)
No. of days stop work due to health	-13.482	-12.174	-0.012	-0.009	-0.002	0.031	0.012
	(14.148)	(12.177)	(0.014)	(0.029)	(0.037)	(0.030)	(0.013)
Ownership of nonfarm enterprise	64.801	36.279	-0.208**	-0.074	-0.232	0.113	0.037
	(117.809)	(92.729)	(0.092)	(0.213)	(0.284)	(0.222)	(0.091)
Agric cooperative in community	-289.341**	-216.262**	-0.063	-0.157	-1.305***	-0.014	-0.049
	(126.804)	(102.106)	(0.105)	(0.227)	(0.300)	(0.231)	(0.099)
Bank in community	-156.046	-125.670	-0.531***	-0.898***	-0.702**	-0.199	-0.283***
	(110.140)	(87.904)	(0.118)	(0.256)	(0.348)	(0.248)	(0.106)
Mobile phone network in community	-27.012	-6.382	-0.119	-0.365**	-0.756***	-0.449**	-0.296***
	(94.178)	(74.248)	(0.080)	(0.174)	(0.240)	(0.196)	(0.082)
Extension office in community	246.467**	176.202**	-0.016	-0.163	0.179	-0.399**	-0.022
	(101.644)	(80.584)	(0.084)	(0.177)	(0.264)	(0.190)	(0.081)
Irrigated fields in community	-127.355	-189.479*	-0.732***	-1.023***	-0.689*	-0.643**	-0.396***
	(141.998)	(110.995)	(0.127)	(0.287)	(0.368)	(0.271)	(0.119)
Perceived rain pattern	130.025*	83.228	0.015	0.211	0.245	0.436***	0.052
	(76.134)	(61.261)	(0.067)	(0.142)	(0.194)	(0.149)	(0.062)
Log of expenditure on agrochemicals	36.112*	26.795	0.012	0.133***	0.155***	0.180***	0.036***
	(20.745)	(16.778)	(0.016)	(0.033)	(0.045)	(0.032)	(0.013)
Log of expenditure on hired labour	71.737***	59.043***	0.013	0.051*	0.175***	0.062*	0.048***
	(18.084)	(14.652)	(0.014)	(0.031)	(0.042)	(0.032)	(0.013)
No. of crops produced	20.060	16.005	0.102***	0.232***	0.497***	0.455***	0.028
	(30.903)	(22.672)	(0.022)	(0.049)	(0.071)	(0.055)	(0.023)
Log of total value of hh assets	10.185	5.534	0.046***	0.069**	0.214***	0.207***	0.084***
	(14.050)	(11.337)	(0.012)	(0.027)	(0.038)	(0.032)	(0.013)
Log of agric land endowment	232.050***	179.891***	0.059*	0.264***	0.264**	0.325***	0.120***
	(46.561)	(36.469)	(0.035)	(0.077)	(0.105)	(0.090)	(0.038)
Navigable road to community	303.148**	221.342**	0.402***	1.141***	1.817***	1.707***	0.435***
	(121.743)	(95.973)	(0.141)	(0.290)	(0.381)	(0.289)	(0.121)

Access to public transport	-0.559	-15.517	-0.002	0.123	0.456	-0.659***	-0.081
	(108.866)	(87.681)	(0.105)	(0.224)	(0.290)	(0.246)	(0.096)
Household in southern Ghana	-157.917	-101.313	0.251**	0.245	1.582***	-0.650***	0.079
	(132.823)	(106.879)	(0.103)	(0.242)	(0.328)	(0.244)	(0.106)
Household in coastal zone	-328.527	-229.661	-0.357	0.086	-3.373**	-0.883	-0.355
	(441.204)	(294.147)	(0.517)	(0.740)	(1.326)	(0.868)	(0.365)
Household in forest zone	-457.234	-297.162	-0.366	0.039	-2.346*	-0.537	-0.107
	(422.074)	(277.235)	(0.515)	(0.724)	(1.306)	(0.855)	(0.360)
Household in savannah zone	-1329.855***	-962.992***	-0.546	-0.808	-4.043***	-2.171**	-0.799**
	(438.706)	(292.806)	(0.525)	(0.762)	(1.351)	(0.880)	(0.372)
Constant	3881.123***	2892.560***	4.145***	3.544***	3.273**	1.267	0.460
	(538.544)	(374.938)	(0.595)	(0.941)	(1.560)	(1.041)	(0.446)
Observations	3005	3005	3005	3005	3005	3005	3005
F-statistic/Wald Chi-square	31.547***	29.268***	16.906***	35.777***	35.083***	23.107***	20.698***
R-squared	0.300	0.276	0.221	0.381	0.290	0.223	0.230
KP Weakid test	837.682***	837.682***	302.487***	597.179***	597.179***	302.487***	302.487***
C-D Weakid test	693.873***	693.873***	287.528***	573.207***	573.207***	287.528***	287.528***
KP Underid test	829.546	829.546***	393.915***	393.792***	393.792***	393.915***	393.915***
Hansen J (Overid test)	5.365*	4.712*	6.478**	0.000	0.000	0.752	0.032

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Standard errors in parentheses; PCFEXP, PAEFEXP and HDDS estimated using ivreg2; Stunting and Wasting estimated using ivprobit; FIES estimated using extended ordered probit; Source: Produced by the author using the GLSS7 Data

Table A14 continued

Variable	Stunting	Wasting	Underweight	FIES	HCLCI
Commercialisation (25-100%)	-0.019**	-0.046***	-0.006	0.004*	
	(0.010)	(0.013)	(0.011)	(0.002)	
Sex of head	-0.093	-0.139	0.129	0.091	0.345
	(0.230)	(0.313)	(0.279)	(0.066)	(0.734)
Age of head	-0.001	0.003	-0.007	0.007***	-0.004
	(0.005)	(0.007)	(0.006)	(0.002)	(0.016)
Household size	0.063***	-0.061*	0.022	-0.043***	-0.343***
	(0.023)	(0.034)	(0.026)	(0.009)	(0.102)
Locality of household	-0.033	0.556	0.012	-0.014	5.506***
	(0.235)	(0.372)	(0.277)	(0.070)	(0.913)
Marital status of head	-0.127	0.356	-0.437	0.176***	0.265
	(0.263)	(0.392)	(0.300)	(0.063)	(0.688)
Years of education of head	0.001	0.000	-0.028	0.050***	-0.013
	(0.015)	(0.020)	(0.018)	(0.005)	(0.056)
Received cash remittance	-0.078	0.262	0.034	0.100**	0.181

	(0.130)	(0.177)	(0.148)	(0.047)	(0.517)
No. of days stop work due to health	0.039	-0.215	0.041	-0.021**	-0.054
	(0.028)	(0.143)	(0.029)	(0.009)	(0.106)
Ownership of nonfarm enterprise	0.062	-0.382	0.374**	0.408***	-1.283*
	(0.174)	(0.263)	(0.189)	(0.068)	(0.732)
Agric cooperative in community	-0.284	-0.102	-0.433	-0.197***	5.341***
	(0.227)	(0.333)	(0.274)	(0.069)	(0.857)
Bank in community	-0.711***	0.283	-0.402	0.047	4.916***
	(0.250)	(0.335)	(0.280)	(0.068)	(0.762)
Mobile phone network in community	-0.019	0.083	-0.158	-0.167***	-1.612***
	(0.141)	(0.189)	(0.152)	(0.054)	(0.513)
Extension office in community	-0.057	-0.223	0.184	0.156***	-1.115*
	(0.173)	(0.265)	(0.194)	(0.058)	(0.655)
Irrigated fields in community	-0.446*	0.748**	0.113	0.088	11.004***
	(0.250)	(0.292)	(0.258)	(0.078)	(1.005)
Perceived rain pattern	0.017	0.270	0.283**	-0.033	-0.195
	(0.125)	(0.174)	(0.144)	(0.045)	(0.483)
Log of expenditure on agrochemicals	-0.008	-0.006	0.003	-0.004	0.169
	(0.030)	(0.040)	(0.034)	(0.010)	(0.113)
Log of expenditure on hired labour	-0.008	0.039	0.010	0.037***	0.289***
	(0.027)	(0.036)	(0.031)	(0.009)	(0.103)
No. of crops produced	-0.002	0.012	0.060	0.004	-0.219
	(0.038)	(0.052)	(0.043)	(0.016)	(0.165)
Log of total value of hh assets	-0.033	-0.007	-0.044*	0.049***	-0.037
	(0.022)	(0.030)	(0.025)	(0.009)	(0.091)
Log of agric land endowment	-0.009	0.030	-0.023	0.021	1.471***
	(0.066)	(0.092)	(0.076)	(0.023)	(0.240)
Navigable road to community	0.076	-0.381	-0.427*	-0.015	2.148**
	(0.217)	(0.257)	(0.232)	(0.091)	(0.892)
Access to public transport	-0.338**	0.215	-0.066	0.134**	0.222
	(0.161)	(0.215)	(0.181)	(0.068)	(0.683)
Household in southern Ghana	0.063	-0.336	-0.118	-0.106	-1.658**
	(0.210)	(0.302)	(0.240)	(0.075)	(0.754)
Household in coastal zone	3.791	3.184	2.505	-0.525	2.631
	(97.249)	(250.078)	(96.216)	(0.333)	(4.394)
Household in forest zone	3.579	3.155	2.800	-0.301	6.229
	(97.248)	(250.078)	(96.215)	(0.330)	(4.352)
Household in savannah zone	3.859	3.043	2.924	-0.758**	0.453
	(97.248)	(250.078)	(96.215)	(0.340)	(4.430)
Market in community					24.440***

					(0.584)
Constant	-3.699	-3.120	-3.261		31.498***
	(97.249)	(250.078)	(96.217)		(4.661)
Observations	964	964	964	3005	
Wald Chi-square	77.314***	38.519*	45.525**	559.180***	
Wald test of exogeneity	10.920***	5.003**	3.446*		

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Standard errors in parentheses; PCFEXP, PAEFEXP and HDDS estimated using ivreg2; Stunting, Wasting and Underweight estimated using ivprobit; FIES estimated using extended ordered probit; Source: Produced by the author using the GLSS7 Data

Table A15: Impact of agricultural commercialisation on food and nutrition security outcomes (Primary 25-100%)

Variable	PCFDEXP	FDEXP	HDDS	FCS	Vit. A	Proteins	H. iron
Commercialisation (25-100%)	53.524***	292.957***	0.097**	-0.438	0.306***	0.320***	0.220**
	(20.718)	(103.216)	(0.041)	(0.372)	(0.098)	(0.124)	(0.088)
Sex of head	240.098	-740.042	-1.645***	0.942	-2.923**	-3.784***	-2.323**
	(310.348)	(1048.332)	(0.584)	(5.211)	(1.378)	(1.457)	(0.910)
Age of head	-3.156	19.938	-0.000	0.019	-0.022	-0.035	-0.031
	(6.264)	(28.459)	(0.012)	(0.120)	(0.030)	(0.031)	(0.022)
Household size	-344.807***	-146.597	0.176***	0.553	0.319**	0.261	-0.010
	(35.051)	(170.779)	(0.066)	(0.589)	(0.153)	(0.168)	(0.136)
Marital status of head	-629.065	1651.515	0.512	-6.784	2.320	2.905	2.939**
	(539.801)	(1734.867)	(0.664)	(6.116)	(1.546)	(1.958)	(1.395)
Years of education of head	18.474	42.990	0.046*	0.129	0.083	0.075	0.100*
	(13.613)	(65.149)	(0.027)	(0.228)	(0.059)	(0.070)	(0.052)
Received cash remittance	-129.526	1059.222	0.235	1.929	0.515	0.133	0.304
	(244.187)	(1224.481)	(0.507)	(4.514)	(0.999)	(1.218)	(0.825)
No. of days stop work due to health	-1.129	-5.102	-0.005	-0.025	-0.016	-0.020	-0.012
	(1.638)	(8.082)	(0.005)	(0.027)	(0.014)	(0.015)	(0.008)
Ownership of nonfarm enterprise	226.093	1117.959	0.543	2.630	2.333**	1.219	0.753
	(151.911)	(695.055)	(0.420)	(3.890)	(0.947)	(1.083)	(0.753)
Agric cooperative in community	111.439	922.570	-0.699	-6.198	-0.170	0.178	0.582
	(269.335)	(993.586)	(0.559)	(3.848)	(1.175)	(1.419)	(1.003)
Bank in community	-449.766	-4043.158	-1.375	14.936	-5.423*	-4.415	-3.583
	(612.764)	(2716.895)	(1.248)	(10.526)	(2.861)	(3.644)	(2.516)
Mobile phone network in community	-198.979	1624.765	2.079**	-4.522	3.388	0.344	0.799
	(544.020)	(2452.191)	(0.928)	(6.839)	(2.162)	(2.426)	(1.796)
Agric extension office in community	86.728	1070.261	-1.219***	3.225	-2.217**	-1.845*	-0.519
	(184.639)	(724.165)	(0.389)	(3.949)	(0.938)	(1.092)	(0.769)
Irrigated fields in community	168.464	460.634	0.398	2.008	0.989	0.444	-0.174
	(205.948)	(888.550)	(0.390)	(2.909)	(0.831)	(0.987)	(0.698)

Perceived rain pattern	55.984	-696.574	0.335	2.942	0.127	0.938	0.972
	(264.039)	(1135.940)	(0.530)	(4.378)	(1.234)	(1.459)	(1.019)
Log of expenditure on agrochemicals	-4.617	-129.535	0.162**	-0.482	0.182	0.261	0.158
	(35.889)	(163.405)	(0.082)	(0.738)	(0.185)	(0.208)	(0.145)
Log of expenditure on hired labour	-7.428	97.440	0.161**	0.868*	0.545***	0.720***	0.437***
	(32.441)	(165.157)	(0.064)	(0.498)	(0.150)	(0.189)	(0.135)
No. of crops produced	-159.337*	-187.593	0.098	0.460	-0.629	-0.007	0.119
	(96.756)	(492.415)	(0.202)	(1.664)	(0.420)	(0.488)	(0.345)
Log of total value of hh assets	139.446***	613.196*	0.490***	-2.568***	0.959***	1.238***	0.656***
	(51.867)	(322.300)	(0.097)	(0.954)	(0.238)	(0.284)	(0.213)
Log of agric land endowment	157.173	366.278	0.037	7.280***	0.348	0.333	0.350
	(147.475)	(587.023)	(0.206)	(1.717)	(0.536)	(0.563)	(0.449)
Navigable road to community	-72.398	-84.800	0.836	-9.561*	1.574	-0.135	-0.197
	(291.711)	(1188.993)	(0.649)	(5.611)	(1.472)	(1.918)	(1.384)
Access to public transport	284.668	37.624	0.374	-3.425	0.142	-0.316	-0.369
	(287.549)	(1319.017)	(0.483)	(4.251)	(1.108)	(1.298)	(0.940)
Household in NR	-2110.464***	-12617.362***	0.910	6.454	1.034	-1.343	-3.004***
	(395.906)	(1728.143)	(0.593)	(5.518)	(1.466)	(1.599)	(1.087)
Household in UER	-1854.613***	-10891.577***	-3.086***	-17.246***	-2.081	-6.245***	-4.399***
	(377.825)	(1820.407)	(0.589)	(5.994)	(1.426)	(1.648)	(1.216)
Household in UWR	-1465.859***	-6768.957***	0.324	-12.836*	-1.763	-6.926***	-5.372***
	(541.377)	(2393.452)	(0.899)	(7.474)	(2.200)	(2.507)	(1.735)
Household in SR	-1982.660***	-10286.853***	1.105	11.108*	0.824	-0.299	-2.670*
	(457.174)	(2258.177)	(0.714)	(6.437)	(1.915)	(2.102)	(1.433)
Constant	2488.584	-2184.455	-5.047	77.228**	-19.312**	-12.223	-7.058
	(1846.866)	(8394.196)	(3.505)	(32.451)	(8.305)	(10.256)	(7.396)
Observations	448	448	448	448	448	448	448
F-statistic/Wald Chi-square	10.588***	8.905***	10.796***	4.243***	7.469***	11.501***	10.222***
R-squared	0.457	0.391	0.230	0.012	0.190	0.268	0.274
Log likelihood	-3912.646	-4598.082	-1102.343	-2075.764	-1467.103	-1535.884	-1379.770
KP Weakid test	8.687***	8.687***	24.552***	8.687***	24.552***	24.552***	24.552***
C-D Weakid test	8.693***	8.693***	24.578***	8.693***	24.578***	24.578***	24.578***
KP Underid test	24.918***	24.918***	22.521***	24.918***	22.521***	22.521***	22.521***
Hansen J (Overid test)	0.263	3.401	0.000	2.369	0.000	0.000	0.000

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Standard errors in parentheses; PCFDEXP, FDEXP, HDDS and FCS estimated using ivreg2; FIES, HHS and HFIAS estimated using extended ordered probit; Source: Produced by the author using Primary Data 2022

Table A15 continued

Variable	FIES	HCLCI	HHS	HCLCI	HFIAS	HCLCI
Commercialisation (25-100%)	0.028		0.050***		0.030	
	(0.025)		(0.019)		(0.020)	
Sex of head	-0.280	4.854	0.356	4.820	0.231	4.818
	(0.285)	(3.099)	(0.272)	(3.068)	(0.245)	(3.071)
Age of head	-0.002	-0.000	0.010	0.002	0.002	0.002
	(0.005)	(0.063)	(0.006)	(0.063)	(0.005)	(0.063)
Household size	-0.035	-0.257	-0.073**	-0.263	-0.088***	-0.264
	(0.027)	(0.335)	(0.032)	(0.334)	(0.028)	(0.333)
Marital status of head	0.132	-10.735***	0.342	-10.853***	0.425	-10.856***
	(0.338)	(2.726)	(0.382)	(2.704)	(0.355)	(2.702)
Years of education of head	0.000	-0.030	0.007	-0.020	0.008	-0.021
	(0.011)	(0.133)	(0.013)	(0.134)	(0.012)	(0.134)
Received cash remittance	0.184	-2.772	0.150	-2.703	0.526**	-2.676
	(0.210)	(2.341)	(0.260)	(2.336)	(0.254)	(2.333)
No. of days stop work due to health	-0.002	0.006	-0.000	0.006	-0.003	0.006
	(0.003)	(0.039)	(0.002)	(0.039)	(0.003)	(0.039)
Ownership of nonfarm enterprise	0.096	-0.508	0.144	-0.591	-0.255	-0.598
	(0.170)	(2.121)	(0.193)	(2.131)	(0.164)	(2.130)
Agric cooperative in community	-0.049	-7.380***	0.088	-7.353***	-0.279	-7.286***
	(0.282)	(2.619)	(0.306)	(2.653)	(0.232)	(2.665)
Bank in community	0.287	23.883***	-1.322**	23.089***	-0.122	23.055***
	(0.570)	(3.272)	(0.581)	(3.271)	(0.584)	(3.259)
Mobile phone network in community	0.746	-12.066***	0.915*	-12.292***	0.793*	-12.121***
	(0.553)	(4.093)	(0.513)	(4.104)	(0.463)	(4.110)
Agric extension office in community	0.127	2.115	0.341*	2.078	0.153	2.249
	(0.178)	(2.204)	(0.198)	(2.273)	(0.174)	(2.243)
Irrigated fields in community	-0.069	-0.192	0.488**	-0.314	0.074	-0.087
	(0.147)	(2.153)	(0.195)	(2.324)	(0.156)	(2.292)
Perceived rain pattern	-0.070	4.286*	-0.824***	4.234*	-0.228	4.241*
	(0.279)	(2.394)	(0.263)	(2.391)	(0.218)	(2.392)
Log of expenditure on agrochemicals	-0.020	0.578	-0.027	0.594*	-0.037	0.587
	(0.033)	(0.360)	(0.035)	(0.358)	(0.035)	(0.358)
Log of expenditure on hired labour	0.024	-0.100	-0.028	-0.120	0.016	-0.122
	(0.032)	(0.323)	(0.035)	(0.324)	(0.031)	(0.324)
No. of crops produced	0.013	-0.742	0.068	-0.730	0.065	-0.736
	(0.087)	(0.908)	(0.095)	(0.907)	(0.091)	(0.907)
Log of total value of hh assets	-0.003	-1.472***	0.036	-1.485***	0.071	-1.476***
	(0.044)	(0.362)	(0.046)	(0.359)	(0.048)	(0.359)

Log of agric land endowment	0.082	2.348***	-0.053	2.349***	-0.227**	2.349***
	(0.098)	(0.889)	(0.141)	(0.882)	(0.104)	(0.882)
Navigable road to community	0.163	-7.387***	0.197	-7.624***	-0.322	-7.421***
	(0.370)	(2.565)	(0.330)	(2.655)	(0.297)	(2.635)
Access to public transport	-0.480	5.064**	-0.222	5.389**	-0.172	5.223**
	(0.298)	(2.394)	(0.247)	(2.421)	(0.249)	(2.440)
Household in NR	0.247	2.047	0.562*	1.797	0.102	1.948
	(0.300)	(2.955)	(0.308)	(3.000)	(0.280)	(2.983)
Household in UER	-0.226	4.299	-0.196	4.754	-0.534*	5.121
	(0.287)	(3.999)	(0.304)	(4.216)	(0.305)	(4.041)
Household in UWR	1.003*	-10.790***	1.669***	-10.512***	0.981**	-10.459***
	(0.578)	(3.773)	(0.476)	(3.766)	(0.461)	(3.770)
Household in SR	0.191	-5.909	0.439	-5.110	0.019	-4.793
	(0.405)	(4.138)	(0.374)	(4.306)	(0.373)	(4.244)
Market in community		0.021		0.851		0.368
		(1.510)		(2.014)		(2.003)
Average hclci in community		0.121		0.254		0.288
		(0.235)		(0.276)		(0.262)
Average moi in community		0.432**		0.325		0.301
		(0.188)		(0.231)		(0.227)
Constant		50.167***		50.075***		49.720***
		(8.275)		(8.241)		(8.123)
Corr(e.hclci,e.outcomes)		0.686***		-0.125		0.119
		(0.139)		(0.289)		(0.269)
Observations	448		448		448	
Wald Chi-square	66.414***		89.657***		93.009***	
Log likelihood	-2038.925		-2096.084		-2253.262	

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Standard errors in parentheses; PCFDEXP, FDEXP, HDDS and FCS estimated using ivreg2; FIES, HHS and HFIAS estimated using extended ordered probit; Source: Produced by the author using Primary Data 2022

Table A16: Impact of crop commercialisation on food and nutrition outcomes (GLSS7)

Variable	PCFEXP	PAEFEXP	HDDS	FCS	Vit. A	Proteins	H. iron
Crop commercialisation	6.619***	4.761***	0.028***	0.068***	0.038***	0.024***	0.012***
	(1.450)	(1.174)	(0.002)	(0.004)	(0.004)	(0.003)	(0.001)
Sex of head	411.526***	48.757	-0.217***	-0.373***	-0.889***	-0.254**	0.043
	(71.037)	(58.302)	(0.065)	(0.133)	(0.167)	(0.115)	(0.047)
Age of head	3.359**	4.703***	-0.001	-0.004	0.003	-0.002	-0.000
	(1.377)	(1.147)	(0.001)	(0.003)	(0.003)	(0.003)	(0.001)
Household size	-208.141***	-166.168***	0.070***	0.157***	0.145***	0.157***	0.054***

	(8.883)	(7.023)	(0.007)	(0.016)	(0.020)	(0.018)	(0.007)
Locality of household	-298.939***	-299.971***	-0.091	0.070	-0.935***	0.107	-0.017
	(70.538)	(56.108)	(0.064)	(0.135)	(0.172)	(0.121)	(0.053)
Marital status of head	-483.278***	-195.344***	0.296***	0.612***	1.118***	0.653***	0.249***
	(71.953)	(54.419)	(0.065)	(0.130)	(0.161)	(0.113)	(0.046)
Years of education of head	14.553***	13.395***	0.008	-0.010	0.010	-0.018*	-0.002
	(4.932)	(4.058)	(0.005)	(0.010)	(0.014)	(0.010)	(0.004)
Received cash remittance	343.017***	256.539***	0.244***	0.393***	0.380***	0.604***	0.210***
	(50.191)	(40.702)	(0.046)	(0.101)	(0.127)	(0.099)	(0.042)
No. of days stop work due to health	-5.522	-4.948	0.015	0.025	-0.010	0.043**	0.014*
	(8.254)	(7.115)	(0.009)	(0.020)	(0.023)	(0.019)	(0.008)
Ownership of nonfarm enterprise	77.645	54.453	0.104*	0.141	-0.064	0.255**	0.114**
	(63.323)	(51.376)	(0.059)	(0.126)	(0.160)	(0.129)	(0.055)
Agric cooperative in community	-179.159*	-151.866*	0.071	0.219	-0.978***	0.104	0.095
	(98.900)	(78.252)	(0.085)	(0.188)	(0.236)	(0.178)	(0.078)
Bank in community	1.196	-0.377	-0.188**	0.223	0.340	0.344**	0.043
	(91.235)	(71.770)	(0.088)	(0.197)	(0.249)	(0.173)	(0.074)
Mobile phone network in community	109.552**	63.573	-0.142***	-0.469***	-0.571***	-0.446***	-0.285***
	(54.311)	(43.096)	(0.053)	(0.114)	(0.147)	(0.122)	(0.051)
Extension office in community	199.402**	144.266**	-0.129*	-0.308*	0.157	-0.419***	-0.053
	(85.210)	(66.571)	(0.076)	(0.163)	(0.227)	(0.158)	(0.068)
Irrigated fields in community	41.567	6.441	-0.156**	0.334**	0.309	-0.191	-0.139**
	(79.215)	(63.506)	(0.072)	(0.153)	(0.191)	(0.136)	(0.059)
Perceived rain pattern	62.739	19.409	0.105**	0.313***	0.337***	0.349***	0.041
	(41.456)	(33.951)	(0.041)	(0.088)	(0.109)	(0.085)	(0.036)
Log of expenditure on agrochemicals	38.064***	32.639***	0.039***	0.157***	0.152***	0.113***	0.044***
	(10.144)	(8.389)	(0.009)	(0.019)	(0.024)	(0.017)	(0.007)
Log of expenditure on hired labour	44.853***	38.472***	0.037***	0.064***	0.142***	0.093***	0.038***
	(9.804)	(7.994)	(0.009)	(0.019)	(0.025)	(0.018)	(0.008)
No. of crops produced	11.161	3.473	0.100***	0.224***	0.405***	0.415***	0.016
	(17.677)	(13.365)	(0.015)	(0.032)	(0.043)	(0.033)	(0.014)
Log of total value of hh assets	8.453	7.521	0.060***	0.092***	0.140***	0.149***	0.066***
	(7.529)	(6.209)	(0.007)	(0.017)	(0.022)	(0.018)	(0.008)
Log of agric land endowment	198.549***	164.724***	0.064***	0.187***	0.150**	0.335***	0.154***
	(25.854)	(20.851)	(0.022)	(0.046)	(0.059)	(0.051)	(0.023)
Navigable road to community	555.142***	256.591***	0.100	0.201	0.510***	1.004***	0.268***
	(63.782)	(51.186)	(0.071)	(0.148)	(0.176)	(0.148)	(0.063)
Access to public transport	181.406***	90.005*	-0.044	-0.121	0.370**	-0.596***	-0.076
	(60.938)	(49.841)	(0.065)	(0.139)	(0.161)	(0.139)	(0.057)
Household in southern Ghana	-70.959	-28.015	0.258***	0.015	1.233***	-0.662***	-0.011

	(100.105)	(80.943)	(0.080)	(0.193)	(0.242)	(0.175)	(0.074)
Household in coastal zone	62.136	12.500	-0.538	0.170	-2.213**	-0.322	-0.239
	(243.269)	(219.100)	(0.439)	(0.728)	(1.111)	(0.707)	(0.342)
Household in forest zone	156.585	95.759	-0.512	0.390	-1.002	0.003	0.063
	(231.898)	(211.330)	(0.437)	(0.718)	(1.101)	(0.699)	(0.339)
Household in savannah zone	-593.023**	-528.847**	-0.730	-0.187	-2.356**	-1.012	-0.546
	(247.460)	(222.578)	(0.446)	(0.747)	(1.129)	(0.718)	(0.347)
Constant	1923.980***	1905.393***	4.798***	5.461***	4.537***	1.373*	0.808**
	(271.737)	(240.316)	(0.459)	(0.779)	(1.164)	(0.752)	(0.360)
Observations	6637	6637	6637	6637	6637	6637	6637
F-statistic	81.898***	72.164***	95.081***	116.981***	70.901***	51.146***	56.965***
R-squared	0.337	0.302	0.256	0.328	0.260	0.224	0.237
KP Weakid test	1466.054***	1466.054***	1701.215***	1701.215***	1261.459***	1261.459***	1261.459***
C-D Weakid test	1604.655***	1604.655***	2065.311***	2065.311***	1396.072***	1396.072***	1396.072***
KP Underid test	1184.739***	1184.739***	970.819***	970.819***	1094.243***	1094.243***	1094.243***
Hansen J (Overid test)	4.374**	3.193*	0.000	0.000	11.930***	0.376	6.094**

Table A16 continued

Variable	Stunting	Wasting	Underweight	FIES	HCLCI
Crop commercialisation	-0.003	-0.028***	-0.014***	0.003***	
	(0.002)	(0.003)	(0.003)	(0.001)	
Sex of head	-0.127	-0.054	0.133	0.100**	3.630***
	(0.130)	(0.159)	(0.152)	(0.045)	(0.815)
Age of head	0.001	0.005	-0.002	0.004***	0.025
	(0.003)	(0.003)	(0.003)	(0.001)	(0.018)
Household size	0.027**	-0.033**	0.004	-0.037***	-0.397***
	(0.012)	(0.014)	(0.013)	(0.005)	(0.098)
Locality of household	-0.419***	-0.242*	-0.398***	-0.123***	-1.411*
	(0.115)	(0.136)	(0.131)	(0.045)	(0.838)
Marital status of head	0.052	0.017	-0.199	0.113***	-1.889**
	(0.147)	(0.176)	(0.167)	(0.043)	(0.780)
Years of education of head	0.001	0.011	-0.002	0.045***	0.006
	(0.008)	(0.010)	(0.009)	(0.004)	(0.064)
Received cash remittance	-0.114	0.074	-0.124	0.113***	0.026
	(0.072)	(0.087)	(0.083)	(0.033)	(0.595)
No. of days stop work due to health	0.024	-0.029	0.001	-0.021***	0.065
	(0.016)	(0.021)	(0.018)	(0.006)	(0.115)
Ownership of nonfarm enterprise	0.084	-0.042	0.158	0.320***	-2.595***
	(0.091)	(0.110)	(0.103)	(0.043)	(0.778)

Agric cooperative in community	-0.106	-0.139	-0.126	-0.185***	6.818***
	(0.139)	(0.188)	(0.170)	(0.056)	(1.000)
Bank in community	-0.579***	0.188	-0.092	0.043	11.536***
	(0.150)	(0.197)	(0.183)	(0.055)	(0.980)
Mobile phone network in community	-0.482***	-0.542***	-0.642***	-0.218***	3.388***
	(0.073)	(0.089)	(0.083)	(0.037)	(0.679)
Extension office in community	-0.010	0.045	-0.005	0.141***	0.789
	(0.121)	(0.168)	(0.152)	(0.049)	(0.879)
Irrigated fields in community	-0.268**	-0.055	-0.194	0.232***	0.445
	(0.124)	(0.139)	(0.140)	(0.051)	(0.924)
Perceived rain pattern	0.097	-0.034	0.094	0.022	-0.492
	(0.066)	(0.079)	(0.075)	(0.029)	(0.538)
Log of expenditure on agrochemicals	-0.021	0.022	-0.010	0.016**	-0.122
	(0.016)	(0.018)	(0.018)	(0.007)	(0.119)
Log of expenditure on hired labour	-0.012	0.038**	0.024	0.032***	0.392***
	(0.014)	(0.017)	(0.016)	(0.006)	(0.113)
No. of crops produced	-0.019	0.024	0.012	0.029***	0.273
	(0.023)	(0.029)	(0.027)	(0.011)	(0.198)
Log of total value of hh assets	-0.018	-0.007	-0.029**	0.049***	0.085
	(0.012)	(0.014)	(0.013)	(0.006)	(0.101)
Log of agric land endowment	0.009	-0.068	-0.012	0.003	1.487***
	(0.036)	(0.046)	(0.042)	(0.015)	(0.274)
Navigable road to community	-0.993***	-1.118***	-1.215***	-0.012	10.356***
	(0.097)	(0.111)	(0.105)	(0.050)	(0.866)
Access to public transport	-0.369***	-0.053	-0.193*	0.148***	5.538***
	(0.087)	(0.108)	(0.101)	(0.045)	(0.805)
Household in southern Ghana	0.288**	0.059	0.100	-0.026	-0.767
	(0.132)	(0.182)	(0.159)	(0.056)	(1.015)
Household in coastal zone	4.097	2.313	2.956	-0.952***	1.356
	(151.494)	(125.385)	(152.746)	(0.319)	(4.899)
Household in forest zone	3.794	2.017	2.847	-0.810**	2.474
	(151.493)	(125.385)	(152.746)	(0.318)	(4.855)
Household in savannah zone	4.179	2.114	2.914	-1.275***	-3.664
	(151.494)	(125.385)	(152.746)	(0.323)	(4.970)
Market in community					17.273***
					(0.821)
Average moi in community					0.746***
					(0.015)
Constant	-2.793	-1.011	-1.486		-2.019
	(151.494)	(125.385)	(152.746)		(5.184)

Observations	2234	2234	2234	6637
Wald Chi-square	617.710***	723.510***	755.938***	1370.701***
Wald test of exogeneity	10.530***	14.071***	10.278***	

Table A17: Impact of livestock commercialisation on food and nutrition outcomes (GLSS7)

Variable	PCFEXP	PAEFEXP	HDDS	FCS	Vit. A	Proteins	H. iron
Livestock commercialisation	139.687**	101.196**	0.476**	1.552**	1.240**	0.768**	0.330**
	(64.257)	(47.473)	(0.192)	(0.619)	(0.498)	(0.311)	(0.134)
Sex of head	452.898***	81.961	-0.198	-0.255	-0.819	-0.225	0.050
	(120.842)	(91.262)	(0.354)	(1.143)	(0.912)	(0.569)	(0.245)
Age of head	6.269**	6.866***	0.011	0.037	0.037	0.017	0.007
	(3.196)	(2.402)	(0.010)	(0.031)	(0.025)	(0.016)	(0.007)
Household size	-229.121***	-183.269***	0.004	-0.060	-0.020	0.063	0.010
	(16.695)	(12.451)	(0.046)	(0.150)	(0.121)	(0.076)	(0.033)
Locality of household	-622.886***	-540.393***	-1.154**	-3.660*	-4.067***	-1.901**	-0.836**
	(193.499)	(143.075)	(0.579)	(1.873)	(1.509)	(0.942)	(0.406)
Marital status of head	-406.159***	-147.760	0.620*	1.642	1.961**	1.163**	0.486*
	(126.399)	(93.242)	(0.369)	(1.185)	(0.949)	(0.592)	(0.255)
Years of education of head	12.753	12.031*	0.007	-0.010	0.010	-0.015	-0.002
	(8.967)	(6.767)	(0.027)	(0.087)	(0.070)	(0.044)	(0.019)
Received cash remittance	467.432***	355.733***	0.600**	1.551*	1.313*	1.194**	0.471**
	(97.940)	(73.004)	(0.288)	(0.924)	(0.745)	(0.466)	(0.201)
No. of days stop work due to health	7.879	4.568	0.051	0.155	0.094	0.101	0.040
	(15.472)	(11.585)	(0.048)	(0.153)	(0.123)	(0.078)	(0.034)
Ownership of nonfarm enterprise	-143.079	-85.863	-0.824*	-2.706*	-2.167*	-1.123	-0.492
	(152.024)	(113.389)	(0.454)	(1.464)	(1.178)	(0.736)	(0.317)
Agric cooperative in community	-421.847*	-334.405*	-0.642	-2.367	-3.125*	-1.263	-0.482
	(230.525)	(171.847)	(0.674)	(2.182)	(1.752)	(1.098)	(0.473)
Bank in community	66.468	35.114	0.071	0.440	0.080	0.164	0.012
	(173.196)	(128.058)	(0.512)	(1.660)	(1.333)	(0.839)	(0.359)
Mobile phone network in community	-729.678*	-548.479*	-3.000**	-9.754**	-7.999***	-5.025***	-2.247***
	(397.267)	(293.191)	(1.192)	(3.842)	(3.090)	(1.933)	(0.833)
Extension office in community	0.688	2.026	-0.749	-2.449	-1.640	-1.531*	-0.524
	(187.322)	(137.872)	(0.558)	(1.801)	(1.456)	(0.908)	(0.391)
Irrigated fields in community	-494.666*	-377.237*	-1.797**	-5.165*	-4.064*	-2.826**	-1.287**
	(279.066)	(205.735)	(0.841)	(2.716)	(2.185)	(1.361)	(0.586)
Perceived rain pattern	-22.969	-35.278	-0.143	-0.535	-0.343	-0.075	-0.139
	(85.605)	(63.898)	(0.258)	(0.831)	(0.667)	(0.418)	(0.180)
Log of expenditure on agrochemicals	63.726***	46.639***	0.141**	0.479**	0.407**	0.243**	0.107**

	(21.278)	(15.907)	(0.064)	(0.205)	(0.165)	(0.104)	(0.045)
Log of expenditure on hired labour	57.361***	45.100***	0.081	0.192	0.231*	0.136	0.061
	(18.032)	(13.524)	(0.053)	(0.171)	(0.137)	(0.087)	(0.037)
No. of crops produced	57.841	29.397	0.291***	0.834**	0.872***	0.664***	0.128*
	(36.940)	(27.270)	(0.109)	(0.350)	(0.281)	(0.177)	(0.077)
Log of total value of hh assets	36.882**	30.667**	0.165***	0.427**	0.408***	0.322***	0.135***
	(18.134)	(13.578)	(0.055)	(0.174)	(0.141)	(0.088)	(0.038)
Log of agric land endowment	287.840***	233.448***	0.394**	1.196**	0.889**	0.806***	0.356***
	(55.797)	(41.877)	(0.156)	(0.501)	(0.408)	(0.257)	(0.111)
Navigable road to community	-760.924	-710.147	-4.409**	-14.977**	-11.949**	-6.732**	-3.011**
	(694.412)	(512.758)	(2.072)	(6.675)	(5.365)	(3.353)	(1.444)
Access to public transport	667.715***	420.947**	1.596**	4.958**	4.220**	1.731	0.963**
	(226.614)	(166.512)	(0.685)	(2.203)	(1.769)	(1.109)	(0.479)
Household in southern Ghana	2.559	22.585	0.423	0.676	1.852	-0.226	0.147
	(159.910)	(119.617)	(0.469)	(1.520)	(1.222)	(0.764)	(0.327)
Household in coastal zone	45.190	-13.832	1.556	5.240	2.323	2.081	0.830
	(562.960)	(425.239)	(1.728)	(5.313)	(4.244)	(2.638)	(1.158)
Household in forest zone	-92.347	-98.550	0.760	2.777	1.207	0.979	0.534
	(521.099)	(395.588)	(1.611)	(4.912)	(3.921)	(2.433)	(1.072)
Household in savannah zone	-1109.520**	-927.820**	-0.716	-1.433	-2.648	-1.615	-0.756
	(535.565)	(406.520)	(1.657)	(5.070)	(4.049)	(2.513)	(1.105)
Constant	1996.563***	2052.510***	3.009	1.223	0.643	-0.245	0.006
	(600.941)	(455.501)	(1.837)	(5.674)	(4.539)	(2.816)	(1.235)
Observations	7260	7260	7260	7260	7260	7260	7260
F-statistic	31.081***	29.199***	3.608***	1.924***	3.112***	4.471***	3.755***
KP Weakid test	6.080*	6.080*	6.080*	6.080*	6.080*	6.080*	6.080*
C-D Weakid test	8.690*	8.690*	8.690*	8.690*	8.690*	8.690*	8.690*
KP Underid test	6.070**	6.070**	6.070**	6.070**	6.070**	6.070**	6.070**
Hansen J (Overid test)	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table A17 continued

Variable	Stunting	Wasting	Underweight	FIES	HCLCI
Livestock commercialisation	-0.699	-0.419	-0.522	0.034***	
	(1.094)	(0.666)	(0.823)	(0.010)	
Sex of head	-1.268	-0.745	-0.719	0.080*	0.016
	(2.105)	(1.279)	(1.581)	(0.045)	(0.718)
Age of head	-0.024	-0.009	-0.020	0.004***	-0.027*
	(0.044)	(0.027)	(0.033)	(0.001)	(0.016)

Household size	0.127	0.038	0.085	-0.032***	0.136
	(0.191)	(0.116)	(0.144)	(0.008)	(0.088)
Locality of household	2.348	1.259	1.594	-0.192***	2.705***
	(4.455)	(2.711)	(3.349)	(0.038)	(0.688)
Marital status of head	0.499	0.303	0.122	0.102**	-0.738
	(1.489)	(0.902)	(1.116)	(0.040)	(0.691)
Years of education of head	0.078	0.057	0.056	0.032***	-0.006
	(0.142)	(0.086)	(0.107)	(0.009)	(0.056)
Received cash remittance	-0.896	-0.401	-0.716	0.118***	-0.733
	(1.399)	(0.850)	(1.051)	(0.033)	(0.527)
No. of days stop work due to health	-0.076	-0.082	-0.065	-0.012	-0.083
	(0.211)	(0.128)	(0.158)	(0.007)	(0.101)
Ownership of nonfarm enterprise	1.534	0.971	1.265	0.165**	1.674**
	(2.394)	(1.457)	(1.800)	(0.081)	(0.669)
Agric cooperative in community	0.212	-0.086	0.007	-0.179***	1.981**
	(1.308)	(0.799)	(0.983)	(0.051)	(0.911)
Bank in community	1.620	0.835	1.211	0.037	-0.077
	(3.712)	(2.259)	(2.789)	(0.053)	(0.897)
Mobile phone network in community	4.538	2.426	3.106	-0.358***	6.039***
	(7.884)	(4.800)	(5.928)	(0.040)	(0.622)
Extension office in community	1.424	0.786	1.083	0.042	1.454*
	(2.559)	(1.558)	(1.924)	(0.060)	(0.803)
Irrigated fields in community	0.832	0.554	0.691	0.041	3.496***
	(1.949)	(1.184)	(1.464)	(0.090)	(0.812)
Perceived rain pattern	0.425	0.151	0.308	-0.007	0.502
	(0.751)	(0.456)	(0.563)	(0.028)	(0.480)
Log of expenditure on agrochemicals	-0.147	-0.086	-0.130	0.015**	-0.220**
	(0.228)	(0.138)	(0.171)	(0.006)	(0.104)
Log of expenditure on hired labour	-0.088	-0.037	-0.048	0.025***	-0.069
	(0.169)	(0.102)	(0.126)	(0.008)	(0.104)
No. of crops produced	-0.241	-0.155	-0.197	0.027***	-0.410**
	(0.383)	(0.233)	(0.287)	(0.009)	(0.168)
Log of total value of hh assets	-0.117	-0.054	-0.087	0.046***	-0.201**
	(0.190)	(0.116)	(0.143)	(0.009)	(0.089)
Log of agric land endowment	-0.609	-0.547	-0.521	0.025*	-0.537**
	(1.006)	(0.612)	(0.756)	(0.014)	(0.249)
Navigable road to community	5.938	2.724	3.832	-0.329***	10.418***
	(11.041)	(6.722)	(8.300)	(0.123)	(0.783)
Access to public transport	-2.843	-1.840	-2.201	0.227***	-3.202***
	(3.841)	(2.340)	(2.888)	(0.040)	(0.731)

Household in southern Ghana	0.043	-0.163	-0.110	0.002	-0.343
	(1.127)	(0.684)	(0.845)	(0.050)	(0.894)
Household in coastal zone	-8.556	-5.085	-6.556	-0.039	-3.042
	(15.023)	(9.146)	(11.291)	(0.203)	(3.431)
Household in forest zone	-8.199	-5.127	-6.272	-0.003	-1.152
	(14.096)	(8.583)	(10.595)	(0.190)	(3.389)
Household in savannah zone	-6.147	-3.830	-4.839	-0.415*	0.751
	(11.719)	(7.135)	(8.806)	(0.217)	(3.504)
Market in community					2.199***
					(0.744)
Constant	9.491	6.346	7.990		2.791
	(14.322)	(8.720)	(10.764)		(3.675)
Observations	2434	2434	2434	7260	
Wald Chi-square	13.011*	47.378***	30.065*	2657.136***	
Wald test of exogeneity	28.487***	7.023***	10.839***		

Table A18: Impact of crop commercialisation on food and nutrition outcomes (Primary data)

Variable	PCFDEXP	FDEXP	HDDS	FCS	Vit. A	Proteins	H. iron
Crop commercialisation	33.084***	155.789***	0.069***	0.294***	0.073**	0.117***	0.077***
	(6.572)	(30.784)	(0.013)	(0.089)	(0.029)	(0.035)	(0.025)
Sex of head	36.047	-765.844*	-0.909***	-3.838*	-1.575**	-3.413***	-1.659***
	(140.444)	(433.796)	(0.336)	(2.191)	(0.713)	(0.847)	(0.557)
Age of head	-6.434*	-8.053	-0.018**	-0.025	-0.028	-0.024	-0.021
	(3.830)	(16.943)	(0.009)	(0.058)	(0.018)	(0.021)	(0.014)
Household size	-236.008***	-126.590	0.032	0.191	0.202**	-0.030	-0.114
	(22.544)	(106.766)	(0.047)	(0.306)	(0.101)	(0.110)	(0.082)
Marital status of head	-436.892*	91.484	0.101	1.374	0.227	1.126	0.621
	(234.630)	(572.863)	(0.372)	(2.375)	(0.757)	(1.038)	(0.702)
Years of education of head	11.788	21.379	0.004	0.151	0.061	0.089*	0.059*
	(8.521)	(38.278)	(0.018)	(0.114)	(0.037)	(0.045)	(0.033)
Received cash remittance	74.189	661.427	-0.248	0.817	-0.177	-0.780	-0.083
	(150.126)	(761.898)	(0.322)	(2.435)	(0.732)	(0.856)	(0.606)
No. of days stop work due to health	-0.585	0.159	0.001	-0.019	-0.011***	-0.019***	-0.012***
	(0.778)	(3.846)	(0.003)	(0.014)	(0.004)	(0.005)	(0.003)
Ownership of nonfarm enterprise	188.635*	809.296	0.810***	5.096***	2.786***	2.898***	1.787***
	(111.571)	(521.611)	(0.310)	(1.883)	(0.635)	(0.768)	(0.513)
Agric cooperative in community	-165.156	-259.577	0.334	-0.651	-0.564	-0.488	0.086
	(184.825)	(771.017)	(0.415)	(2.858)	(0.910)	(1.192)	(0.830)
Bank in community	665.988**	2791.811***	-0.882**	-0.804	0.597	1.482	0.741

	(271.175)	(1001.759)	(0.447)	(2.687)	(0.990)	(1.120)	(0.809)
Mobile phone network in community	-28.907	1151.762	0.484	0.381	0.587	-0.310	0.494
	(285.921)	(1240.368)	(0.607)	(3.415)	(1.180)	(1.508)	(1.059)
Agric extension office in community	10.456	-62.691	-0.547*	1.786	-1.571***	-1.074	0.039
	(113.510)	(483.166)	(0.302)	(2.132)	(0.595)	(0.802)	(0.559)
Irrigated fields in community	175.179	478.774	0.373	1.572	0.297	0.289	0.058
	(120.834)	(481.848)	(0.249)	(1.507)	(0.499)	(0.631)	(0.445)
Perceived rain pattern	64.755	-170.706	-0.051	-0.353	0.532	0.982	1.018*
	(145.682)	(666.736)	(0.330)	(2.129)	(0.689)	(0.832)	(0.591)
Log of expenditure on agrochemicals	18.022	-6.023	0.150***	-0.090	0.161*	0.261**	0.173**
	(17.485)	(78.167)	(0.045)	(0.293)	(0.087)	(0.110)	(0.073)
Log of expenditure on hired labour	-9.593	84.921	0.134***	0.797***	0.435***	0.494***	0.267***
	(17.533)	(85.512)	(0.040)	(0.232)	(0.085)	(0.108)	(0.076)
No. of crops produced	-70.041	123.637	0.316**	0.618	-0.816***	-0.611*	-0.243
	(63.486)	(314.167)	(0.139)	(0.934)	(0.295)	(0.358)	(0.250)
Log of total value of hh assets	48.702*	99.905	0.231***	-1.155**	0.593***	0.903***	0.449***
	(25.184)	(156.677)	(0.065)	(0.520)	(0.146)	(0.171)	(0.123)
Log of agric land endowment	101.060	353.015	-0.107	1.689*	0.305	-0.082	0.008
	(94.454)	(348.603)	(0.141)	(0.968)	(0.314)	(0.400)	(0.322)
Navigable road to community	-525.726**	-2379.545**	1.134***	-1.843	-2.328***	-4.012***	-2.626***
	(211.850)	(1010.495)	(0.394)	(2.573)	(0.903)	(1.076)	(0.727)
Access to public transport	71.347	-537.364	0.503	-1.796	0.420	-0.729	-0.793
	(167.664)	(763.508)	(0.353)	(2.094)	(0.682)	(0.828)	(0.580)
Household in NR	-1384.679***	-8934.145***	-0.222	-1.580	-1.000	-3.248***	-3.905***
	(299.531)	(1366.872)	(0.446)	(3.243)	(1.119)	(1.260)	(0.851)
Household in UER	-1508.381***	-9699.501***	-2.516***	-13.926***	-4.658***	-8.704***	-6.289***
	(291.617)	(1368.606)	(0.438)	(3.124)	(1.027)	(1.219)	(0.859)
Household in UWR	-1195.976***	-6743.545***	-0.509	-9.085**	-4.491***	-8.765***	-6.571***
	(351.877)	(1578.381)	(0.599)	(4.027)	(1.350)	(1.622)	(1.150)
Household in SR	-1608.375***	-9599.709***	-0.083	5.998*	0.693	-1.250	-3.026***
	(300.215)	(1426.832)	(0.515)	(3.455)	(1.306)	(1.430)	(0.930)
Constant	2997.740***	8716.755***	0.653	27.021***	2.970	8.824***	6.810***
	(619.672)	(2784.015)	(1.134)	(8.058)	(2.490)	(3.108)	(2.247)
Observations	858	858	858	858	858	858	858
F-statistic	19.819***	24.862***	42.071***	15.941***	12.742***	20.662***	17.635***
R-squared	0.460	0.487	0.456	0.344	0.244	0.265	0.249
Log likelihood	-7351.987	-8625.532	-2096.865	-3699.741	-2731.302	-2902.431	-2572.806
KP Weakid test	61.033***	61.033***	89.163***	80.468***	89.163***	80.468***	80.468***
C-D Weakid test	54.704***	54.704***	93.874***	93.139***	93.874***	93.139***	93.139***
KP Underid test	91.016***	91.016***	75.161***	63.662***	75.161***	63.662***	63.662***

Hansen J (Overid test)	0.552	3.233*	0.000	0.000	0.000	0.000	0.000

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Standard errors in parentheses; all models estimated using ivreg2; Source: Produced by the author using Primary Data 2022

Table A18 continued

Variable	FIES	HCLCI	HHS	HCLCI	HFIAS	HCLCI
Crop commercialisation	0.027***		0.034***		0.025***	
	(0.006)		(0.005)		(0.006)	
Sex of head	-0.345**	3.657	0.113	3.657	0.005	3.657
	(0.157)	(2.342)	(0.156)	(2.342)	(0.148)	(2.342)
Age of head	-0.002	-0.015	0.003	-0.015	-0.005	-0.015
	(0.004)	(0.066)	(0.004)	(0.066)	(0.004)	(0.066)
Household size	-0.030	0.356	-0.071***	0.356	-0.062***	0.356
	(0.021)	(0.343)	(0.024)	(0.343)	(0.023)	(0.343)
Marital status of head	-0.022	-6.375**	0.053	-6.375**	0.244	-6.375**
	(0.165)	(2.764)	(0.179)	(2.764)	(0.168)	(2.764)
Years of education of head	0.004	0.043	0.000	0.043	0.003	0.043
	(0.008)	(0.134)	(0.009)	(0.134)	(0.008)	(0.134)
Received cash remittance	0.196	-5.197**	0.114	-5.197**	0.219	-5.197**
	(0.149)	(2.570)	(0.172)	(2.570)	(0.160)	(2.570)
No. of days stop work due to health	-0.001	-0.002	0.001	-0.002	-0.002	-0.002
	(0.001)	(0.032)	(0.001)	(0.032)	(0.002)	(0.032)
Ownership of nonfarm enterprise	-0.000	-5.954***	0.234*	-5.954***	-0.235*	-5.954***
	(0.121)	(2.245)	(0.132)	(2.245)	(0.133)	(2.245)
Agric cooperative in community	0.211	4.861	0.383*	4.861	0.125	4.861
	(0.174)	(3.552)	(0.202)	(3.552)	(0.188)	(3.552)
Bank in community	0.374*	7.489**	-0.480**	7.489**	-0.501***	7.489**
	(0.218)	(3.544)	(0.226)	(3.544)	(0.188)	(3.544)
Mobile phone network in community	-0.098	-20.061***	-0.055	-20.061***	0.063	-20.061***
	(0.274)	(4.086)	(0.276)	(4.086)	(0.277)	(4.086)
Agric extension office in community	0.098	9.172***	0.238*	9.172***	0.305**	9.172***
	(0.127)	(2.242)	(0.138)	(2.242)	(0.131)	(2.242)
Irrigated fields in community	0.022	-0.480	0.363***	-0.480	0.160	-0.480
	(0.109)	(1.768)	(0.120)	(1.768)	(0.104)	(1.768)
Perceived rain pattern	-0.085	-2.111	-0.576***	-2.111	0.005	-2.111
	(0.157)	(2.423)	(0.165)	(2.423)	(0.150)	(2.423)
Log of expenditure on agrochemicals	-0.032	0.019	-0.019	0.019	-0.032	0.019
	(0.021)	(0.307)	(0.022)	(0.307)	(0.021)	(0.307)

Log of expenditure on hired labour	0.010	0.139	-0.011	0.139	-0.009	0.139
	(0.019)	(0.325)	(0.020)	(0.325)	(0.020)	(0.325)
No. of crops produced	0.111*	-0.670	0.185***	-0.670	0.169***	-0.670
	(0.059)	(0.986)	(0.064)	(0.986)	(0.063)	(0.986)
Log of total value of hh assets	0.048**	-0.927**	0.005	-0.927**	0.069***	-0.927**
	(0.024)	(0.360)	(0.027)	(0.360)	(0.025)	(0.360)
Log of agric land endowment	0.004	3.043***	-0.012	3.043***	-0.112*	3.043***
	(0.066)	(0.950)	(0.070)	(0.950)	(0.065)	(0.950)
Navigable road to community	0.625***	19.290***	0.537**	19.290***	0.506**	19.290***
	(0.196)	(2.264)	(0.213)	(2.264)	(0.197)	(2.264)
Access to public transport	-0.138	12.202***	-0.106	12.202***	0.054	12.202***
	(0.159)	(2.664)	(0.157)	(2.664)	(0.159)	(2.664)
Household in NR	-0.068	-10.275***	0.215	-10.275***	-0.235	-10.275***
	(0.231)	(3.311)	(0.231)	(3.311)	(0.228)	(3.311)
Household in UER	-0.225	0.807	-0.005	0.807	-0.110	0.807
	(0.220)	(3.789)	(0.221)	(3.789)	(0.234)	(3.789)
Household in UWR	0.089	-20.480***	0.504*	-20.480***	0.411	-20.480***
	(0.289)	(4.200)	(0.295)	(4.200)	(0.291)	(4.200)
Household in SR	-0.074	-14.680***	0.184	-14.680***	-0.348	-14.680***
	(0.265)	(3.901)	(0.269)	(3.901)	(0.265)	(3.901)
Average moi in community		0.931***		0.931***		0.931***
		(0.097)		(0.097)		(0.097)
Constant		15.927*		15.927*		15.927*
		(8.131)		(8.131)		(8.131)
Cut1	0.546		1.201**		1.254**	
	(0.532)		(0.531)		(0.543)	
Cut2	1.750***		1.795***		1.640***	
	(0.524)		(0.520)		(0.537)	
Cut3					1.950***	
					(0.535)	
Corr(e.crop_hci, outcomes)		-0.077		-0.267**		-0.181
		(0.132)		(0.135)		(0.133)
Observations		858		858		858
Wald Chi-square		440.041***		652.206***		454.759***
Log likelihood		-4489.866		-4379.520		-4594.051

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Standard errors in parentheses; all models estimated using ivreg2; Source: Produced by the author using Primary Data 2022

Table A19: Impact of livestock commercialisation on food and nutrition outcomes (Primary data)

Variable	PCFDEXP	FDEXP	HDDS	FCS	Vit. A	Proteins	H. iron
Livestock commercialisation	223.851*	1196.649*	0.582	2.734	0.541	0.943	0.618
	(135.593)	(714.381)	(0.371)	(2.072)	(0.403)	(0.697)	(0.466)
Sex of head	-59.413	-1199.429	-1.351	-5.305	-1.943	-3.760	-1.760
	(510.020)	(2734.790)	(1.274)	(6.369)	(1.383)	(2.314)	(1.542)
Age of head	-16.584	-68.460	-0.042	-0.137	-0.052	-0.071	-0.048
	(12.758)	(67.650)	(0.033)	(0.164)	(0.037)	(0.057)	(0.037)
Household size	-182.843***	11.243	0.080	0.198	0.211	0.073	-0.030
	(65.332)	(345.057)	(0.172)	(0.815)	(0.181)	(0.280)	(0.182)
Marital status of head	-429.550	-543.588	-0.157	1.741	0.080	0.974	0.384
	(590.455)	(3171.499)	(1.478)	(7.864)	(1.660)	(2.777)	(1.811)
Years of education of head	0.624	-25.283	-0.024	0.046	0.031	0.017	0.004
	(26.834)	(143.975)	(0.070)	(0.339)	(0.078)	(0.122)	(0.079)
Received cash remittance	-607.461	-2923.171	-2.056	-7.615	-2.585	-4.131	-2.340
	(622.120)	(3332.312)	(1.721)	(8.939)	(1.808)	(2.911)	(1.920)
No. of days stop work due to health	-6.011	-29.041	-0.014	-0.089	-0.022	-0.042	-0.028
	(9.385)	(49.389)	(0.025)	(0.119)	(0.025)	(0.042)	(0.028)
Ownership of nonfarm enterprise	-567.485	-3364.706	-1.353	-4.602	0.542	-0.572	-0.489
	(502.072)	(2680.230)	(1.407)	(7.112)	(1.582)	(2.415)	(1.601)
Agric cooperative in community	623.371	2874.952	1.865	6.116	-0.243	1.031	1.213
	(479.039)	(2501.741)	(1.301)	(6.452)	(1.440)	(2.240)	(1.404)
Bank in community	-687.497	-2796.371	-4.055	-10.578	-2.028	-2.777	-2.076
	(1190.861)	(6372.303)	(3.053)	(15.547)	(3.195)	(5.446)	(3.568)
Mobile phone network in community	175.720	1612.992	0.423	1.288	1.142	0.960	1.288
	(1027.968)	(5359.298)	(2.527)	(12.073)	(2.490)	(4.394)	(2.961)
Agric extension office in community	15.632	95.322	-0.357	1.056	-1.577	-0.914	0.271
	(420.082)	(2239.067)	(1.104)	(5.361)	(1.144)	(1.824)	(1.189)
Irrigated fields in community	-316.405	-2411.210	-0.632	-5.704	-0.504	-1.443	-1.039
	(424.854)	(2295.407)	(1.156)	(5.975)	(1.233)	(2.052)	(1.375)
Perceived rain pattern	-568.307	-3410.484	-1.814	-6.955	-0.703	-1.154	-0.533
	(604.592)	(3219.898)	(1.653)	(8.418)	(1.884)	(2.843)	(1.885)
Log of expenditure on agrochemicals	-22.294	-211.885	0.076	-0.427	0.031	0.098	0.068
	(56.409)	(293.023)	(0.145)	(0.726)	(0.162)	(0.252)	(0.168)
Log of expenditure on hired labour	-83.231	-306.561	-0.021	0.168	0.347*	0.332	0.142
	(68.368)	(360.023)	(0.180)	(0.925)	(0.194)	(0.306)	(0.205)
No. of crops produced	-16.603	418.218	0.333	0.301	-0.968*	-0.677	-0.302
	(190.252)	(1037.844)	(0.500)	(2.399)	(0.550)	(0.843)	(0.554)
Log of total value of hh assets	207.464	1019.838	0.723*	0.910	1.230***	1.702**	0.959**
	(148.738)	(789.135)	(0.414)	(2.094)	(0.444)	(0.720)	(0.472)

Log of agric land endowment	178.832	735.949	-0.015	1.979	0.605	0.209	0.174
	(178.910)	(930.306)	(0.475)	(2.299)	(0.553)	(0.798)	(0.533)
Navigable road to community	-165.855	-1112.898	1.969	-0.215	-1.883	-3.333	-2.231
	(489.097)	(2632.029)	(1.312)	(6.470)	(1.322)	(2.198)	(1.472)
Access to public transport	-389.250	-2780.396	-0.683	-7.989	-0.621	-2.580	-2.009
	(666.373)	(3485.990)	(1.718)	(8.756)	(1.855)	(3.046)	(2.062)
Household in NR	-609.025	-4395.606	2.841	12.044	1.844	1.333	-1.136
	(1282.438)	(6618.386)	(3.405)	(18.163)	(3.821)	(6.275)	(4.123)
Household in UER	-1832.728***	-11467.794***	-2.835*	-15.126*	-5.159***	-9.058***	-6.618***
	(687.430)	(3522.457)	(1.679)	(8.859)	(1.876)	(3.075)	(2.033)
Household in UWR	-384.389	-3355.759	1.828	-0.065	-1.962	-5.000	-4.296
	(1415.257)	(7376.133)	(3.639)	(18.841)	(3.892)	(6.474)	(4.211)
Household in SR	-688.159	-4961.701	2.897	16.882	3.651	3.304	-0.165
	(1234.362)	(6381.501)	(3.175)	(16.917)	(3.659)	(5.931)	(3.866)
Constant	1701.271	3206.015	-2.698	12.785	-1.447	2.068	2.575
	(2367.604)	(12309.621)	(6.219)	(32.651)	(6.590)	(11.299)	(7.523)
Observations	714	714	714	714	714	714	714
F-statistic	2.280***	2.173***	4.061***	2.179***	4.257***	3.292***	2.876***
Log likelihood	-6835.510	-8025.620	-2586.708	-3718.988	-2655.856	-2968.474	-2664.995
KP Weakid test	11.603***	11.603***	2.720	2.192	2.720	2.192	2.192
C-D Weakid test	11.504***	11.504***	2.772	2.140	2.772	2.140	2.140
KP Underid test	13.284***	13.284***	2.787	2.259	2.787	2.259	2.259
Hansen J (Overid test)	0.029	0.058	0.000	0.000	0.000	0.000	0.000

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Standard errors in parentheses; all models estimated using ivreg2; Source: Produced by the author using Primary Data 2022

Table A19 continued

Variable	FIES	HCLCI	HHS	HCLCI	HFIAS	HCLCI
Livestock commercialisation	0.064***		0.064***		0.061***	
	(0.006)		(0.006)		(0.009)	
Sex of head	-0.152	0.857	-0.034	0.857	-0.039	0.857
	(0.180)	(2.167)	(0.150)	(2.167)	(0.152)	(2.167)
Age of head	-0.005	0.044	-0.003	0.044	-0.006	0.044
	(0.004)	(0.050)	(0.003)	(0.050)	(0.004)	(0.050)
Household size	-0.003	-0.024	-0.014	-0.024	-0.019	-0.024
	(0.019)	(0.265)	(0.022)	(0.265)	(0.023)	(0.265)
Marital status of head	-0.000	-0.712	0.004	-0.712	0.081	-0.712
	(0.175)	(2.489)	(0.171)	(2.489)	(0.177)	(2.489)

Years of education of head	-0.002	0.037	-0.002	0.037	-0.002	0.037
	(0.008)	(0.109)	(0.008)	(0.109)	(0.008)	(0.109)
Received cash remittance	-0.140	2.499	-0.169	2.499	-0.147	2.499
	(0.152)	(2.160)	(0.151)	(2.160)	(0.159)	(2.160)
No. of days stop work due to health	-0.002	0.028	-0.002	0.028	-0.002	0.028
	(0.003)	(0.035)	(0.002)	(0.035)	(0.003)	(0.035)
Ownership of nonfarm enterprise	-0.244*	2.669	-0.149	2.669	-0.299**	2.669
	(0.125)	(1.770)	(0.124)	(1.770)	(0.138)	(1.770)
Agric cooperative in community	0.302	-1.897	0.289	-1.897	0.248	-1.897
	(0.209)	(2.230)	(0.207)	(2.230)	(0.184)	(2.231)
Bank in community	-0.196	5.850	-0.418	5.850	-0.555**	5.850
	(0.288)	(3.634)	(0.263)	(3.634)	(0.251)	(3.634)
Mobile phone network in community	-0.090	-2.772	-0.020	-2.772	0.024	-2.772
	(0.315)	(3.704)	(0.288)	(3.704)	(0.279)	(3.704)
Agric extension office in community	0.028	0.743	0.059	0.743	0.123	0.743
	(0.125)	(1.809)	(0.132)	(1.809)	(0.148)	(1.809)
Irrigated fields in community	-0.151	2.120	-0.066	2.120	-0.089	2.120
	(0.107)	(1.588)	(0.116)	(1.588)	(0.110)	(1.588)
Perceived rain pattern	-0.174	2.451	-0.287*	2.451	-0.125	2.451
	(0.138)	(2.032)	(0.148)	(2.032)	(0.146)	(2.032)
Log of expenditure on agrochemicals	-0.015	0.135	-0.013	0.135	-0.020	0.135
	(0.017)	(0.219)	(0.016)	(0.219)	(0.018)	(0.219)
Log of expenditure on hired labour	-0.019	0.315	-0.023	0.315	-0.024	0.315
	(0.018)	(0.247)	(0.017)	(0.247)	(0.018)	(0.247)
No. of crops produced	0.059	-0.255	0.054	-0.255	0.065	-0.255
	(0.065)	(0.818)	(0.063)	(0.818)	(0.067)	(0.818)
Log of total value of hh assets	0.060**	-0.835**	0.042	-0.835**	0.075***	-0.835**
	(0.027)	(0.423)	(0.030)	(0.423)	(0.028)	(0.423)
Log of agric land endowment	0.040	-0.089	0.051	-0.089	0.020	-0.089
	(0.064)	(0.778)	(0.068)	(0.778)	(0.059)	(0.778)
Navigable road to community	0.310	0.967	0.232	0.967	0.330	0.967
	(0.285)	(1.856)	(0.249)	(1.856)	(0.299)	(1.856)
Access to public transport	-0.136	3.363*	-0.139	3.363*	-0.079	3.363*
	(0.151)	(1.989)	(0.146)	(1.989)	(0.174)	(1.989)
Household in NR	0.257	-6.507**	0.390*	-6.507**	0.182	-6.507**
	(0.263)	(2.802)	(0.211)	(2.802)	(0.310)	(2.802)
Household in UER	-0.088	0.433	-0.005	0.433	-0.098	0.433
	(0.229)	(2.930)	(0.195)	(2.928)	(0.245)	(2.930)
Household in UWR	0.162	-6.355*	0.317	-6.355*	0.320	-6.355*
	(0.344)	(3.586)	(0.284)	(3.585)	(0.294)	(3.586)

Household in SR	0.238	-6.589**	0.326	-6.589**	0.089	-6.589**
	(0.271)	(3.084)	(0.238)	(3.083)	(0.344)	(3.084)
Average moi in community		0.125*		0.125*		0.125*
		(0.074)		(0.074)		(0.074)
Constant		7.911		7.911		7.911
		(7.018)		(7.014)		(7.018)
Cut1	0.458		0.599		0.763*	
	(0.530)		(0.465)		(0.448)	
Cut2	0.855**		0.738*		0.918**	
	(0.426)		(0.432)		(0.425)	
Cut3					1.038**	
					(0.420)	
Corr(e.crop_hci, outcomes)	-0.932***		-0.965***		-0.909***	
	(0.083)		(0.042)		(0.110)	
Observations	714		714		714	
Wald Chi-square	451.226***		428.893***		455.800***	
Log likelihood	-3560.587		-3460.721		-3638.481	

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Standard errors in parentheses; all models estimated using ivreg2; Source: Produced by the author using Primary Data 2022

Table A20: Effect of agricultural commercialisation on household income

Variable	GLSS7	Primary
HCLCI	0.022***	0.015***
	(0.001)	(0.001)
Sex of head	0.198***	0.043
	(0.063)	(0.088)
Age of head	0.003*	0.001
	(0.002)	(0.002)
Household size	0.054***	0.027**
	(0.008)	(0.012)
Locality of household	-0.435***	
	(0.099)	
Marital status of head	0.116*	0.076
	(0.060)	(0.094)
Years of education of head	0.058***	0.012***
	(0.006)	(0.005)
Received cash remittance	0.472***	0.151*
	(0.057)	(0.090)
No. of days stop work due to ill-health	-0.004	-0.001
	(0.009)	(0.001)
Ownership of nonfarm enterprise	0.124*	0.430***
	(0.065)	(0.068)
Agric cooperative in community	0.069	0.231***
	(0.094)	(0.088)
Bank in community	-0.211**	-0.191*
	(0.083)	(0.109)
Mobile phone network in community	-0.149**	-0.267*
	(0.068)	(0.139)
Agric extension office in community	0.208**	0.180***
	(0.092)	(0.069)
Irrigated fields in community	0.219**	0.152**
	(0.093)	(0.063)
Perceived rain pattern in community	0.062	-0.161*
	(0.065)	(0.091)
Log of expenditure on agrochemicals	-0.029**	-0.015
	(0.014)	(0.011)
Log of expenditure on hired labour	0.038***	0.019*
	(0.013)	(0.011)
No. of crops produced	0.057***	0.146***
	(0.019)	(0.034)
Log of total value of household assets	0.089***	0.352***
	(0.009)	(0.014)
Log of agric land endowment	0.078***	0.401***
	(0.025)	(0.034)
Navigable road to community	0.030	0.311***
	(0.093)	(0.077)
Access to public transport	-0.132*	0.164*
	(0.069)	(0.085)
Household in southern Ghana/NR	0.033	-0.198*
	(0.078)	(0.116)
Household in coastal zone/UER	-0.903***	-0.009
	(0.331)	(0.103)
Household in forest zone/UWR	-1.183***	0.165
	(0.326)	(0.146)
Household in savannah zone/SR	-1.263***	0.499***

	(0.335)	(0.140)
Constant	6.784***	4.430***
	(0.346)	(0.246)
Observations	7332	858
F-statistic	73.857***	93.903***
R-square	0.348	0.746

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Standard errors in parentheses; HCLCI is household crop-livestock commercialisation index; Source: Produced by the author using the GLSS7 and Primary Data.

Table A21: Effect of income on food and nutrition security outcomes (GLSS7)

Variable	PCFEXP	PAEFEXP	HDDS	FCS	Vit. A	Proteins	H. iron
Log of household income	164.027***	135.126***	0.211***	0.600***	0.535***	0.463***	0.201***
	(25.225)	(18.815)	(0.021)	(0.042)	(0.059)	(0.037)	(0.020)
Sex of head	475.065***	56.004	-0.232**	-0.518***	-0.997***	-0.359***	-0.052
	(87.747)	(73.441)	(0.108)	(0.193)	(0.236)	(0.134)	(0.061)
Age of head	6.722***	9.321***	0.001	0.004	0.013**	0.001	0.000
	(1.842)	(1.659)	(0.002)	(0.006)	(0.005)	(0.004)	(0.002)
Household size	-277.401***	-221.648***	0.043***	0.117***	0.127***	0.163***	0.041***
	(19.384)	(15.105)	(0.011)	(0.022)	(0.029)	(0.023)	(0.009)
Locality of household	-75.178	-128.109	0.264**	0.660***	-0.599*	0.107	0.092
	(103.047)	(86.092)	(0.108)	(0.241)	(0.324)	(0.221)	(0.102)
Marital status of head	-579.257***	-247.793***	0.285***	0.547***	1.107***	0.688***	0.312***
	(90.925)	(70.335)	(0.105)	(0.209)	(0.249)	(0.140)	(0.060)
Years of education of head	8.926	5.701	-0.009	-0.051***	-0.042**	-0.052***	-0.017***
	(6.999)	(5.850)	(0.006)	(0.015)	(0.019)	(0.013)	(0.005)
Received cash remittance	252.082***	167.126***	0.147**	0.122	0.182	0.430***	0.135**
	(68.459)	(56.324)	(0.071)	(0.172)	(0.213)	(0.134)	(0.059)
No. of days stop work due to health	-8.781	-6.057	0.017	0.013	-0.012	0.028	0.008
	(10.649)	(9.327)	(0.011)	(0.022)	(0.027)	(0.020)	(0.008)
Ownership of nonfarm enterprise	136.159*	127.409**	-0.023	-0.014	-0.078	0.313**	0.056
	(75.368)	(60.571)	(0.068)	(0.170)	(0.212)	(0.151)	(0.065)
Agric cooperative in community	-176.818	-163.680	0.128	0.552*	-0.951**	0.081	0.155
	(179.526)	(149.434)	(0.133)	(0.333)	(0.437)	(0.307)	(0.143)
Bank in community	146.268	92.165	0.430***	1.478***	1.146***	0.758***	0.233**
	(116.234)	(93.431)	(0.137)	(0.261)	(0.338)	(0.238)	(0.101)
Mobile phone network in community	91.385	85.046	-0.232*	-0.798**	-0.512	-0.503	-0.187
	(138.509)	(102.360)	(0.134)	(0.337)	(0.427)	(0.326)	(0.139)
Extension office in community	315.504**	241.192**	0.163	0.343	0.272	-0.315	-0.149
	(154.929)	(119.607)	(0.116)	(0.295)	(0.445)	(0.304)	(0.126)
Irrigated fields in community	39.745	-55.945	0.105	0.992**	0.606	0.187	-0.245*
	(154.873)	(114.855)	(0.152)	(0.423)	(0.377)	(0.262)	(0.136)
Perceived rain pattern	89.621	48.853	0.298***	0.589***	0.702**	0.520**	0.036
	(90.863)	(74.970)	(0.096)	(0.223)	(0.319)	(0.216)	(0.089)
Log of expenditure on agrochemicals	28.114*	16.894	0.034**	0.153***	0.181***	0.084***	0.040***
	(15.276)	(12.890)	(0.015)	(0.031)	(0.047)	(0.028)	(0.014)
Log of expenditure on hired labour	48.418***	39.973***	0.030**	0.057*	0.086**	0.053**	0.016
	(13.152)	(10.599)	(0.014)	(0.034)	(0.039)	(0.027)	(0.012)
No. of crops produced	49.634	20.044	0.103***	0.225***	0.264***	0.312***	0.005
	(38.521)	(27.475)	(0.030)	(0.060)	(0.093)	(0.062)	(0.030)

Log of total value of hh assets	-1.977	1.151	0.044***	0.039	0.138***	0.138***	0.053***
	(12.125)	(9.996)	(0.012)	(0.027)	(0.038)	(0.030)	(0.013)
Log of agric land endowment	137.187***	115.846***	0.031	0.210***	0.205**	0.194**	0.118***
	(41.683)	(34.498)	(0.037)	(0.073)	(0.097)	(0.093)	(0.041)
Navigable road to community	959.763***	499.290***	0.992***	2.220***	1.796***	1.912***	0.559***
	(136.705)	(106.039)	(0.227)	(0.453)	(0.529)	(0.403)	(0.153)
Access to public transport	122.775	-29.166	-0.031	-0.000	0.048	-0.881**	-0.095
	(133.363)	(113.190)	(0.226)	(0.429)	(0.606)	(0.408)	(0.153)
Household in southern Ghana	18.916	35.661	0.173	-0.177	0.980**	-0.624**	-0.088
	(174.873)	(154.801)	(0.105)	(0.295)	(0.469)	(0.305)	(0.113)
Household in coastal zone	-677.158*	-583.547*	0.123	0.831	-0.914	-0.069	-0.165
	(379.650)	(337.759)	(0.469)	(0.736)	(1.301)	(0.688)	(0.363)
Household in forest zone	-443.722	-369.550	0.232	1.346*	0.007	0.295	0.162
	(367.584)	(330.507)	(0.469)	(0.716)	(1.287)	(0.659)	(0.357)
Household in savannah zone	-1083.015***	-913.123**	-0.262	-0.097	-1.687	-0.913	-0.486
	(397.016)	(354.807)	(0.483)	(0.789)	(1.361)	(0.716)	(0.371)
Constant	1328.655***	1481.737***	2.815***	1.209	0.148	-1.335*	-0.288
	(458.793)	(395.509)	(0.523)	(0.872)	(1.433)	(0.802)	(0.412)
Observations	7332	7332	7332	7332	7332	7332	7332
F-statistic	34.791***	26.924***	34.634***	47.267***	23.098***	25.875***	18.725***
R-square	0.357	0.306	0.237	0.319	0.226	0.236	0.184

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Standard errors in parentheses; All models estimated using OLS; Source: Produced by the author using the GLSS7 Data.

Table A21 continued

Variable	Stunting	Wasting	Underweight	FIES
Log of household income	-0.039*	-0.063***	-0.002	0.069***
	(0.020)	(0.022)	(0.022)	(0.017)
Sex of head	-0.098	-0.046	0.089	0.105
	(0.111)	(0.128)	(0.126)	(0.067)
Age of head	0.001	0.005**	-0.001	0.004***
	(0.002)	(0.003)	(0.003)	(0.001)
Household size	0.026**	-0.016	0.007	-0.045***
	(0.010)	(0.012)	(0.011)	(0.008)
Locality of household	-0.376***	-0.443***	-0.546***	-0.098
	(0.096)	(0.109)	(0.105)	(0.096)
Marital status of head	0.060	-0.011	-0.219	0.144***
	(0.126)	(0.143)	(0.140)	(0.050)
Years of education of head	0.000	0.012	-0.002	0.034***
	(0.007)	(0.008)	(0.008)	(0.005)

Received cash remittance	-0.132**	0.058	-0.093	0.112**
	(0.063)	(0.072)	(0.070)	(0.045)
No. of days stop work due to health	0.021	-0.016	0.010	-0.022***
	(0.013)	(0.016)	(0.015)	(0.007)
Ownership of nonfarm enterprise	0.064	0.132	0.161*	0.256***
	(0.078)	(0.089)	(0.086)	(0.056)
Agric cooperative in community	-0.073	-0.259	-0.108	-0.165
	(0.121)	(0.160)	(0.141)	(0.131)
Bank in community	-0.616***	-0.582***	-0.492***	0.059
	(0.119)	(0.154)	(0.138)	(0.078)
Mobile phone network in community	-0.510***	-0.551***	-0.618***	-0.155*
	(0.066)	(0.076)	(0.072)	(0.088)
Extension office in community	-0.071	-0.109	-0.076	0.159
	(0.106)	(0.135)	(0.124)	(0.110)
Irrigated fields in community	-0.210*	0.022	-0.131	0.205*
	(0.108)	(0.118)	(0.118)	(0.109)
Perceived rain pattern	0.139**	0.003	0.080	0.050
	(0.058)	(0.066)	(0.064)	(0.073)
Log of expenditure on agrochemicals	-0.028**	-0.016	-0.040***	-0.006
	(0.013)	(0.015)	(0.014)	(0.010)
Log of expenditure on hired labour	-0.018	0.001	-0.001	0.031***
	(0.012)	(0.014)	(0.014)	(0.009)
No. of crops produced	-0.035*	-0.025	-0.022	-0.019
	(0.019)	(0.023)	(0.021)	(0.022)
Log of total value of hh assets	-0.012	0.013	-0.005	0.041***
	(0.010)	(0.012)	(0.011)	(0.010)
Log of agric land endowment	-0.008	-0.132***	-0.069**	-0.003
	(0.030)	(0.036)	(0.034)	(0.026)
Navigable road to community	-1.102***	-1.549***	-1.440***	0.079
	(0.081)	(0.087)	(0.084)	(0.114)
Access to public transport	-0.384***	-0.307***	-0.343***	0.182**
	(0.075)	(0.088)	(0.085)	(0.092)
Household in southern Ghana	0.217*	0.078	0.158	-0.001
	(0.113)	(0.134)	(0.126)	(0.138)
Household in coastal zone	0.328	0.124	0.116	0.150
	(0.672)	(0.793)	(0.716)	(0.301)
Household in forest zone	0.075	-0.246	0.032	0.377
	(0.669)	(0.790)	(0.711)	(0.290)
Household in savannah zone	0.330	0.061	0.236	-0.028
	(0.677)	(0.799)	(0.721)	(0.319)

Constant	1.398**	1.776**	1.584**	
	(0.704)	(0.827)	(0.750)	
Cut1				0.636*
				(0.344)
Cut2				1.417***
				(0.348)
Observations	2864	2864	2864	7332
LR chi-square	1286.668***	1649.639***	1578.401***	10.820***
Pseudo R2	0.331	0.462	0.434	
Log likelihood	-1299.022	-961.002	-1029.823	

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Standard errors in parentheses; Stunting, Wasting and Underweight estimated using probitl whiles FIES is estimated using ordered probit; Source: Produced by the author using the GLSS7 Data.

Table A22: Effect of income on food and nutrition security outcomes (Primary data)

Variable	PCFDEXP	FDEXP	HDDS	FCS	Vit. A	Proteins	H. iron
Log of household income	421.257***	2063.125***	0.532***	7.469***	0.747***	1.349***	0.969***
	(62.213)	(275.992)	(0.125)	(0.864)	(0.274)	(0.326)	(0.225)
Sex of head	62.359	-664.774	-0.824**	-3.734	-1.494**	-3.291***	-1.582***
	(166.884)	(740.338)	(0.336)	(2.318)	(0.734)	(0.874)	(0.602)
Age of head	-8.809**	-19.134	-0.023***	-0.042	-0.034*	-0.033	-0.027*
	(4.079)	(18.097)	(0.008)	(0.057)	(0.018)	(0.021)	(0.015)
Household size	-229.457***	-109.404	0.055	0.129	0.221**	-0.006	-0.100
	(22.310)	(98.972)	(0.045)	(0.310)	(0.098)	(0.117)	(0.081)
Marital status of head	-566.788***	-617.922	-0.209	0.064	-0.103	0.601	0.273
	(178.902)	(793.650)	(0.360)	(2.485)	(0.787)	(0.937)	(0.646)
Years of education of head	8.320	14.728	0.002	0.071	0.056	0.079*	0.052*
	(8.747)	(38.803)	(0.018)	(0.121)	(0.038)	(0.046)	(0.032)
Received cash remittance	-76.333	-142.625	-0.524	-1.176	-0.500	-1.320	-0.452
	(171.036)	(758.753)	(0.345)	(2.376)	(0.752)	(0.895)	(0.617)
No. of days stop work due to health	-0.129	2.093	0.002	-0.011	-0.010	-0.018**	-0.011*
	(1.667)	(7.394)	(0.003)	(0.023)	(0.007)	(0.009)	(0.006)
Ownership of nonfarm enterprise	-214.546	-1109.187*	0.107	0.084	1.966***	1.530**	0.854*
	(131.712)	(584.306)	(0.265)	(1.829)	(0.579)	(0.690)	(0.475)
Agric cooperative in community	109.738	969.489	1.028***	0.482	0.115	0.536	0.737
	(167.227)	(741.856)	(0.337)	(2.323)	(0.735)	(0.875)	(0.603)
Bank in community	910.253***	3936.789***	-0.398	0.979	1.104	2.281**	1.266*
	(201.665)	(894.631)	(0.406)	(2.801)	(0.887)	(1.056)	(0.728)
Mobile phone network in community	-530.905**	-1258.028	-0.729	-1.946	-0.612	-2.129	-0.666

	(261.641)	(1160.701)	(0.527)	(3.634)	(1.151)	(1.370)	(0.944)
Agric extension office in community	125.364	487.207	-0.204	1.861	-1.252**	-0.609	0.326
	(130.370)	(578.353)	(0.263)	(1.811)	(0.573)	(0.683)	(0.470)
Irrigated fields in community	53.323	-263.749	0.193	0.134	0.082	-0.074	-0.192
	(119.272)	(529.117)	(0.240)	(1.657)	(0.525)	(0.624)	(0.430)
Perceived rain pattern	107.346	-142.565	0.012	0.782	0.629	1.163	1.151*
	(174.199)	(772.788)	(0.351)	(2.420)	(0.766)	(0.912)	(0.629)
Log of expenditure on agrochemicals	19.129	5.895	0.148***	-0.014	0.162*	0.265**	0.177**
	(21.859)	(96.969)	(0.044)	(0.304)	(0.096)	(0.114)	(0.079)
Log of expenditure on hired labour	-21.619	34.076	0.113***	0.622**	0.410***	0.452***	0.238***
	(20.272)	(89.930)	(0.041)	(0.282)	(0.089)	(0.106)	(0.073)
No. of crops produced	-119.121*	-68.918	0.249*	-0.566	-0.918***	-0.801**	-0.382
	(66.255)	(293.923)	(0.133)	(0.920)	(0.291)	(0.347)	(0.239)
Log of total value of hh assets	-120.641***	-774.570***	-0.007	-3.873***	0.280*	0.353**	0.059
	(33.532)	(148.755)	(0.068)	(0.466)	(0.147)	(0.176)	(0.121)
Log of agric land endowment	75.208	289.972	0.009	-0.191	0.348	-0.088	-0.031
	(69.137)	(306.710)	(0.139)	(0.960)	(0.304)	(0.362)	(0.249)
Navigable road to community	19.052	-39.765	2.478***	1.053	-0.990	-1.969***	-1.317**
	(142.844)	(633.691)	(0.288)	(1.984)	(0.628)	(0.748)	(0.515)
Access to public transport	303.221*	681.402	1.071***	-0.893	0.975	0.108	-0.262
	(159.917)	(709.430)	(0.322)	(2.221)	(0.703)	(0.837)	(0.577)
Household in NR	-1895.976***	-11388.328***	-1.357***	-4.215	-2.138**	-4.990***	-5.024***
	(218.791)	(970.608)	(0.441)	(3.039)	(0.962)	(1.145)	(0.790)
Household in UER	-2163.130***	-12994.839***	-3.903***	-18.201***	-6.085***	-10.923***	-7.732***
	(188.085)	(834.387)	(0.379)	(2.612)	(0.827)	(0.985)	(0.679)
Household in UWR	-2036.944***	-10976.479***	-2.280***	-15.724***	-6.351***	-11.698***	-8.497***
	(270.440)	(1199.732)	(0.545)	(3.756)	(1.189)	(1.416)	(0.976)
Household in SR	-2258.372***	-12886.617***	-1.325**	-0.429	-0.673	-3.458**	-4.503***
	(261.869)	(1161.712)	(0.528)	(3.637)	(1.152)	(1.371)	(0.945)
Constant	2721.430***	7738.249***	1.846*	4.505	3.300	8.496***	6.185***
	(548.118)	(2431.578)	(1.104)	(7.613)	(2.411)	(2.870)	(1.978)
Observations	858	858	858	858	858	858	858
F-statistic	22.982***	25.262***	32.391***	15.167***	10.708***	14.150***	12.121***
R-square	0.418	0.441	0.503	0.322	0.251	0.307	0.275

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Standard errors in parentheses; All models estimated using OLS; Source: Produced by the author using Primary Data 2022.

Table A22 continued

Variable	FIES	HHS	HFIAS
Log of household income	0.307***	0.239***	0.290***
	(0.059)	(0.063)	(0.059)
Sex of head	-0.280*	0.156	0.034
	(0.155)	(0.167)	(0.158)
Age of head	-0.003	0.001	-0.006
	(0.004)	(0.004)	(0.004)
Household size	-0.022	-0.052**	-0.058***
	(0.021)	(0.022)	(0.021)
Marital status of head	-0.136	-0.111	0.100
	(0.166)	(0.182)	(0.171)
Years of education of head	0.003	0.001	0.002
	(0.008)	(0.009)	(0.008)
Received cash remittance	0.054	-0.012	0.097
	(0.154)	(0.170)	(0.164)
No. of days stop work due to health	-0.000	0.001	-0.001
	(0.002)	(0.001)	(0.002)
Ownership of nonfarm enterprise	-0.309***	-0.130	-0.516***
	(0.118)	(0.131)	(0.123)
Agric cooperative in community	0.428***	0.715***	0.339**
	(0.147)	(0.165)	(0.153)
Bank in community	0.450**	-0.213	-0.341*
	(0.195)	(0.211)	(0.194)
Mobile phone network in community	-0.498**	-0.675**	-0.341
	(0.242)	(0.269)	(0.256)
Agric extension office in community	0.178	0.386***	0.391***
	(0.114)	(0.124)	(0.117)
Irrigated fields in community	-0.044	0.237*	0.079
	(0.108)	(0.122)	(0.113)
Perceived rain pattern	-0.052	-0.482***	0.019
	(0.158)	(0.178)	(0.159)
Log of expenditure on agrochemicals	-0.029	-0.020	-0.028
	(0.020)	(0.022)	(0.021)
Log of expenditure on hired labour	-0.000	-0.020	-0.019
	(0.019)	(0.020)	(0.019)
No. of crops produced	0.062	0.147**	0.130**
	(0.060)	(0.066)	(0.063)
Log of total value of hh assets	-0.077**	-0.105***	-0.038
	(0.031)	(0.034)	(0.029)

Log of agric land endowment	0.009	0.071	-0.102
	(0.064)	(0.068)	(0.065)
Navigable road to community	1.018***	1.170***	0.949***
	(0.130)	(0.141)	(0.132)
Access to public transport	0.047	0.174	0.210
	(0.144)	(0.155)	(0.149)
Household in NR	-0.414**	-0.370*	-0.571***
	(0.195)	(0.219)	(0.202)
Household in UER	-0.679***	-0.684***	-0.590***
	(0.167)	(0.179)	(0.173)
Household in UWR	-0.537**	-0.409	-0.206
	(0.247)	(0.279)	(0.256)
Household in SR	-0.527**	-0.434*	-0.788***
	(0.236)	(0.259)	(0.247)
Cut1	0.768	0.535	1.429***
	(0.513)	(0.551)	(0.537)
Cut2	1.846***	1.074*	1.794***
	(0.515)	(0.551)	(0.538)
Cut3			2.092***
			(0.538)
Observations	858	858	858
LR chi-square	399.042***	437.818***	384.429***
Pseudo R2	0.212	0.259	0.191
Log likelihood	-741.273	-627.170	-814.371

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Standard errors in parentheses; All models estimated using OLS; Source: Produced by the author using Primary Data 2022.

Table A23: Impact of agricultural commercialisation on own and purchased food and nutrition security outcomes (GLSS7)

Variable	HDDS_own	HDDS_pur	FCS_own	FCS_pur	Vit. A_own	Vit. A_pur
HCLCI	-0.002	0.013***	-0.003	0.144***	0.001	0.047***
	(0.002)	(0.003)	(0.005)	(0.007)	(0.008)	(0.009)
Sex of head	0.128**	-0.751***	0.473***	-1.091***	0.005	-1.547***
	(0.062)	(0.075)	(0.119)	(0.167)	(0.189)	(0.222)
Age of head	0.003**	-0.006***	0.001	0.001	-0.004	0.015***
	(0.001)	(0.002)	(0.003)	(0.004)	(0.004)	(0.005)
Household size	0.073***	0.130***	0.181***	0.185***	0.100***	0.245***
	(0.008)	(0.009)	(0.019)	(0.020)	(0.025)	(0.027)
Locality of household	0.872***	-1.159***	1.633***	-2.101***	1.133***	-3.259***

	(0.062)	(0.074)	(0.126)	(0.166)	(0.175)	(0.238)
Marital status of head	0.161***	0.667***	0.156	1.028***	0.080	1.895***
	(0.060)	(0.076)	(0.119)	(0.162)	(0.182)	(0.211)
Years of education of head	-0.035***	0.041***	-0.078***	0.057***	-0.051***	0.070***
	(0.005)	(0.006)	(0.010)	(0.013)	(0.016)	(0.018)
Received cash remittance	0.074	0.637***	0.058	1.001***	0.033	0.518***
	(0.049)	(0.054)	(0.102)	(0.126)	(0.155)	(0.167)
No. of days stop work due to health	0.013	0.026**	0.021	0.017	-0.016	-0.011
	(0.009)	(0.011)	(0.018)	(0.023)	(0.027)	(0.031)
Ownership of nonfarm enterprise	-0.162***	0.446***	-0.318***	0.647***	-0.671***	0.881***
	(0.060)	(0.068)	(0.119)	(0.156)	(0.185)	(0.208)
Agric cooperative in community	-0.066	0.013	0.945***	-0.352	-0.845***	-0.909***
	(0.087)	(0.096)	(0.184)	(0.255)	(0.253)	(0.341)
Bank in community	-0.134	-0.337***	0.175	-0.239	-0.884***	0.860**
	(0.098)	(0.109)	(0.195)	(0.286)	(0.305)	(0.384)
Mobile phone network in community	-0.522***	0.473***	-1.272***	0.248*	-1.326***	0.726***
	(0.057)	(0.061)	(0.130)	(0.146)	(0.195)	(0.186)
Extension office in community	-0.392***	-0.009	-0.739***	-0.057	-0.201	0.904***
	(0.075)	(0.082)	(0.161)	(0.218)	(0.236)	(0.307)
Irrigated fields in community	-0.307***	-0.141*	0.721***	0.033	-0.459**	0.679**
	(0.072)	(0.085)	(0.174)	(0.197)	(0.212)	(0.269)
Perceived rain pattern	0.077*	0.256***	0.202**	0.591***	0.147	0.490***
	(0.043)	(0.049)	(0.091)	(0.111)	(0.136)	(0.147)
Log of expenditure on agrochemicals	0.125***	-0.052***	0.217***	0.003	0.293***	-0.057*
	(0.009)	(0.011)	(0.019)	(0.024)	(0.034)	(0.032)
Log of expenditure on hired labour	0.021**	0.078***	0.032	0.106***	0.098***	0.177***
	(0.010)	(0.011)	(0.020)	(0.025)	(0.034)	(0.033)
No. of crops produced	0.284***	-0.028*	0.461***	-0.102***	0.527***	-0.007
	(0.016)	(0.016)	(0.033)	(0.039)	(0.052)	(0.049)
Log of total value of hh assets	0.076***	0.094***	0.174***	0.162***	0.184***	0.128***
	(0.008)	(0.009)	(0.019)	(0.020)	(0.028)	(0.028)
Log of agric land endowment	0.206***	-0.036	0.554***	-0.108*	0.694***	-0.496***
	(0.023)	(0.028)	(0.054)	(0.062)	(0.079)	(0.077)
Navigable road to community	0.827***	-0.123	1.665***	-0.862***	2.004***	-0.903***
	(0.079)	(0.090)	(0.166)	(0.198)	(0.254)	(0.247)
Access to public transport	-0.152**	-0.160**	-0.508***	-0.230	-0.754***	0.980***
	(0.068)	(0.075)	(0.142)	(0.171)	(0.226)	(0.210)
Household in southern Ghana	0.202**	0.478***	0.052	0.478**	1.945***	1.329***
	(0.084)	(0.090)	(0.175)	(0.217)	(0.261)	(0.308)
Household in coastal zone	0.549*	-0.119	0.903*	-0.182	-1.062	-2.792*

	(0.309)	(0.337)	(0.516)	(0.818)	(0.938)	(1.523)
Household in forest zone	1.384***	-0.967***	2.558***	-1.197	1.782*	-3.881**
	(0.307)	(0.334)	(0.513)	(0.809)	(0.935)	(1.510)
Household in savannah zone	0.873***	-1.399***	1.912***	-2.190***	0.745	-4.463***
	(0.318)	(0.345)	(0.542)	(0.833)	(0.966)	(1.538)
Constant	-0.072	8.165***	-0.528	11.006***	-1.048	10.328***
	(0.330)	(0.365)	(0.579)	(0.863)	(1.006)	(1.570)
Observations	7332	7332	7332	7332	7332	7332
F-statistic	123.761***	124.940***	98.771***	147.625***	46.340***	64.352***
R-squared	0.303	0.283	0.287	0.480	0.161	0.259
KP Weakid test	1805.243***	1805.243***	1805.243***	1805.243***	911.934***	911.934***
C-D Weakid test	2121.263***	2121.263***	2121.263***	2121.263***	1072.205***	1072.205***
KP Underid test	1059.256***	1059.256***	1059.256***	1059.256***	1075.360***	1075.360***
Hansen J (Overid test)	0.000	0.000	0.000	0.000	55.823***	65.173***

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; Standard errors in parentheses; HCLCI is the household crop-livestock commercialisation index; _own means from own produced food; _pur means from purchased food; HDDS, FCS, Vit. A, Protein, H. iron are estimated using ivreg2; 0.000 Hansen J for HDDS, FCS and Vit. A implies no Hansen test since only one instrument is used in the estimation (see Table 4.6); Source: Produced by the author using the GLSS7 Data.

Table A23 continued

Variable	Protein_own	Protein_pur	H. iron_own	H. iron_pur
HCLCI	-0.045	0.051***	-0.071	0.009***
	(0.089)	(0.005)	(0.132)	(0.002)
Sex of head	0.395***	-0.851***	0.499***	-0.290***
	(0.136)	(0.142)	(0.055)	(0.046)
Age of head	-0.003	-0.004	-0.002	-0.002**
	(0.004)	(0.003)	(0.002)	(0.001)
Household size	0.191***	0.154***	0.072***	0.042***
	(0.026)	(0.018)	(0.011)	(0.006)
Locality of household	1.283***	-1.372***	0.441***	-0.484***
	(0.131)	(0.152)	(0.058)	(0.053)
Marital status of head	0.062	1.046***	0.043	0.326***
	(0.144)	(0.129)	(0.058)	(0.044)
Years of education of head	-0.086***	0.055***	-0.038***	0.025***
	(0.012)	(0.011)	(0.006)	(0.004)
Received cash remittance	0.134	1.009***	0.153***	0.242***
	(0.127)	(0.110)	(0.056)	(0.037)
No. of days stop work due to health	0.039*	0.019	0.023**	0.001
	(0.023)	(0.021)	(0.010)	(0.007)
Ownership of nonfarm enterprise	-0.197	0.681***	-0.114*	0.284***

	(0.149)	(0.143)	(0.063)	(0.051)
Agric cooperative in community	0.032	0.262	0.052	0.071
	(0.223)	(0.229)	(0.094)	(0.071)
Bank in community	0.287	0.461*	0.058	-0.253***
	(0.236)	(0.257)	(0.096)	(0.075)
Mobile phone network in community	-1.579***	0.536***	-0.532***	0.023
	(0.178)	(0.119)	(0.078)	(0.040)
Extension office in community	-0.613***	-0.235	-0.064	-0.044
	(0.190)	(0.202)	(0.081)	(0.059)
Irrigated fields in community	-0.350**	0.077	-0.069	-0.221***
	(0.174)	(0.174)	(0.078)	(0.055)
Perceived rain pattern	0.264**	0.567***	0.041	0.052
	(0.112)	(0.092)	(0.048)	(0.032)
Log of expenditure on agrochemicals	0.127***	-0.011	0.073***	-0.014**
	(0.021)	(0.020)	(0.010)	(0.007)
Log of expenditure on hired labour	0.008	0.161***	0.005	0.044***
	(0.025)	(0.022)	(0.011)	(0.007)
No. of crops produced	0.712***	-0.078**	-0.031*	-0.011
	(0.044)	(0.031)	(0.018)	(0.011)
Log of total value of hh assets	0.173***	0.153***	0.085***	0.044***
	(0.024)	(0.019)	(0.010)	(0.006)
Log of agric land endowment	0.763***	-0.098*	0.231***	0.067***
	(0.074)	(0.052)	(0.031)	(0.019)
Navigable road to community	1.991***	0.048	0.797***	0.004
	(0.223)	(0.154)	(0.102)	(0.053)
Access to public transport	-0.441**	-0.579***	-0.150*	-0.063
	(0.194)	(0.132)	(0.084)	(0.050)
Household in southern Ghana	-0.697***	-0.107	0.205**	0.043
	(0.193)	(0.222)	(0.089)	(0.063)
Household in coastal zone	-0.743	-0.084	-0.371	-0.312
	(0.677)	(0.822)	(0.375)	(0.240)
Household in forest zone	0.129	-0.409	0.222	-0.333
	(0.676)	(0.812)	(0.374)	(0.235)
Household in savannah zone	0.180	-2.355***	0.015	-0.986***
	(0.700)	(0.831)	(0.383)	(0.243)
Constant	-0.086	4.288***	-0.341	2.577***
	(0.743)	(0.846)	(0.393)	(0.254)
Observations	7332	7332	7332	7332
F-statistic	77.920***	78.392***	31.529***	67.431***
R-squared	0.267	0.326	0.126	0.186

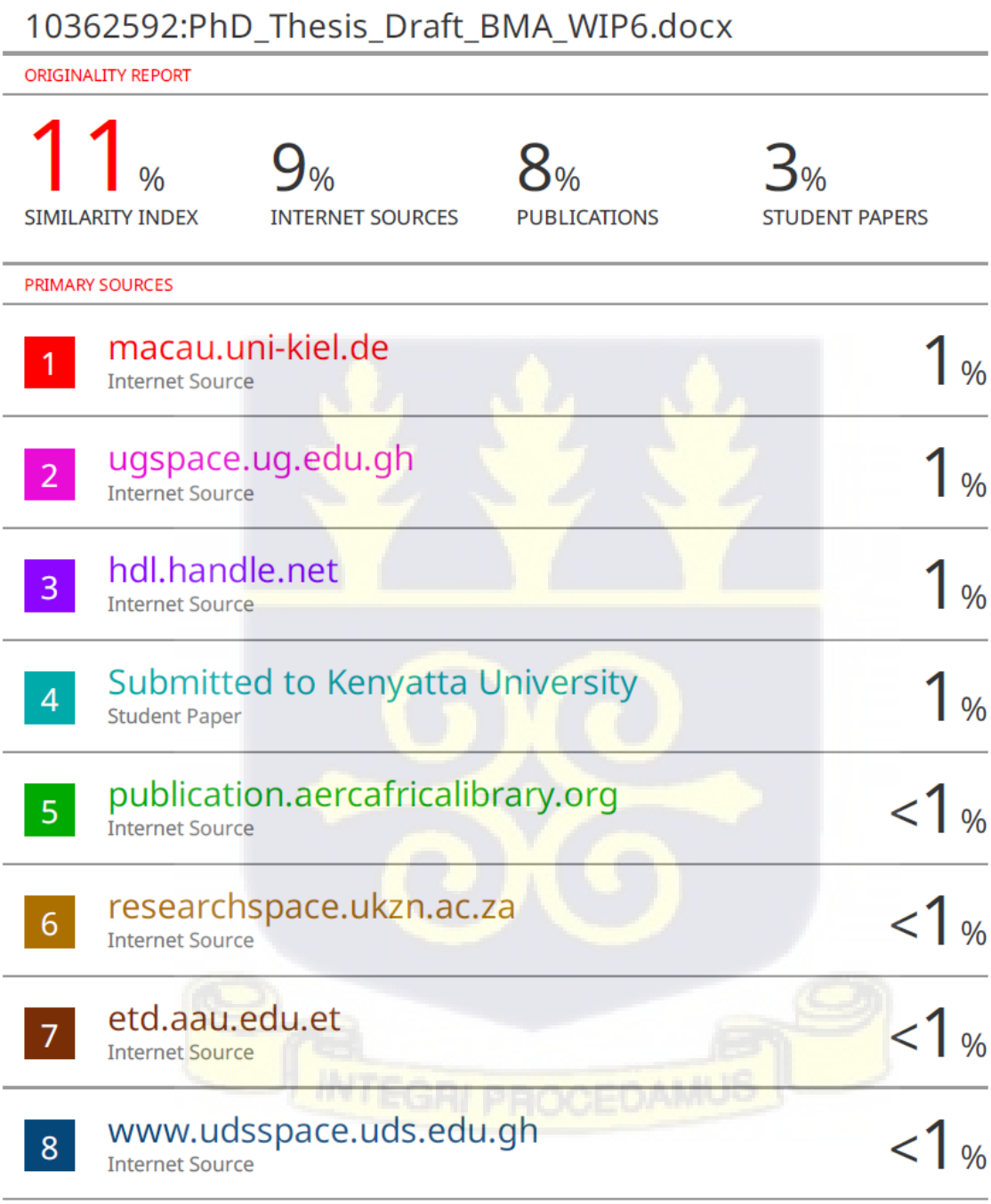
KP Weakid test	911.934***	911.934***	911.934***	911.934***
C-D Weakid test	1072.205***	1072.205***	1072.205***	1072.205***
KP Underid test	1075.360***	1075.360***	1075.360***	1075.360***
Hansen J (Overid test)	105.776***	56.696***	31.100***	4.059**

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$; Standard errors in parentheses; HCLCI is the household crop-livestock commercialisation index; _own means from own produced food; _pur means from purchased food; HDDS, FCS, Vit. A, Protein, H. iron are estimated using ivreg2; Stunting, Wasting and Underweight are estimated using ivprobit; FIES is estimated using eoprobit; Source: Produced by the author using the GLSS7 Data.

Appendix 3: Plagiarism report from TURNITIN

THESIS TITLE: FARM HOUSEHOLDS' AGRICULTURAL COMMERCIALISATION AND FOOD AND NUTRITION SECURITY IN GHANA

STUDENT'S NAME AND ID: BENJAMIN MUSAH ABU (10362592)



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