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Regular Article

Revisiting the effect of agricultural commercialization on food and nutrition security: Does an extended metric provide new insights?

Benjamin Musah Abu [a,b,*], Daniel Bruce Sarpong [a], Yaw Bonsu Osei-Asare [a], Charles Yaw Okyere [a], Taeyoon Kim [c]

[a] Department of Agricultural Economics and Agribusiness, College of Basic and Applied Sciences, University of Ghana, Ghana
[b] Department of Agricultural and Food Economics, Faculty of Agriculture, Food and Consumer Sciences, University for Development Studies, Ghana
[c] Institute of Green Bio Science and Technology, Graduate School of International Agricultural Technology, Seoul National University, South Korea

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ABSTRACT

This study contributes to the agricultural commercialization and food and nutrition security literature by using an extended metric of commercialization that encapsulates crop and livestock dimensions of farm households' market engagements to assess its effects on food and nutrition security outcomes, under the hypothesis that it better reflects the impact of commercialization than the conventional crop commercialization metric. Instrumental variable econometric approaches are applied to nationally representative data from Ghana to assess the effects. The analysis shows that the extended metric of commercialization has significant positive effects on food consumption expenditures, household dietary diversity, consumption of vitamin A-rich, protein-rich, and hem iron-rich foods, and food insecurity experience scale, and significant negative effects on child anthropometric measures of wasting and underweight. This shows that the extended metric improves food and nutrition security. A comparative analysis reveals that the effects of the extended metric are larger than those of the crop metric, demonstrating that the contribution of the livestock subsector accounts for the larger impact of the extended metric. It is further revealed that increase in income from sales is a key transmission channel through which commercialization boosts food and nutrition security. These findings imply that the livestock subsector requires balanced policy attention and interventions as provided for the crop subsector to support the transition to commercial agriculture. It is also imperative to develop and promote well-functioning food systems through enhanced institutional collaboration.

1. Introduction

The benefits of agricultural commercialization to farm households in developing economies are well documented in the literature. For example, agricultural commercialization at the household level boosts farmers' incomes (Barrett et al., 2017; Haji, 2022; Kilimani et al., 2022; Ogutu et al., 2020) and increases productivity (Barrett, 2008; Barrett et al., 2017), especially through investments in purchasing improved inputs. On a larger scale, agricultural commercialization can engender overall rural development through stimulating economic growth (Carletto et al., 2017; Ogutu et al., 2020; von Braun, 1995). While pioneering studies (e.g., Bellemare & Barrett, 2006; Goetz, 1992; Key et al., 2000) focused on understanding the determinants of commercialization, recent studies (e.g., Cazzuffi et al., 2020; Muriithi & Matz, 2015; Ogutu & Qaim, 2019) have provided empirical evidence of the effects of agricultural commercialization on welfare measures, such as income, asset ownership, and poverty. These studies expand our understanding of commercialization in delivering policy-relevant outcomes.

One expanding area of policy-relevant effect of commercialization is food and nutrition security. This nexus has gained wide currency because the challenge of food and nutrition security in developing economies, and indeed globally, has become a key development issue. Although this link was investigated much earlier (e.g., Gross & Underwood, 1971; Hernandez et al., 1974; von Braun & Kennedy, 1994; von Braun, 1995; Dewey, 1981; Fleuret & Fleuret, 1983), in recent times, there has been a tremendous revival (e.g., Abdul Mumin & Abdulai,

* Corresponding author. Department of Agricultural and Food Economics, Faculty of Agriculture, Food and Consumer Sciences, University for Development Studies, P. O. Box TL 1882, Tamale, Ghana.

E-mail addresses: abmusah@uds.edu.gh (B.M. Abu), dbsarpong@ug.edu.gh (D.B. Sarpong), yosei-asare@ug.edu.gh (Y.B. Osei-Asare), cyokyere@ug.edu.gh (C.Y. Okyere), taeyoonkim@snu.ac.kr (T. Kim).

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2022; Bolarinwa et al., 2021; Carletto et al., 2017; Chegere & Kauky, 2022; Gosa et al., 2024; Haji, 2022; Kilimani et al., 2022; Linderhof et al., 2019; Mutea et al., 2025; Nthabeleng et al., 2024; Ogutu et al., 2020; Zheng & Ma, 2023). On a study-by-study basis, the direction of the effect is mixed because studies tend to use different food and nutrition outcomes, making it difficult to sweepingly indicate the direction of the effect. Another key reason for the mixed results could be attributed to context-specific factors. However, examining the balance of evidence shows that commercialization improves food and nutrition security overall.

Despite these notable contributions, one lingering challenge is the measurement of agricultural commercialization. The literature has adopted the Household Crop Commercialization Index (HCCI) proposed by Strasberg et al. (1999) and Govereh et al. (1999). This index is defined as the value of the proportion of total crop output sold relative to the value of total crop output produced, and is expressed mathematically as follows:

$$\boldsymbol{HCCI_i} = \left[\frac{\textit{Gross value of crop sale}_{hhi,year\ j}}{\textit{Gross value of all crop production}_{hhi,year\ j}}\right]*100 \tag{1}$$

However, the HCCI is fraught with several weaknesses, one of which is ignoring the livestock subsector of farm households (Gebreselassie & Sharp, 2007; Jaleta et al., 2009). Meanwhile, livestock production is an integral part of agriculture. For example, it supplements farm incomes during lean seasons and seasons in which crops fail due to climatic shocks. Furthermore, ignoring livestock commercialization not only implicitly assumes that it is not important – a situation that leaves a theoretical vacuum – but also that it is not a reality. Therefore, assessing the food and nutrition security effects of commercialization using the HCCI will not tell the full story, which in econometric terms is described as yielding a biased effect.

This study estimates the effect of an extended metric of commercialization that encapsulates crop and livestock dimensions of farm households' market engagements on their food and nutrition security outcomes. This extended metric provides a departure from previous studies by introducing a more realistic measure of commercialization developed by Abu et al. (2024), named Household Crop-Livestock Commercialization Index (HCLCI), which is defined mathematically as:

$$\boldsymbol{HCLCI_i} = \left[\frac{\sum_{k=1}^{K}\overline{\boldsymbol{P}}_k\boldsymbol{S}_{ik} + \sum_{l=1}^{L}\overline{\boldsymbol{A}}_l\boldsymbol{M}_{il}}{\sum_{k=1}^{K}\overline{\boldsymbol{P}}_k\boldsymbol{Q}_{ik} + \sum_{l=1}^{L}\overline{\boldsymbol{A}}_l\boldsymbol{N}_{il}}\right]*100 \tag{2}$$

Where S_{ik} is farm household i's market sales quantity of crops k valued at the community average price $\overline{P}_k$, Q_{ik} is the quantity of all crops K produced also evaluated as the average community-level price $\overline{P}_k$. M_{il} is the total number of livestock sold at the average sale price $\overline{A}_l$, N_{il} is the total number of livestock owned and L is a vector of all livestock. The measures, $\frac{\sum_{k=1}^{K}\overline{P}_k S_{ik}}{\sum_{k=1}^{K}\overline{P}_k Q_{ik}}$ and $\frac{\sum_{l=1}^{L}\overline{A}_l M_{il}}{\sum_{l=1}^{L}\overline{A}_l N_{il}}$ respectively define the HCCI and the Household Livestock Commercialization Index (HLCI).

Thus, this study contributes by applying this extended metric to assess its effect on food and nutrition security outcomes, under the hypothesis that it better reflects the effect of commercialization than the conventional crop commercialization metric. The motivation stems from the fact that a commercialization metric that focuses on crop and livestock market engagements would not only reflect the widely accepted definitions of commercialization and provide a more holistic measure applicable in future research and policy analysis but also carry a theoretical appeal by representing a significant step towards acknowledging and capturing the dual nature of smallholder farming systems, especially in sub-Saharan Africa. Thus, the extended metric has the capacity to change the theoretical understanding of the relationship between commercialization and food security by accounting for the contribution of the livestock subsector, which has been ignored by previous studies focusing only on the crop subsector. Technically, the contribution of the livestock subsector to food security in previous studies was completely excluded or, at best, accounted for via other means, such as household income. The use of the extended metric directly accounts for both the contributions of the crop and livestock subsectors to food security and thus provides greater explanatory power.

We further differ from previous studies by measuring the commercialization of farm households, which involves all crops and livestock produced, but not selected crops and livestock. In most studies, the construction of the HCCI is restricted to a few crops produced by households. Here, 40 crops (32 food crops and 8 non-food crops) and 11 livestock (1 large, 5 small and 5 poultry) are considered (see Table A.1 in the supplementary material). Another contribution is the use of several food and nutrition outcomes. Few food and nutrition outcomes have been used in most studies. However, this study uses numerous outcomes, including food consumption expenditures, household dietary diversity, and food insecurity experience scale as food security outcomes, and vitamin A, protein, hem iron, and child anthropometric measures (i.e., stunting, wasting, and underweight) as nutrition outcomes. Given that there is no composite measure of food and nutrition security that encapsulates all the pillars (i.e., availability, accessibility, utilization, and stability), the use of diverse outcomes provides the advantage of covering most of the pillars.

The remainder of this paper is organized as follows. Section 2 presents the conceptual framework. Section 3 presents the materials and methods, and Section 4 presents the results and discussion. Section 5 presents the conclusions and policy implications.

2. Conceptual framework

The agricultural commercialization literature traces its theoretical foundation from the microeconomic theory of utility (Bellemare & Barrett, 2006; Bolarinwa et al., 2021; Burke et al., 2015; Key et al., 2000). Based on this theory, farm households aim to maximize their utility, which is a function of consumption bundles and exogeneous factors that influence utility, subject to several constraints, including budget and production technology. The optimization of the utility problem produces the agricultural commercialization function that relates a household's traded quantity to factors such as production capacity, transaction costs, market prices and resource endowments. Fig. 1 presents the conceptual framework that underpins this study, which recognizes that the capacity of a farm household to produce crops (staples and cash) and livestock is influenced by the agricultural farm system.

The system defines household interactions with input markets, the government, and the biophysical environment. In most cases, cash crops are produced for sale, leading directly to crop commercialization. The contribution of staple crops to crop commercialization is influenced by home consumption. Thus, the proportion of staple crops marketed is defined by the difference between the output produced and home consumption, which is referred to as marketable surplus. From the livestock subsector, the decision of a farm household to sell livestock provides the basis for livestock commercialization. Based on crop and livestock output market engagements, Abu et al. (2024) propose a definition and measurement of an extended metric of agricultural commercialization that encapsulates both crop and livestock dimensions. This is referred to as the Household Crop-Livestock Commercialization Index (HCLCI), which is defined as the sum of the proportion of crop and livestock value sold to the sum of the value of crops and livestock produced (see equation (2)).

In the literature, agricultural commercialization boosts farm incomes (Carletto et al., 2017; Kuma et al., 2019; Ogutu et al., 2020) and encourages crop diversification through economies of scope (Ecker, 2018; Govereh & Jayne, 2003). Farm income allows farmers to purchase farm inputs, which increases the productivity of staple and cash crops. Increased production of staple foods increases the availability of own-produced food, while increased production of cash crops increases

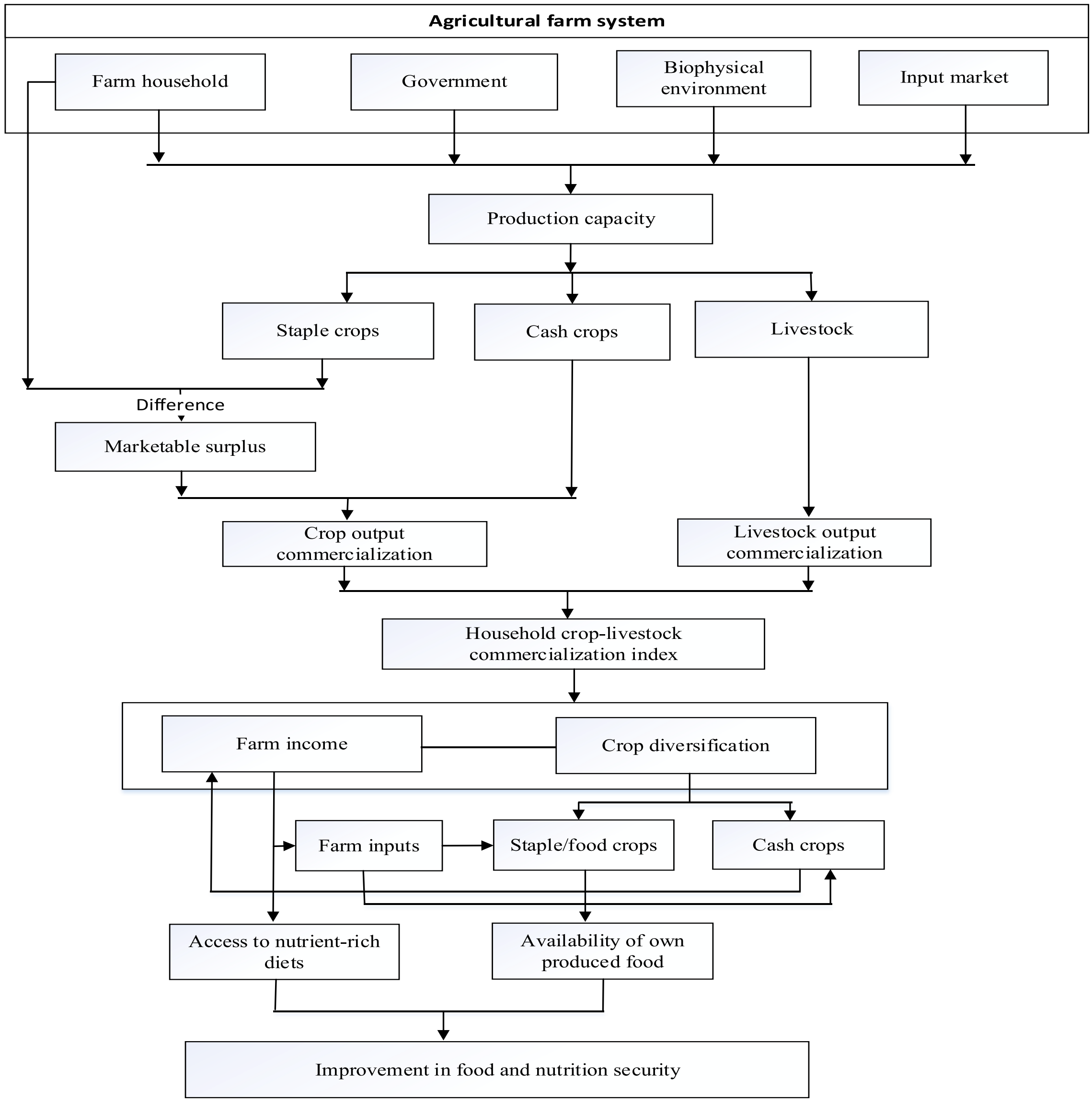

Fig. 1. Conceptual framework.
Source: Adapted and modified from Abu et al. (2024).

farm income, which enhances the financial capacity of households to purchase nutrient-rich foods they do not produce from markets. The availability of own-produced food and purchased food through increased income is expected to improve household food and nutrition security. While the stand-alone crop commercialization metric follows the same transmission channel, the hypothesis of this study implies that the extended metric will reflect a better effect on food and nutrition security outcomes as it incorporates the livestock dimension that the literature has so far ignored.

Despite this deterministic postulation of the conceptual framework, some studies have highlighted potential trade-offs between commercialization and food and nutrition security. Commercialization may shift dietary quality through increased intake of calories and not micronutrients when own-produced food is substituted for purchased food (Remans et al., 2015). Commercialization may dictate disproportionate specialization in the production of cash crops, and increased sales of food may reduce the availability of own food consumption and thus worsen food insecurity, particularly in situations where sale incomes are used to purchase food and market prices are not remunerative (Ogutu et al., 2020; 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). 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 may be prioritized over nutrition (Carletto et al., 2017). Another reason for skepticism about the effect of commercialization is the tendency for men to exercise more control over production and income (von Braun & Kennedy, 1994). Such control has been observed to shift household spending functions away from nutritious foods to other areas of household needs (Fischer & Qaim, 2012). These trade-offs can either reduce the boosting effect of commercialization on food and nutrition security postulated by the conceptual framework or have no or negative effects.

3. Materials and methods

3.1. Data description

This study uses data from the seventh round of the Ghana Living Standards Survey (GLSS7), collected by the Ghana Statistical Service between October 2016 and October 2017. The GLSS7 is a household survey that involves a nationally representative and stratified random sample of 14,009 households in 1000 enumeration areas. The specific design is a stratified two-stage cluster sampling design with Enumeration Areas (EAs) (i.e., a cluster of communities) as Primary Sampling Units (PSUs) and stratification by urban/rural communities. Questionnaires were adopted from the Living Standards Measurement Survey of the World Bank. The dataset has emerged as one of the most important and richest in Ghana, as it presents comprehensive and reliable 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, as well as 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.

Of the 14,009 households, 7332 are agricultural households, defined as households engaged in at least one crop production (6637 households) or livestock farming (7260 households). The descriptive statistics of the variables pertaining to the agricultural sample are presented in Table 1. Most households have men as heads (75.9%), and the average age of heads of farm households is approximately 49 years. Farm households typically have a maximum formal educational qualification of primary school, as the mean level of education is 4.7 years. Sixteen percent of farm households diversified into nonfarm activities. Nonfarm engagement is an important source of diversification for farm households, as households use it to raise alternative incomes. The average farm size is 2.68 ha. Investments in productivity-enhancing inputs are low. For example, the average expenditure per hectare on agrochemicals (i.e., inorganic fertilizers, insecticides and herbicides) is GHS221.2 (US $51.80[1]). Approximately 14.5 percent of farm households live in communities with an agricultural 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).

It is estimated that one extension agent serves 1,250 farmers in Ghana (Peasant Farmers Association of Ghana, 2019). Despite the importance of farmer organizations for farmer welfare (Grashuis & Su, 2019; Wedig & Wiegratz, 2018), farmer participation in agricultural cooperatives is low, as only 10.6 percent of farm households live in communities with agricultural cooperatives. Table 2 presents the results on the extended metric of agricultural commercialization (see Table A.1 in the supplementary material for detailed results for the separate crops and livestock indices). Of the 7332 farm households, 89.54 percent produced both crops and livestock, implying that the majority of Ghanaian farm households jointly operate crop and livestock production. However, 21.96 percent of farmers sold both crops and livestock. Thus, as the majority of farm households jointly produce crops and livestock, the proportion of those who jointly sell is much lower.

The aggregate level of the extended commercialization of the sample farm households is 26.44 percent. This level of commercialization from the extended metric is lower than that of the crop metric (35.20%). However, because these average indices fall into the surplus-oriented category,[2] both the crop and extended metrics display the same description of Ghanaian agriculture: surplus-oriented agriculture. The level of commercialization marginally increases to 28.38 percent for households engaged in both crop and livestock production. However, if commercialization is conditioned on households producing and selling crops and livestock, the level of commercialization increases to 40.44 percent. The results show sex disparity in commercialization, with male-headed households being slightly more commercialized (27.10%) than female-headed households (24.38%).

3.2. Measurement of food and nutrition security

Several indicators, reported in Table 3, are used to proxy food and nutrition security outcomes (see the supplementary material B.1 for the detailed description of the outcomes), while Table 4 reports the corresponding descriptive statistics of these food and nutrition security outcomes. The average per adult real food consumption expenditure is GHS1,565 (US$366.51). The mean number of food groups consumed by households (i.e., household dietary diversity score) is 6.2. This implies that farm households consume approximately six food groups on average.

The prevalence of anthropometric conditions of stunting, underweight, and wasting in children in farm households are 41.4 percent, 33.1 percent and 31.6 percent, respectively. These prevalence rates are alarming, and stakeholders need to find urgent solutions to these challenges. It is important to note that the food and nutrition security measures used do not capture all the dimensions of food security, especially in light of the proposal for a six-dimensional food security (see Clapp et al., 2022). The measures capture – albeit individually and not cumulatively – availability, access, and utilization dimensions of food security, but not the stability and now agency and sustainability dimensions. HDDS, stunting, wasting, and underweight capture the utilization dimension of food security (Anderman et al., 2014). Vitamin A, protein, hem iron and FIES are all measures of availability and accessibility. Furthermore, food consumption expenditures and HDDS capture the accessibility dimension of food security (Kennedy et al., 2011; Lovon & Mathiassen, 2014) as they help measure economic access to food.

3.3. Empirical strategy

To measure the effect of the extended metric of agricultural commercialization on food and nutrition security in a household farm setting, we specify the following generic regression model:

$$\boldsymbol{FNS_i} = \boldsymbol{\delta_0} + \boldsymbol{\delta_1 AC_i} + \boldsymbol{\delta_2 X_{i1}} + \boldsymbol{\varepsilon_{i1}} \tag{3}$$

where FNS_i indexes household food and nutrition security outcomes (see Table 3), AC_i denotes the extended metric of agricultural commercialization of the household (i.e., equation (2) and see Table 2), X_{i1} represents all control variables hypothesized to influence FNS_i (see Table 1), δ_0, δ_1 and δ_2 are the estimated parameters, and ε_{i1} is the error term. The parameter of interest is δ_1, which captures the effect of AC_i on FNS_i.

Considering the food and nutrition security outcomes in Table 3, we can re-specify equation (3) as follows:

$$\boldsymbol{FNS_{ij}} = \boldsymbol{\alpha_{0j}} + \boldsymbol{\alpha_{1j} AC_i} + \boldsymbol{\alpha_{2j} X_{i1}} + \boldsymbol{\epsilon_{ij1}} \tag{4a}$$

$$\boldsymbol{FNS_{ik}} = \boldsymbol{\beta_{0k}} + \boldsymbol{\beta_{1k} AC_i} + \boldsymbol{\beta_{2k} X_{i1}} + \boldsymbol{u_{ik1}} \tag{4b}$$

$$\boldsymbol{FNS_{il}} = \boldsymbol{\gamma_{0l}} + \boldsymbol{\gamma_{1l} AC_i} + \boldsymbol{\gamma_{2l} X_{i1}} + \boldsymbol{v_{il1}} \tag{4c}$$

Where j ($j = 1, \ldots, 5$), k ($k = 1, 2, 3$) and l ($l = 1$) respectively represent continuous, dummy, and ordered food and nutrition security outcomes in Table 3. α_1, β_1, and γ_1 measure the effect of commercialization on the various outcomes.

Since we cannot control for all factors in X_{i1} or sustain the assumption of orthogonality between AC_i and the respective error terms, there are potential issues of selectivity bias and endogeneity that constrain OLS, probit and ordered probit estimators to yield unbiased and

[1] 1US$ was an average of 4.27GHS between October 2016 and October 2017 (the data collection period).

[2] From FAO (1989): (i) farmers who sell less than 25 percent of their produce (i.e., sales <25%) are characterized as subsistent-oriented; (ii) farmers who sell at least 25 percent but less than 50 percent of their produce (i.e., 25% ≤ sales <50%) are characterized as surplus-oriented; and (iii) farmers who sell at least 50 percent of their produce (i.e., sales ≥50%) are characterized as commercial-oriented.

Table 1
Descriptive statistics of variables.

Variable	All Sample (n = 7332)		Non-market participants (n = 5722)		Market participants (n = 1610)		Mean difference
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
Socioeconomic characteristics							
Sex of head (1 = male)	0.759	0.428	0.744	0.437	0.814	0.389	−0.071***
Age of head (years)	48.74	15.57	48.80	15.74	48.51	14.93	0.294
Household size	5.103	3.123	4.898	2.927	5.832	3.645	−0.934***
Marital status of head (1 = married)	0.739	0.439	0.724	0.447	0.792	0.406	−0.068***
Education of head (years)	4.675	4.965	4.786	5.007	4.281	4.791	0.506***
Received cash remittance (1 = yes)	0.341	0.474	0.333	0.471	0.367	0.482	−0.034**
Nonfarm engagement (1 = yes)	0.160	0.367	0.164	0.371	0.145	0.353	0.019*
Value of assets (GHS)	661.1	8776	521.0	8982	1159	7983	−637.896**
Household income (GHS)	4476	10,284	4403	10,645	4733	8880	−329.488
Stop work due to illness (number)	0.700	2.354	0.680	2.312	0.772	2.496	−0.092
Farm characteristics							
Number of crops produced	2.383	1.641	2.185	1.585	3.086	1.643	−0.901***
Agric land endowment (ha)	11.17	298.5	11.30	320.4	10.70	202.3	0.604
Expenditure on agrochemicals (GHS/ha)	221.2	1054	213.3	700.9	249.2	1819.3	−35.957
Expenditure on hired labour (GHS/ha)	130.5	620.1	126.9	596.1	143.2	698.8	−16.278
Community characteristics							
Agric extension office (1 = yes)	0.145	0.353	0.132	0.338	0.199	0.399	−0.063***
Agric cooperatives (1 = yes)	0.106	0.308	0.0947	0.293	0.152	0.359	−0.052***
Irrigation fields (1 = yes)	0.112	0.316	0.111	0.315	0.120	0.325	−0.004
Perceived rain pattern (1 = better)	0.567	0.496	0.577	0.494	0.537	0.499	0.046***
Navigable road (1 = yes)	0.676	0.468	0.610	0.488	0.912	0.283	−0.301***
Public transport availability (1 = yes)	0.535	0.499	0.491	0.500	0.688	0.464	−0.202***
Mobile phone network (1 = yes)	0.524	0.499	0.471	0.499	0.707	0.455	−0.241***
Bank (1 = yes)	0.156	0.363	0.143	0.350	0.201	0.401	−0.060***
Market (1 = yes)	0.234	0.424	0.214	0.410	0.305	0.461	−0.091***
HCLCI average (%)	26.44	19.23	24.69	19.28	32.76	17.71	−7.987***
Market orientation (%)	23.10	20.49	20.82	20.42	31.22	18.62	−10.386***
Location characteristics							
Resides in rural area (1 = yes)	0.830	0.376	0.809	0.393	0.902	0.298	−0.093***
Lives in southern Ghana (1 = yes)	0.454	0.498	0.466	0.499	0.409	0.492	0.058***
Lives in coastal zone (1 = yes)	0.113	0.317	0.122	0.327	0.083	0.276	0.039***
Lives in forest zone (1 = yes)	0.361	0.480	0.365	0.481	0.347	0.476	0.018
Lives in savannah zone (1 = yes)	0.521	0.500	0.508	0.500	0.566	0.496	−0.059***
Lives in Greater Accra area (1 = yes)	0.005	0.070	0.005	0.073	0.003	0.056	0.002

Note(s): Mean difference calculated using the *t*-test.

Table 2
Extended commercialization indices.

Metric	Percent
Production and sale	
Produced crop and livestock (n = 7332)	89.54
Sold crop and livestock (n = 7332)	21.96
Commercialization indices	
HCLCI overall (n = 7332)	26.44
HCLCI crop and livestock producers (n = 6565)	28.38
HCLCI crop and livestock producers and sellers (n = 1610)	40.44
HCLCI only crop producers (n = 6637)	28.31
HCLCI only livestock producers (n = 7260)	26.49
HCLCI: Female headed (n = 1766)	24.38*
HCLCI: Male headed (n = 5566)	27.10*

Note(s): * denotes significant differences between males and females using the *t*-test.

Table 3
Measurements of food and nutrition security outcomes.

Variable	Measurement
Food security outcomes:	
Per adult equivalent real annual food consumption expenditure	Continuous: GHS/annum
Household Dietary Diversity Score (HDDS)	Continuous: number of food groups consumed
Food Insecurity Experience Scale (FIES)	Ordered: 0 = Severe food insecurity; 1 = Moderate food insecurity; 2 = Food security to mild food insecurity)
Nutrition outcomes:	
Vitamin A	Continuous: household frequency consumption of vitamin A rich foods over 7 days
Protein	Continuous: household frequency consumption of protein rich foods over 7 days
Hem iron	Continuous: household frequency consumption of hem iron rich foods over 7 days
Stunting	Dummy: 1 = if child is stunted; 0 otherwise
Wasting	Dummy: 1 = if child is wasted; 0 otherwise
Underweight	Dummy: 1 = if child is underweight; 0 otherwise

consistent estimates, respectively for equations (4a), (4b) and (4c). 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 commercialization. Unobserved characteristics (e.g., innate farm management and entrepreneurial abilities) may impose a joint influence on commercialization 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 commercialization through productivity gains, is very likely (Ogutu et al., 2020).

In this study, endogeneity is controlled for by employing instrumental variable two-stage regression approaches for equations (4a) and (4b). Specifically for equation (4a) (i.e., for all the continuous outcomes), a two-step generalized method of moment (GMM) approach is adopted to obtain efficient estimates of the coefficients, as well as consistent estimates of the standard errors. The GMM is preferred to the two-stage least squares (2SLS) because it is more efficient and robust to

Table 4
Descriptive statistics of food and nutrition security outcomes.

Indicators	All Sample			Non-market participants			Market participants			Mean difference
	Sample	Mean	S.D.	Sample	Mean	S.D.	Sample	Mean	S.D.	
Continuous outcomes										
Per adult real food expenditure (GHS)	7332	1565	1586	5722	1524	1546	1610	1708	1713	−183.966***
Dietary diversity (no. of food groups)	7332	6.214	1.893	5722	6.022	1.867	1610	6.896	1.826	−0.873***
Vitamin A (frequency)	7332	7.587	4.957	5722	7.184	4.663	1610	9.019	5.660	−1.835***
Protein (frequency)	7332	4.995	3.804	5722	4.578	3.395	1610	6.476	4.705	−1.898***
Hem iron (frequency)	7332	1.952	1.611	5722	1.818	1.508	1610	2.429	1.859	−0.610***
Binary outcomes										
Stunting (HAZ < -2SD) (1 = yes)	2864	0.414	0.493	2160	0.464	0.499	704	0.259	0.438	0.206***
Underweight (WAZ < -2SD) (1 = yes)	2864	0.331	0.471	2160	0.399	0.490	704	0.125	0.331	0.274***
Wasting (WHZ < -2SD) (1 = yes)	2864	0.316	0.465	2160	0.390	0.488	704	0.087	0.282	0.304***
Ordered outcome										
	Freq.	%		Freq.	%		Freq.	%		
FIES										0.011
Severe food insecurity	2584	35.24		2015	35.21		569	35.34		
Moderate food insecurity	1977	26.96		1532	26.77		445	27.64		
No hunger to mild food insecurity	2771	37.79		2175	38.01		596	37.02		

Note(s): FIES is food insecurity experience scale (FIES); mean difference calculated using *t*-test.

heteroscedasticity (Kuma et al., 2019). The first stage of this instrumental variable approach is specified as follows:

$$\boldsymbol{AC_{ij}} = \boldsymbol{\eta_{0j}} + \boldsymbol{\eta_{1j}X_{i1}} + \boldsymbol{\eta_{2j}M_i} + \boldsymbol{\xi_{ij1}} \tag{5}$$

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, which satisfies two requirements, namely relevance (defined as an instrument possessing a strong correlation with the variable it is instrumenting for) and exogeneity (defined as an instrument being orthogonal or uncorrelated with the outcome). Two instruments are identified, namely community average commercialization index and community average market orientation index.

The community average commercialization index is derived by taking the average commercialization indices of all households in the same community, excluding the household of interest. This aggregate index is expected to influence household-level commercialization. This expectation is driven by the literature on the influence of social networks and neighbourhood effects on marketing and agricultural technology adoption (Andersson et al., 2015; Magnan et al., 2015; Ogutu et al., 2020). When households in a community mimic each other in their commercialization behaviour, the average commercialization in the community is likely to be high. The community average commercialization index is not expected to correlate with food and nutrition outcomes. Other studies have applied this instrument (e.g., Cazzuffi et al., 2020).

The community average market orientation index is derived by taking the average of the market orientation indices of all households in the same community, excluding households of interest. Following (Gebremedhin, and Jaleta, 2010), we calculate the market orientation index[3] as follows:

$$\boldsymbol{MOI_i} = \frac{\sum_{c=1}^{k} \boldsymbol{CSCI_c L_{ci}}}{\boldsymbol{L_i}} \tag{6}$$

Where MOI_i is market orientation index of household i, $CSCI_c$ is crop-specific commercialization 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, fertilizers, 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 correlate with commercialization. However, this behaviour of households does not influence food and nutrition security.

After estimating equation (5) with these potentially valid instruments, the second stage of the IV approach involves estimating

$$\boldsymbol{FNS_{ij}} = \boldsymbol{\pi_{0j}} + \boldsymbol{\pi_{1j}AC_i} + \boldsymbol{\pi_{2j}X_{i1}} + \boldsymbol{\epsilon_{ij1}} \tag{7}$$

Where all the variables are as defined before, and equation (4a) and equation (7) are similar. However, α_{1j} and π_{1j} are different because the former represents a biased and inconsistent estimate of the effect of commercialization on food and nutrition security using OLS and the latter represents the unbiased and consistent estimate of the effect of commercialization 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 commercialization), weak identification (i.e., instruments correlated with commercialization (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 (4b), except that it is a binary and not a continuous version.[4]

A similar two-step IV estimation approach is applied to equation (4c), except that this approach accounts for the ordered nature of the outcome. 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

[3] 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.

[4] Given the design of the GLSS7, in implementing the models, the PSUs, stratification by urban/rural classifications and sampling weights are accounted for to obtain appropriate variance estimation.

covariate. Recalling equation (4c) and equation (5), an extended ordered probit model specifies a simultaneous estimation of:

$$\boldsymbol{FNS}_{il} = \gamma_{0l} + \gamma_{1l}\boldsymbol{AC}_i + \gamma_{2l}\boldsymbol{X}_{i1} + \boldsymbol{\nu}_{il1} \tag{4c}$$

$$\boldsymbol{AC}_{il} = \boldsymbol{\eta}_{0l} + \boldsymbol{\eta}_{1l}\boldsymbol{X}_{i1} + \boldsymbol{\eta}_{2l}\boldsymbol{M}_i + \boldsymbol{\xi}_{il1} \tag{5}$$

Equation (5) 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 (5) and the simultaneous modelling of the error terms, ν_{il1} and ξ_{il1}, which also overcomes selectivity bias.

Following the literature (see, for example, Haji, 2022; Ogutu et al., 2020), the commercialization effect in the presence of substitutability between own-produced food and purchased food is assessed. The rationale for this assessment is to examine whether commercialization decreases diet availability and quality from own-produced food. To undertake this, the effect model (i.e., equation (3)) is re-estimated; however, with food and nutrition security outcomes constructed from own-produced food and purchased foods. The re-estimated models are specified as follows:

$$\boldsymbol{FNS\_own}_{ij} = \boldsymbol{\varphi}_{0j} + \boldsymbol{\varphi}_{1j}\boldsymbol{AC}_i + \boldsymbol{\varphi}_{2j}\boldsymbol{X}_{i1} + \boldsymbol{\varepsilon}_{ij1} \tag{8a}$$

$$\boldsymbol{FNS\_pur}_{ij} = \boldsymbol{\phi}_{0j} + \boldsymbol{\phi}_{1j}\boldsymbol{AC}_i + \boldsymbol{\phi}_{2j}\boldsymbol{X}_{i1} + \boldsymbol{\epsilon}_{ij1} \tag{8b}$$

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 equations (8a) and (8b) are undertaken for only HDDS, vitamin A, protein, and hem iron. If commercialization dampens the availability of own-produced food, the effect (i.e., φ) should be significantly negative. A significantly positive estimate of ϕ would imply that commercialization stimulates purchases of nutrients.

The role of income as a key transmission channel (argued in Fig. 1 as a pathway of commercialization) is examined using the following specifications:

$$\boldsymbol{INCOME}_i = \boldsymbol{\varpi}_0 + \boldsymbol{\varpi}_1\boldsymbol{AC}_i + \boldsymbol{\varpi}_2\boldsymbol{X}_{i1} + \boldsymbol{\varepsilon}_{ij1} \tag{9}$$

$$\boldsymbol{FNS}_{ij} = \boldsymbol{\varrho}_{0j} + \boldsymbol{\varrho}_{1j}\boldsymbol{INCOME}_i + \boldsymbol{\varrho}_{2j}\boldsymbol{X}_{i1} + \boldsymbol{\epsilon}_{ij1} \tag{10}$$

Where *INCOME* is the total household income. The hypotheses are that ϖ_1 and ϱ_1 are significantly positive. Equations (9) and (10) are not estimated jointly and not estimated to measure causal effect but association.

4. Results and discussion

4.1. Relevance and exogeneity of instruments

Table A.2 in the supplementary material reports the evidence on the relevance of the instruments. The results suggest that the two instruments are statistically significant determinants of agricultural commercialization, confirming that they satisfy the relevance requirement. The second validity test checks the exogeneity of the instruments, as reported in Table A.3 in the supplementary material. The two instruments are only simultaneously exogenous in vitamin A, protein, hem iron, and stunting models, implying that they are all used as instruments to estimate the effect for these outcomes. The average commercialization index is exogenous in HDDS, wasting, and underweight models and is thus used for the effect estimation for these outcomes. The average market orientation index is exogenous in food expenditure and FIES models and is thus used for the effect estimation for these outcomes.

In addition to the tests of relevance and exogeneity, the instrumental variable regression provides statistical tests of the quality of the instruments (Table A.4). The first is the weak identification test, which tests whether the instruments are weakly correlated with the endogenous variable (commercialization). When the instruments are weak, the IV estimator performs poorly. The results in Table A.4 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, implying that the instruments are not weakly correlated with commercialization. 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 commercialization). The evidence suggests that the Kleibergen-Paap LM statistic is statistically significant, implying that the instruments are relevant because the null hypothesis of an under-identified model 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, implying that the instruments are valid and confirms the earlier tests of instrument validity.

4.2. Main effects

After testing and confirming the validity of the instruments for the respective outcomes, the effect of the extended metric of agricultural commercialization on various measures of food and nutrition security in Ghana is estimated and reported in Table 5 (see Table A.4 in the supplementary material for full estimates). After controlling for all relevant factors, the extended commercialization metric significantly affects all food and nutrition security indicators, except stunting. The extended metric of commercialization has a significantly positive effect on food consumption expenditures, household dietary diversity, consumption of vitamin A-rich, protein-rich, and hem iron-rich foods, and food insecurity experience scale, and a significantly negative effect on child anthropometric measures of wasting and underweight. Specifically, increasing the extended commercialization by 1 percent increases annual adult equivalent consumption expenditure by GHS5.594 (US $1.31), increases the number of food groups consumed by 0.037, increases consumption of vitamin A-rich, protein-rich, and hem iron-rich foods by 0.051, 0.026, and 0.015, respectively. Further, for the FIES estimate, a 1 percent increase in commercialization increases the probability of experiencing 'food security to mild food insecurity' by 0.4 percent. For child anthropometric measures, it is revealed that a 1 percent increase in commercialization reduces the probability of children wasting and being underweight by 4.3 percent and 2.0 percent, respectively. Taking all these findings together, the results suggest that the extended metric of commercialization improves the food and nutrition security of farm households in Ghana.

This evidence corroborates existing literature. For example, the positive effect of commercialization on dietary diversity observed confirms several studies (Nthabeleng et al., 2024; Zheng & Ma, 2023; Chegere & Kauky, 2022; Nkegbe & Abdul Mumin, 2022; Ochieng et al.,

Table 5
Effect of agricultural commercialization on food and nutrition security.

Outcome	Estimate	Std. error
Per adult equivalent annual food expenditure	5.594**	2.589
HDDS	0.037***	0.003
Vitamin A	0.051***	0.007
Protein	0.026***	0.005
Hem iron	0.015***	0.002
Stunting	−0.003	0.005
Wasting	−0.043***	0.006
Underweight	−0.020***	0.005
FIES	0.004*	0.002

Note(s): *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$; food expenditure, HDDS, vitamin A, protein, hem iron are estimated using ivreg2; Stunting, wasting and underweight are estimated using ivprobit; FIES is estimated using eoprobit; PSUs, stratification and sampling weights accounted for in the estimation of parameters.

2019; Sibhatu et al., 2022; Usman & Haile, 2022). This 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 effect of commercialization on the intake of protein, iron, and vitamin A. The findings of Nthabeleng et al. (2024), Sibhatu et al. (2022), Usman and Haile (2022), and Kuma et al. (2019) that report that households with higher levels of commercialization have better food security outcomes is corroborated by the positive estimates of the effect of commercialization on the self-reported food security indicator of FIES. Regarding child anthropometric measures of wasting and underweight, this corroborates the evidence of Haji (2022), who reported that more commercialized households have children with a lower probability of wasting and underweight.

The main channel or transmission mechanism through which commercialization boosts food and nutrition security is income (i.e., crop sale income). Several studies (Carletto et al., 2017; Haji, 2022; Kilimani et al., 2022; Muriithi & Matz, 2015; Ochieng et al., 2019; Ogutu et al., 2020) have reported that income from commercialization is a prominent channel through which commercialization stimulates food and nutrition security. Income from commercialization improves food and nutrition security by providing households with the capacity to purchase food and other essential calories and micronutrients (Carletto et al., 2017; Ecker, 2018; Kuma et al., 2019; Ogutu et al., 2020; von Braun, 1995). Beyond raising income, commercialization 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 specialization, which provides the liquidity to procure productivity-enhancing inputs (Barrett, 2008; Muriithi & Matz, 2015; von Braun & Kennedy, 1994).

The effect of commercialization on the anthropometric measure of child stunting is not statistically significant. This corroborates the evidence of Chegere and Kauky (2022), Carletto et al. (2017) and Anderman et al. (2014) who found that commercialization does not significantly affect child stunting. This may indicate the complexity of nutrition indicators relative to food security indicators. Nutrition encapsulates food security in addition to capturing specific requirements of health, dietary quality, and biological utilization. This complexity may dictate lower responsiveness to commercialization relative to food security indicators. Furthermore, several studies (e.g., Gosa et al., 2024; Linderhof et al., 2019) have noted the heterogeneity in the effect of commercialization on food and nutrition outcomes. This implies that commercialization does not uniquely influence all food and nutrition security outcomes.

4.3. *Comparing effects: extended metric (HCLCI) versus crop (HCCI) and livestock (HLCI) metrics*

Given that there are three metrics (i.e., HCLCI, HCCI, and HLCI), their respective effects on food and nutrition security indicators are compared. The respective estimates are reported in Table 6 (see Table 5 for a summary of estimates (or Table A.4 for full estimates) of the HCLCI and Tables A.5 and A.6 in the supplementary material for full estimates of HCCI and HLCI, respectively). Two key findings are deduced from the comparative analysis of the effects of the three metrics. First, it is revealed that consistently the estimated effects for the HLCI metric are larger than those for the HCLCI and HCCI. Second, the estimated effects for the HCLCI are also larger relative to those for the HCCI. These findings point to a key implication: comparatively, livestock commercialization exerts greater effects on food and nutrition security than crop commercialization.

This implication accounts for the consistently larger effects of the extended commercialization metric relative to the crop commercialization metric. The importance of the livestock subsector to agricultural commercialization cannot be discounted. The effects of the extended commercialization metric on food and nutrition security relative to crop commercialization are larger in magnitude because of the influence of livestock commercialization.

Table 6
Comparative effects of three metrics of agricultural commercialization.

Outcome	Estimate		
	HCLCI	HCCI	HLCI
Per adult equivalent annual food expenditure	5.594**	3.618***	101.196**
HDDS	0.037***	0.025***	0.476**
Vitamin A	0.051***	0.028***	1.240**
Protein	0.026***	0.018***	0.768**
Hem iron	0.015***	0.009***	0.330**
Stunting	−0.003	−0.000	−0.699
Wasting	−0.043***	−0.030***	−0.419
Underweight	−0.020***	−0.013***	−0.522
FIES	0.004*	0.002	0.034***
Observations	7332	6637	7260

Note(s): *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$; PSUs, stratification and sampling weights accounted for in the estimation of parameters.

4.4. *Income pathway and substitution of own and purchased food*

The last section of the results tests whether agricultural commercialization affects household income. The results presented in Table A.7 in the supplementary material indicate that extended commercialization is a positive correlate of household income. A 1 percent increase in extended commercialization increases household income by 2.3 percent. This confirms the income pathway posited in the conceptual framework in Fig. 1. Finally, the effect of commercialization on the substitution of own-produced food for purchased food is examined, as this further helps to understand the transmission of commercialization to food and nutrition security. This assessment is conducted for only HDDS, vitamin A, protein, and hem iron consumption because these are the outcomes for which data are available to partition into own-produced and purchased. The results, presented in Table A.8 in the supplementary material, suggest that commercialization has no statistically significant effect on own-produced food and nutrition security outcomes. However, the effect is consistently and significantly positive for purchased food and nutrition security outcomes. This may appear contradictory because increased commercialization may reduce the amount of food available for consumption, such that a statistically significant negative effect of commercialization on own-produced food is expected. However, the results show that commercialization 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 confirms the role of income from sales in stimulating the procurement of diverse diets.

5. Conclusion and policy implications

This study uses an extended metric of agricultural commercialization that encapsulates both crop and livestock dimensions of farm households' market engagements to assess its effects on several food and nutrition security outcomes in Ghana, under the hypothesis that this extended metric better reflects the effect of agricultural commercialization on food and nutrition security than the conventional crop commercialization metric. Relative to the crop index, the extended metric represents a significant step towards capturing the dual nature of smallholder farming systems in sub-Saharan Africa and provides a more holistic measure that can be applied in future research and policy analysis. Consistent with previous studies, the extended metric of agricultural commercialization improves the food and nutrition security of farm households in Ghana. However, in a departure from existing findings, we find that the estimated effects are larger for the livestock commercialization index relative to the extended and crop indices. The estimated effects are further larger for the extended index relative to the crop index. These findings point to a key implication, that is, livestock commercialization exerts more effects on food and nutrition security than crop commercialization. By extension, this implication accounts for the consistently larger effects of the extended commercialization metric relative to the crop commercialization metric. Further, it is found that the consumption of own-produced food does not suffer due to increased commercialization while it encourages the consumption of purchased diets through income gained from sales. The main conclusion is that using the extended commercialization index to account for the effect(s) of agricultural commercialization on food and nutrition security in Ghana is a better approach than using the crop commercialization index. Thus, the extended commercialization index is a key strategy for boosting food and nutrition security for farm households in Ghana.

This conclusion calls for a strategic reorientation of agricultural policy to place greater emphasis on livestock development. Thus, it is imperative to balance attention from policy and interventions for the livestock subsector to support the drive for a transition to productive and commercialized agriculture in Ghana. The Ministry of Food and Agriculture (MoFA) should increase investment in livestock-specific interventions, including improved access to veterinary and animal health services through the deployment of qualified veterinarians and other animal health professionals, especially in less developed areas; improved livestock breeds and husbandry practices to increase productivity; increased investment in disease monitoring and surveillance to reduce livestock mortality and morbidity; measures to curb antimicrobial resistance through training on the proper use of antibiotics; credit for livestock rearing; and improve market infrastructure for livestock products and develop organized livestock value chains through investment in cold storage, slaughter facilities, processing, packaging and distribution. While the livestock subsector is as important as the crop subsector, as demonstrated here, historically, policy attention has been skewed toward crop agriculture; however, the evidence presented here suggests that a more balanced allocation of resources—if not a livestock-focused approach—may yield greater improvements in food and nutrition security. Furthermore, MoFA needs to pay critical attention to the effective and efficient implementation of livestock development policies. Over the years, livestock policies and strategies have suffered from implementation problems (i.e., non-implementation and inadequate implementation) that curtail their capacity to fully address the constraints in the livestock subsector. The government of Ghana should efficiently allocate resources for the implementation of these policies.

Since agricultural commercialization holds significant food and nutrition security benefits, there is a need to integrate nutrition-sensitive approaches into agricultural policy and align agricultural policy with national nutrition strategies in the Ministry of Health (MoH) and the Ghana Health Service. Therefore, it is important to enhance effective collaborative efforts between MoH, Ministry of Trade, Agribusiness, and Industry (MoTAI), and MoFA. Nutrition education and awareness campaigns should accompany commercialization efforts to maximize welfare gains. Thus, this study demonstrates that it is important for the government of Ghana to develop and promote well-functioning food systems by enhancing institutional collaborations and cooperations and strengthening policies that create an enabling environment within the food value chain. Food should be produced in the most productive and efficient way (the role of MoH), efficiently marketed (the roles of MoFA and MoTAI), and prepared and consumed in the most nutritious and healthy way (the role of MoH). This cannot be achieved without the cooperation and collaboration of all relevant stakeholders, especially in policy design and implementation. Ideal food systems require all connecting institutions to collaborate and cooperate, and the evidence that agricultural commercialization boosts food and nutrition security points in this direction.

The stronger effects associated with the extended commercialization index highlight the benefits of integrated farming systems. Policies should therefore promote crop–livestock integration as a pathway to agricultural commercialization. Mixed farming systems enable complementarities such as the use of crop residues for feed and manure for soil fertility, thereby improving overall farm productivity. The results show that increased commercialization does not compromise the consumption of own-produced food. Rather, it facilitates greater consumption of purchased and potentially more diverse diets through increased income. This finding challenges the concern that market-oriented production may undermine household food self-sufficiency. Instead, commercialization appears to strengthen both direct (own production) and indirect (market purchases) food access channels.

Despite its contributions, this study has certain weaknesses. The first weakness relates to the data. Market price volatility is an important variable that influences commercialization; however, this has not been accounted for because it is unavailable. Future studies should control for price volatility. The use of panel data will better capture the influence of volatility. Furthermore, the structure of production and consumption differs between large, medium, and small livestock. However, no further contextual issues related to these differences were explored. Studies accounting for these contextual heterogeneities across scale of production would provide more nuanced evidence. Second, the extended metric does not comprehensively solve the problem of appropriately measuring commercialization. Although it is better than measuring individual crops and livestock commercialization, it still does not capture the input dimension of commercialization suggested in the literature. It is recommended for future studies to find ways of developing a metric that simultaneously captures crops, livestock, and input dimensions would be a novel addition to the literature.

CRediT authorship contribution statement

Benjamin Musah Abu: Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Daniel Bruce Sarpong:** Writing – review & editing, Supervision, Methodology. **Yaw Bonsu Osei-Asare:** Writing – review & editing, Supervision, Methodology. **Charles Yaw Okyere:** Writing – review & editing, Supervision, Methodology. **Taeyoon Kim:** Writing – review & editing, Supervision, Methodology.

Data availability statement

The data used in this study are available from the corresponding author upon reasonable request.

Ethical statement

Ethical approval is not applicable to this manuscript since secondary data was used.

Declaration of the use of AI

The authors declare that no AI tools were used for the preparation of this study.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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