Improving the market for livestock production households to alleviate food insecurity in the Philippines

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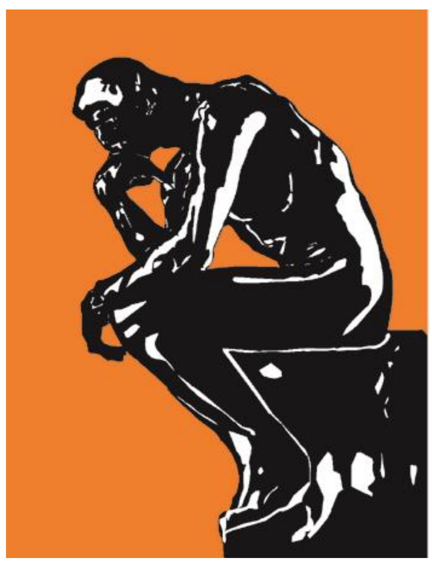

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Abstract

Food security is one of the major concerns in the Philippines. Although livestock and poultry production accounts for a significant proportion of the country's agricultural output, smallholder households are still vulnerable to food insecurity. The current study aims to examine how livestock production and selling difficulties affect smallholder households' food-insecure conditions. For this objective, Bayesian Mindsponge Framework (BMF) analytics was employed on a dataset of the Food and Agriculture Organization's Data in Emergencies Monitoring (DIEM) system. We found that production and selling difficulties significantly adversely affect food insecurity in the Philippines. However, their effects vary according to the severity of food insecurity. In particular, production and selling difficulties affect the households' likelihood of eating less healthy and nutritious food equally. However, the production difficulties have more negligible impacts on the possibility of skipping meals and even ambiguous impacts on the likelihood of not eating for a whole day compared to the effects of selling difficulties. Moreover, we also found that the market plays a crucial role in facilitating not only livestock trading but also livestock production (e.g., purchase of feed and medicines). Based on these findings, we suggest that the livestock market needs to be expanded and regulated to maintain the balancing prices between livestock products and products and services used for livestock production, and facilitate the product-exchanging mechanism.

Keywords: market, agricultural households, food security, Mindsponge Theory, information-processing

"— Wherever there is food, there is freedom!"

In "Dream"; *The Kingfisher Story Collection* (2022)

1. Introduction

Food security is "all people, at all times, have social, economic, and physical access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (Food and Agriculture Organization, 1996; Lin et al., 2022). More food needs to be produced to meet human needs, especially when achieving food system sustainability is a global priority and when the food 'problem' has become a global obsession (Garnett, 2014). Food security has four main pillars: food availability, access to food, the stability of food supplies, and food utilization (Lin et al., 2022). The problems that arise in any pillar can lead to food insecurity.

Food insecurity is a critical global public health issue related to poverty, mainly in developing countries (Abafita & Kim, 2014; Mazenda et al., 2022; Shakeel & Shazli, 2021). It is the condition of not having access to sufficient or adequate quality food to meet one's basic needs. The Food Security Information Network estimated that 258 million people in 58 countries/territories (22.7% of the analyzed population) faced acute food insecurity in 2022 (Food Security Information Network, 2023). Food insecurity was exacerbated by the Covid-19 pandemic, in which the global food supply chain from farm to fork was paralyzed due to lockdowns (Torero, 2020). Even in the United States (US), the world's leading economy, 34.4% of households with children $\leq$ 12 years old were reported to be food insecure by the end of April 2020, doubling 2018's proportion with 15.1% (Bauer, 2020). Food insecurity is even worse in developing countries, typically the Philippines. According to Rapid Nutrition Assessment Survey (RNAS) conducted by the Food and Nutrition Research Institute, around 62.1% of Filipino households faced moderate to severe food insecurity during the Covid-19 pandemic (Food and Nutrition Research Institute, 2021).

In the Philippines, 29% of the labor force is employed in the agricultural sector, which accounts for 9% of the country's total GDP. Regarding the nation's entire agricultural output, crops account for 49% of production, with livestock and poultry coming in second place, accounting for 25% (Barroga et al., 2020). The volume of pig and poultry production has increased by 195 and 332%, respectively, over the previous 30 years, paralleling the 85% increase in the human population (Barroga et al., 2020). Livestock production in the Philippines is dualistic, comprising of backyard or smallholder and commercial production systems. However, most livestock is reared by smallholder farmers (Ortega et al., 2021). Smallholder production is characterized by ownership of fewer than 21 heads of adult animals or less than 41 heads of young animals, or a combination of fewer than 21 heads of adult and 22 heads of young animals, while commercial production had higher numbers (Alawneh et al., 2014; Philippine Statistics Authority, 2013).

Research has shown that 850 million of the world's 868 million undernourished people are in developing nations (Rupasi et al., 2014), leaving a large gap between global demand and development. By 2050, there will be about nine billion people on the planet, and the demand for animal products is expected to quadruple globally (Kharas, 2010). Future predictions anticipate that the demand for more nutrient-dense diets and proteins of animal origin, such as for meat and milk, will expand owing to population expansion, urbanization, income growth, and dietary change (Akasha et al., 2021; Lapar et al., 2003). Because of this change, smallholder livestock farmers now have new and growing market prospects. Therefore, on the surface, the future appears to contain huge untapped potential for smallholder livestock producers, particularly opportunities to escape the poverty trap by developing tactics that would facilitate greater entry and sustained profitability from expanding livestock markets (Lapar et al., 2003).

Despite the expectation to contribute to national food security (Roxas, 1995), the Philippines' smallholder livestock producers tend to be the population that has a high risk of food insecurity. According to the World Food Programme Philippines's Food Security Monitoring survey conducted in October 2022, around 25% of agricultural households were food insecure, while only 9% of non-agricultural households reported experiencing food insecurity (Cruz, 2022). The emergence of African Swine Fever in 2019 and the Coronavirus in 2020 caused havoc on the livestock production industry, affecting livelihoods and food security among smallholder farmers (Briones & Espineli, 2022). Due to the reduced income, agricultural households are more likely to adopt coping strategies to overcome food insecurity, such as borrowing money for food, purchasing food on credit, and spending savings. When the livestock smallholder farmers still have to borrow money for food or purchase food on credit, their contribution to maintaining national food security will be limited.

Therefore, the current study aims to explore how the difficulties in smallholder farmers' works affect their food insecurity and which kind of difficulties (production or trading difficulties) have more severe effects. By knowing the main factors contributing to the food insecurity of smallholder farmers, policymakers and governmental agencies will be able to plan and implement appropriate policies and programs that can alleviate the smallholder farmers' food insecurity and improve their food production efficiency.

Specifically, the study's analysis was separated into two main parts: statistical and descriptive analyses. For the statistical analysis, we employed the Bayesian Mindsponge Framework (BMF) analytics (Nguyen et al., 2022b). Specifically, the Mindsponge Theory, an information-processing theory of the mind, was used to reason how difficulties of smallholder farmers (i.e., production and trading difficulties) affect their food insecurity (Vuong, 2023). Then, a Bayesian analysis was conducted on the dataset provided by Food and Agriculture Organization to validate our theoretical assumptions and reasonings. Then, we employed descriptive analysis to identify factors causing the production and trading difficulties of the households.

2. Methodology

2.1. Theoretical foundation

The current study employed the Mindsponge Theory as the theoretical foundation for constructing the models (Vuong, 2023). It was originally referred to as the mindsponge mechanism, a conceptual framework explaining the dynamics of acculturation and global thinking (Vuong & Napier, 2015). Later, by incorporating evidence from life and neurosciences, the mechanism is upgraded into theory. Mindsponge Theory is an information-processing theory that explains how a mind absorbs and processes information. The theory has been employed in multiple studies in various psychological and social disciplines (Asamoah et al., 2023; Cheng et al., 2023; Kumar et al., 2022; Lu et al.; Nguyen & Jones, 2022a, 2022b; Ruining & Xiao, 2022; Santirocchi et al., 2023; Tanemura et al., 2022; Vuong et al., 2023; Vuong, Le, et al., 2022).

In the theory, the mind is defined as an information collection-cum-processor. Although this definition is often referred to the mental collection and process of the human mind, it can also be applied to a wide range of biological and social systems (Vuong, 2023). In the current study, a household can be viewed as an information collection-cum-processor, or a collective mind.

According to the Mindsponge Theory, a mind (or an information-processing system) has the following properties:

- It reflects the natural patterns of systems in the biosphere.
- It is a dynamic process that is dynamically balanced.
- It involves cost-benefit evaluation, which aims to increase the perceived benefit and reduce the perceived cost of the system.
- It consumes energy and thus follows the principle of energy saving.
- It has a goal(s) and priority, depending on the demand of the system
- Its fundamental purpose is to prolong the system's existence in one way or another, including survival, growth, and reproduction.

Analogously, as a part of the natural system, a household of smallholder farmers also express such properties: dynamics (or subject to change), cost-benefit optimization, energy consumption, prioritization, and desire for existence prolongation. In the case of livestock smallholder farmers' households, food consumption is required to prolong the system's existence. To obtain food, they need to exchange information with the surrounding environment, either by producing the food themselves (i.e., rearing livestock) or exchanging it with other households (i.e., trading in the market) (Vuong, Nguyen, et al., 2022a). As the livestock smallholder farmers' collection of information is optimized for rearing livestock (Nguyen et al., 2023), they tend to buy rearing resources from the market (e.g., feed, medicines, etc.) to produce livestock for self-sustaining and sell for money (which is used for later trading in the market). Multiple factors can contribute to the information-exchanging processes of households to obtain food.

Among them, information availability and accessibility are two common elements. Information availability refers to the physical existence of the information in reality, while information accessibility refers to whether the households can discern and access the information if it exists. Therefore, when the information required for livestock production (e.g., knowledge, feed, medicines, etc.) is lacking and cannot be obtained from the market due to high prices, the production and subsequent trading processes are adversely affected. As a result, the food intake of the household will decline, increasing the likelihood of food insecurity.

Specifically, several studies have linked the production and trading difficulties to the effectiveness and efficiency of livestock. According to Balehegn et al. (2020), the greatest challenge in developing the livestock industry in many low-to-medium-income countries

(LMICs) and achieving food and nutritional security is the lack of a sufficient supply of high-quality feed. Availability of adequate livestock feed is a challenge that requires farmers to know more information on alternative feed resources that can be provided to animals for consumption. Several studies have reported challenges associated with livestock production, such as the availability of pasture and feed, access to water resources, animal breeding and management, global trade, climate change and fluctuation, marketing, and socioeconomic constraints (Eeswaran et al., 2022; Mbatha, 2021). Prem (1999) also highlighted that nutrition, animal health, animal genetics and extension services are part of the challenges affecting farmers and agricultural household productivity. Knowledge and understanding of animal diseases, their control mechanisms, the availability of vaccines and their usage are essential in promoting good animal health in a herd (Prem, 1999).

Based on the above reasoning, we assumed households with livestock production and selling difficulties are more likely to experience food insecurity.

2.2. Model construction and analysis

2.2.1. Variable selection

Data was obtained from the Data in Emergencies Monitoring (DIEM) system of the Food and Agriculture Organization (FAO) (2021). The FAO's DIEM-Monitoring System collects, analyses, and shares shock and livelihood data in nations prone to multiple shocks. DIEM-Monitoring System updates information on how shocks affect farming communities' livelihoods and food security to influence decision-making. The data are collected from producers, traders, marketers, input suppliers, extension officers, and other key informants.

Through the DIEM system, the FAO conducted a household survey in 2021 to monitor agricultural livelihoods and food security in the Philippines. A random sampling strategy was utilized to select 2087 households representative at the regional level (admin 1) for seven out of 18 regions of the country. The survey was undertaken between 31 August-31 October 2021 through telephone interviews using random digital dialing in the following provinces: Cagayan Valley, Calabarzon, Central Luzon, Ilocos, Soccsksargen, Western Visayas, and the Bangsamoro Autonomous Region in Muslim Mindanao (BARMM). Each survey interview had a duration of 20 minutes and was administered in one of the Philippines' official languages, English, Cebuano/ Bisaya, Tagalog/ Filipino, Ilocano, Pangasinan, Ilonggo/ Hiligaynon, and Maguindanao.

To measure the food insecurity of livestock smallholder farmers, we employed three variables retrieved from the DIEM's original dataset: *fies_whlday*, *fies_skipped*, and *fies_healthy*. These variables were transformed into *ExtremeFoodInsecurity*, *FoodInsecurity*, and *LessNutrition*, respectively, for the sake of presentation and interpretation. The selected variables correspond to the severity of the household's food insecurity, from lack of nutrition (*LessNutrition*) to skipping a meal (*fies_skippedI)* and not eating for a whole day (*fies_whlday*) (see Table 1).

Variables *ls_proddif* and *ls_salesdif* in the original dataset were retrieved and transformed into *ProductionDifficulty* and *SellingDifficulty* to estimate whether the respondents' households had faced any production or selling of their products within the last three months. These two variables were used as predictors variables, while three variables about food insecurity were used as outcome variables, subsequently resulting in three different statistical models (see Subsection 2.2.2)

Table 1. Data descriptions

Variable name	**Explanation**	**Coded variable(s) in the dataset**	**Value**
ExtremeFoodInsecurity	Whether the respondent's household did not eat for a whole day because of a lack of money or other resources to get food during the last 30 days	*fies_whlday*	1 = Yes 0 = No
FoodInsecurity	Whether the respondent's household skipped a meal because of a lack of money or other resources to get food during the last 30 days	*fies_skipped*	1 = Yes 0 = No
LessNutrition	Whether the respondent's household was unable to eat healthy and nutritious food because of a lack of money or other resources to get food during the last 30 days	*fies_healthy*	1 = Yes 0 = No
ProductionDifficulty	Whether the respondent's household had faced any difficulty with livestock production over the last 3 months	*ls_proddif*	1 = Yes 0 = No
SellingDifficulty	Whether the respondent's household had faced any difficulty with selling the products over the last 3 months	*ls_salesdif*	1 = Yes 0 = No

2.2.2. Statistical models

To identify the effects of livestock production and selling difficulties of smallholder farmers on their food insecurity, we constructed three models, each with similar predictor variables but a different outcome variable. Model 1 with *LessNutrition* as the outcome variable is presented as follows:

$$LessNutrition \sim normal(\mu, \sigma) \tag{1.1}$$

$$\mu_i = \beta_0 + \beta_1 * ProductionDifficulty_i + \beta_2 * SellingDifficulty_i \tag{1.2}$$

$$\beta \sim normal(M, S) \tag{1.3}$$

The probability around μ is determined by the form of the normal distribution, whose width is specified by the standard deviation σ. μ_i indicates the likelihood that smallholder farmer i is unable to eat healthy and nutritious food; $ProductionDifficulty_i$ indicates whether farmer i experiences any production difficulties; $SellingDifficulty_i$ whether farmer i experiences any selling difficulties. Model 1 has four parameters: the coefficients, β_1 and β_2, the intercept, β_0, and the standard deviation of the "noise", σ. The coefficients of the predictor variables are distributed as a normal distribution around the mean denoted M and with the standard deviation denoted S.

The logical network of Model 1 is displayed in Figure 1.

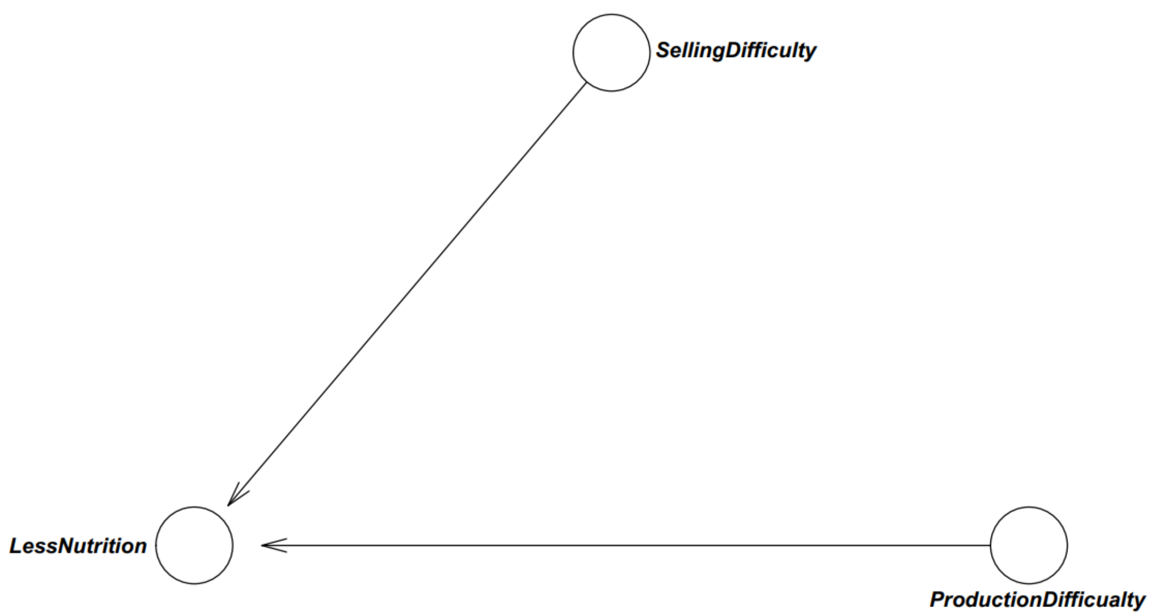

Figure 1. Logical network of Model 1

Similarly, Model 2, with *FoodInsecurity* being the outcome variable, and Model 3, with *ExtremeFoodInsecurity* as the outcome variable, are presented as follows:

$$FoodInsecurity \sim normal(\mu, \sigma) \tag{2.1}$$

$$\mu_i = \beta_0 + \beta_1 * ProductionDifficulty_i + \beta_2 * SellingDifficulty_i \tag{2.2}$$

$$\beta \sim normal(M, S) \tag{2.3}$$

In this model, μ_i indicates the likelihood that smallholder farmer i skips a meal because of a lack of money or other resources to get food.

$$ExtremeFoodInsecurity \sim normal(\mu, \sigma) \tag{3.1}$$

$$\mu_i = \beta_0 + \beta_1 * ProductionDifficulty_i + \beta_2 * SellingDifficulty_i \tag{3.2}$$

$$\beta \sim normal(M, S) \tag{3.3}$$

Here, μ_i indicates the likelihood that smallholder farmer i does not eat for a whole day because of a lack of money or other resources to get food.

2.2.3. Analysis and validation

The Bayesian Mindsponge Framework (BMF) analytics was employed in the current study as the analytical framework (Nguyen et al., 2022a, 2022b). Specifically, the analytics combines the reasoning capabilities of Mindsponge Theory and the inference advantages of the Bayesian analysis (Vuong, Nguyen, et al., 2022a). We employed the Mindsponge theory to reason and construct models for examining how livestock production and selling difficulties affect food security in the Philippines (see Subsection 2.1 for the theoretical foundation and Subsection 2.2.2 for constructed models). The theory has been employed in various disciplines to study and explain many psycho-social phenomena. One of its strengths is that it provides an information-processing analytical framework (with important principles) that enables us to construct parsimonious models (Bentler & Mooijaart, 1989; Cougle, 2012; Simon, 2001). As for Bayesian analysis, its theoretical construct helps fit the parsimonious models. In particular, in Bayesian inference, all properties, including unknown parameters and uncertainties, are considered and treated as probability, so it is not required to add control variables into the model (Gill, 2014).

Other advantages of Bayesian analysis also make the BMF analytics preferential in this study. With the support of the Markov chain Monte Carlo algorithm, Bayesian analysis can produce a more precise estimation with a small sample size, comparatively with methods dependent on the asymptotic assumption, as it only utilizes the data at hand for inference (Dunson, 2001; Uusitalo, 2007). The current study's sample size is relatively small, so employing Bayesian analysis can help improve the precision of the estimated results. Moreover, as stated by Halsey, the fickle *p*-value is a major reason causing irreproducible results, causing crises in various disciplines (including psychological and social sciences) (Camerer et al., 2018; Halsey et al., 2015; Open Science Collaboration, 2015). The Bayesian analysis depends on credible intervals, which are theoretically more advantageous than confidence intervals and can be visually plotted for result interpretation, so the *p*-value is not required for evaluation (McElreath, 2018; Wagenmakers et al., 2018).

We employed the bayesvl R package to perform Bayesian analysis due to its user-friendly operating style, capability to depict attention-grabbing images, and cost-effectiveness (La & Vuong, 2019; Vuong, 2018; Vuong, Nguyen, et al., 2022b). For the simulation set-up, we used four Markov chains, each with 5,000 iterations (of which the first 2,000 were designated warmup iterations), to fit the models. As the current study is explorative, we applied uninformative priors for all parameters to avoid subjective bias. After the models were fitted, the effective sample size (*n_eff*) and Gelman-Rubin shrink factor (*Rhat*) were evaluated to determine whether the Markov chains were well-convergent. When the *Rhat* values are equal to 1, and the *n_eff* values are greater than 1,000, it indicates that the Markov chain's parameters have converged well. If so, the Markov property can be deemed held. The trace, Gelman-Rubin-Brooks, and autocorrelation plots were also used to confirm the Markov chains convergence.

3. Results

3.1. Impacts of livestock production and selling difficulties on food insecurity

3.1.1. Model 1: LessNutrition as the outcome variable

As can be seen from Table 2, all the *n_eff* values are larger than 1,000, and *Rhat* values are equal to 1, so Model 1's Markov chains can be deemed convergent. The trace plots shown in Figure 2 confirm the convergence. In particular, after the warmup period (2,000th iteration), all the Markov chains fluctuate around a central equilibrium, showing a clear signal of convergence.

Table 2: Model 1's simulated posterior coefficients.

Parameter	Mean	Standard deviation	n_eff	Rhat
Constant	-1.38	0.35	6057	1
b_ProductionDifficulty_LessNutrition	1.03	0.46	6577	1

b_SellingDifficulty_LessNutrition	1.10	0.46	7154	1

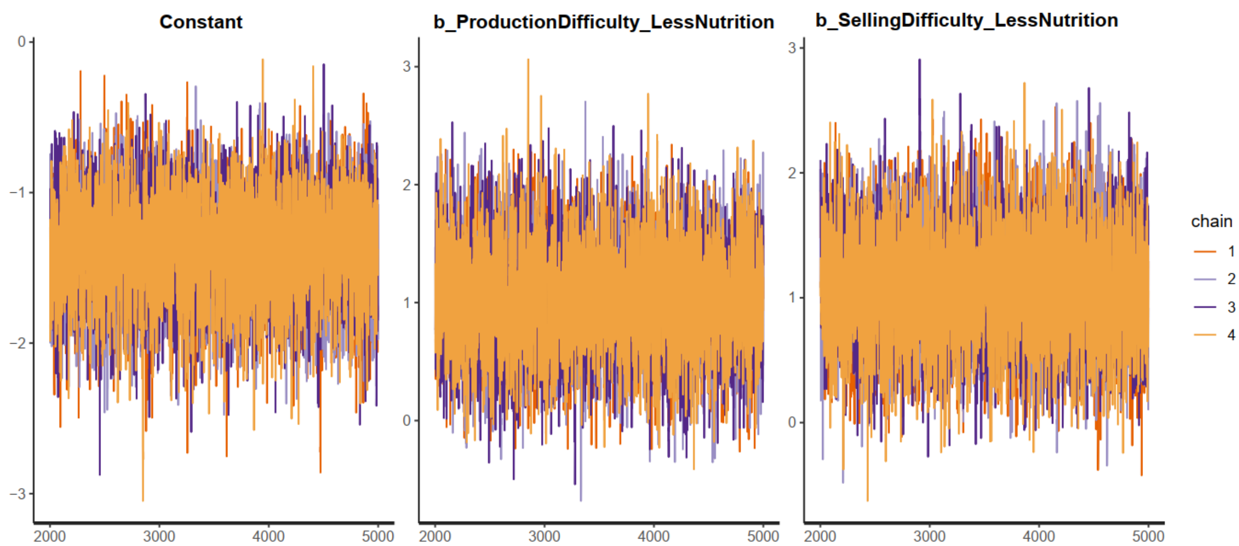

Figure 2: Model 1's trace plots

Figure 3 demonstrates the *Rhat* value of each parameter's simulated value. The value shrinks rapidly to 1 after some finite iterations, implying the convergence of the chains. Also, the Markov property, or the memoryless property of the stochastic simulation process, can be evaluated through the autocorrelation plots. The autocorrelation levels of all parameters decline swiftly to 0, validating the existence of Markov property during the simulation (see Figure 4).

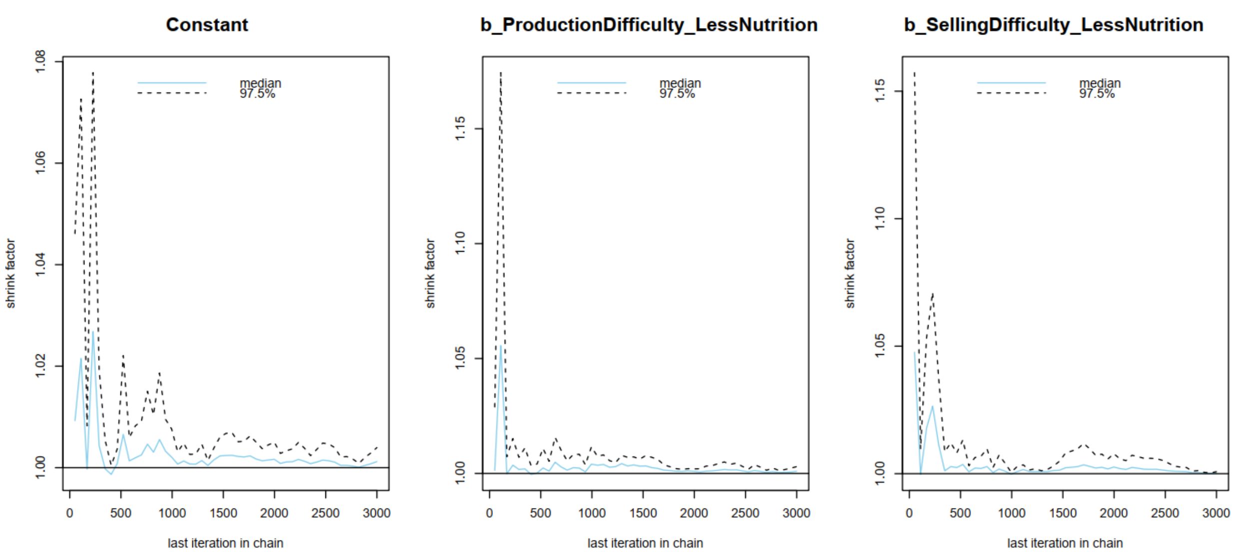

Figure 3: Model 1's Gelman-Rubin-Brooks plots

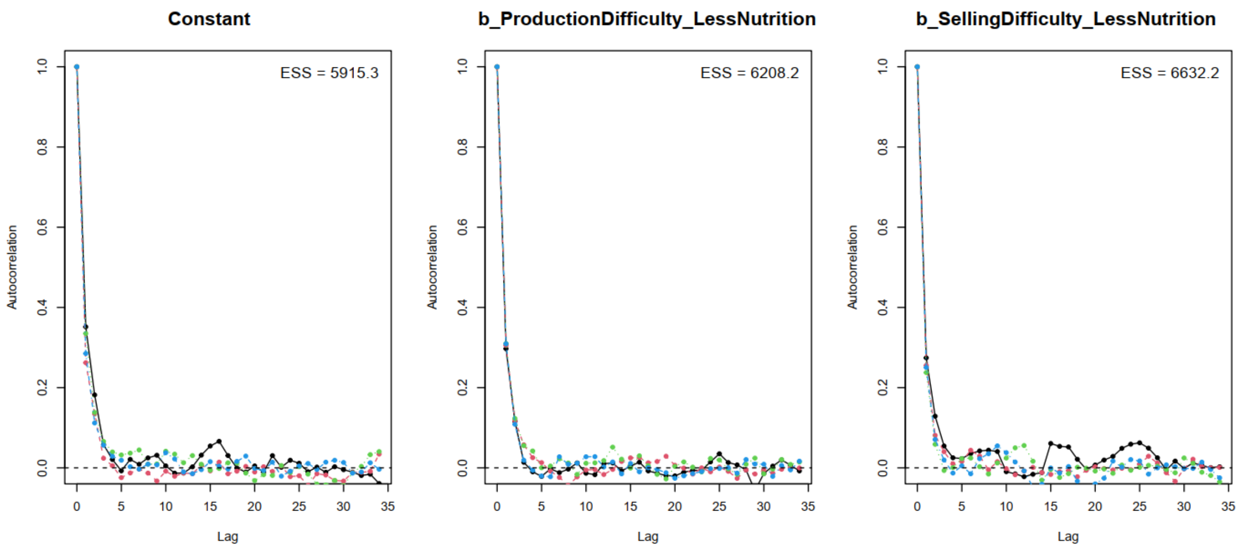

Figure 4: Model 1's autocorrelation plots

Estimated results in Table 2 indicate that both *ProductionDifficulty* and *SellingDifficulty* have positive impacts on *LessNutrition* ($M_{ProductionDifficulty\_LessNutrition}$= 1.03 and $S_{ProductionDifficulty\_LessNutrition}$= 0.46; $M_{SellingDifficulty\_LessNutrition}$= 1.10 and $S_{SellingDifficulty\_LessNutrition}$= 0.46). The results suggest that livestock production and selling difficulties are statistically significant and linked to a higher likelihood of consuming food with lower nutritional value. The impact of livestock selling difficulties on the likelihood of consuming food with lower nutritional value is almost similar to that of livestock production difficulties (Figure 5).

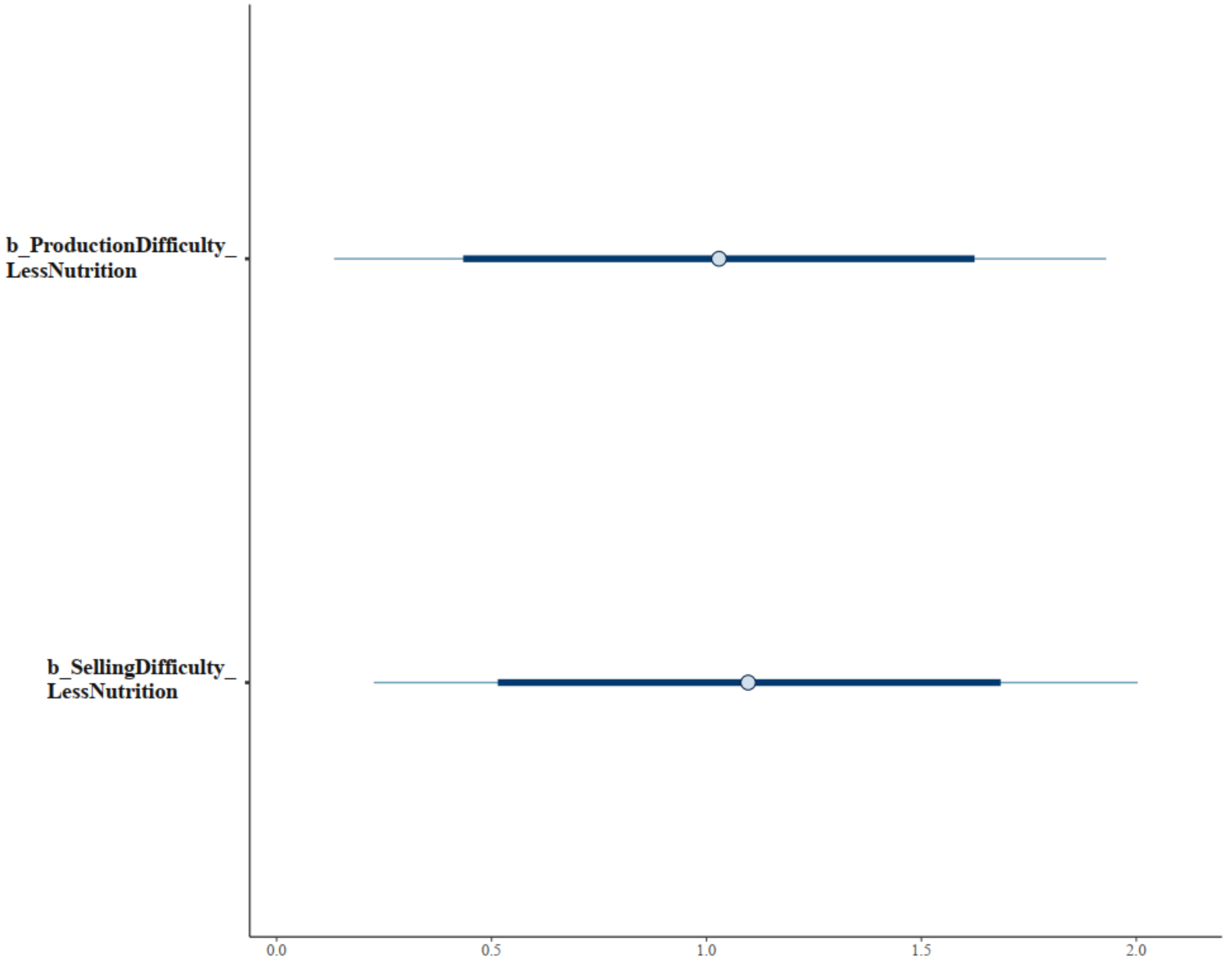

Figure 5: Model 1's posterior distributions

Posterior distributions of the parameters are illustrated in Figure 5. All of the distribution of *ProductionDifficulty* and *SellingDifficulty* lie on the positive sides of the *x*-axis, suggesting highly reliable positive associations of *ProductionDifficulty* and *SellingDifficulty* with *LessNutrition*.

3.1.2. Model 2: FoodInsecurity as the outcome variable

Based on the *n_eff* and *Rhat* values, we can deem that Model 2's Markov chains are all well-convergent (see Table 3). The trace plots (see Figure 6), Gelman-Rubin-Brooks plots (see Figure A1), and autocorrelation plots (see Figure A2) also confirm their convergence.

Table 3: Model 2's simulated posterior coefficient

Parameter	Mean	Standard deviation	n_eff	Rhat
Constant	-1.49	0.37	6307	1

b_ProductionDifficulty_ FoodInsercurity	0.85	0.47	6431	1
b_SellingDifficulty_FoodInsercurity	1.45	0.46	6643	1

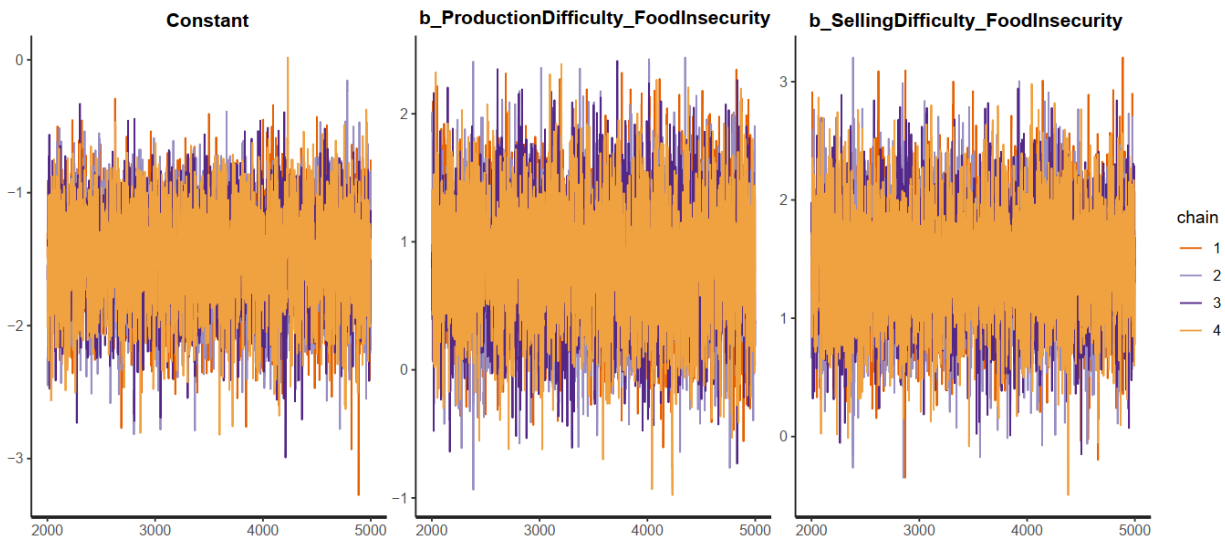

Figure 6: Model 2's trace plots

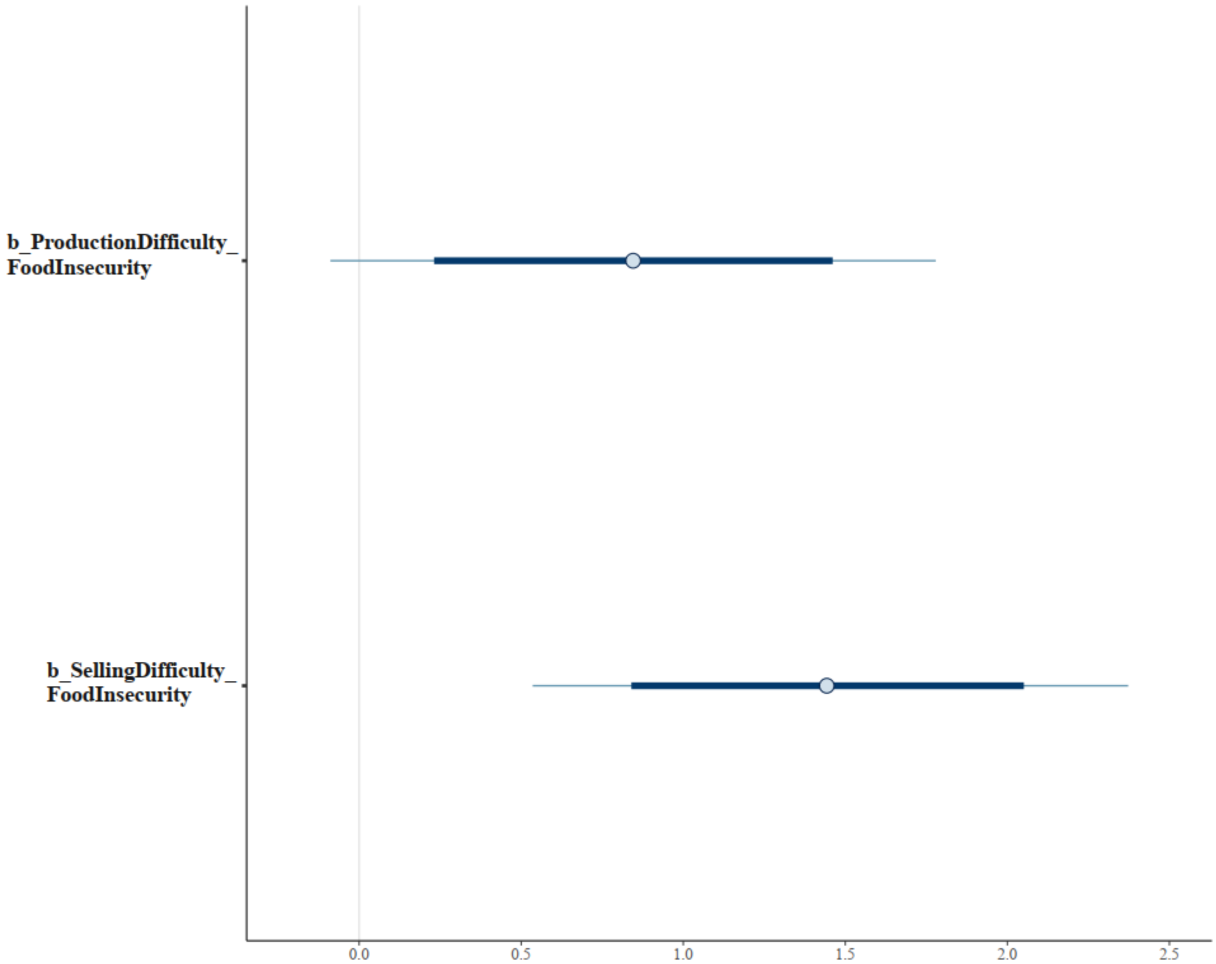

Figure 7: Model 2's posterior distributions

As can be seen from Table 3, both *ProductionDifficulty* and *SellingDifficulty* have positive impacts on *FoodInsercurity* ($M_{ProductionDifficulty\_FoodInsercurity} =$ 0.85 and $S_{ProductionDifficulty\_FoodInsercurity} =$ 0.47; $M_{SellingDifficulty\_FoodInsercurity} =$ 1.45 and $S_{SellingDifficulty\_FoodInsercurity} =$ 0.46). However, the effect *SellingDifficulty* has a larger magnitude on *FoodInsercurity* than that of *ProductionDifficulty.* To elaborate, the findings imply that farmers facing difficulties in livestock production and selling were more likely to skip meals due to a lack of money or other resources. The impact of livestock selling difficulties on food security conditions is stronger than livestock production difficulties (see Figure 7).

In Figure 7, both the posterior distributions of *ProductionDifficulty* and *SellingDifficulty* lie on the positive side of the axis, indicating highly reliable positive associations of *ProductionDifficulty* and *SellingDifficulty* with *FoodInsercurity*.

3.1.3. Model 3: ExtremeFoodInsecurity as the outcome variable

The statistical diagnosis values (i.e., *n_eff* and *Rhat*) and visual diagnoses of trace, Gelman-Rubin-Brooks, and autocorrelation plots confirm the convergence of Model 3's Markov chains (see Table 4 and Figures 8, A3, and A4). Thus, the estimated results can be used for interpretation.

Table 4: Model 3's simulated posterior coefficient

Parameter	Mean	Standard deviation	n_eff	Rhat
Constant	-12.45	5.68	1666	1
b_ProductionDifficulty_ ExtremeFoodInsercurity	1.18	1.45	2678	1
b_SellingDifficulty_ ExtremeFoodInsercurity	9.56	5.73	1649	1

Figure 8: Model 3's trace plots

Table 4 indicates that only *SellingDifficulty* has a positive impact on *ExtremeFoodInsercurity* ($M_{SellingDifficulty\_ExtremeFoodInsercurity}$ = 9.56 and $S_{SellingDifficulty\_ExtremeFoodInsercurity}$ = 1.18), while the effect of *ProductionDifficulty* on *ExtremeFoodInsercurity* is ambiguous ($M_{ProductionDifficulty\_ExtremeFoodInsercurity}$ = 1.18 and $S_{ProductionDifficulty\_ExtremeFoodInsercurity}$ = 1.45). These findings imply that challenges in selling the livestock are linked to a higher likelihood of experiencing extreme food security conditions (i.e., not eating for a whole day), but challenges in producing the livestock are not.

The estimated posterior distribution of *SellingDifficulty* lies entirely on the positive side of the *x*-axis, indicating a highly reliable positive association between *SellingDifficulty* and *ExtremeFoodInsercurity*. Meanwhile, the distribution of *ProductionDifficulty* shows an unclear pattern (see Figure 9).

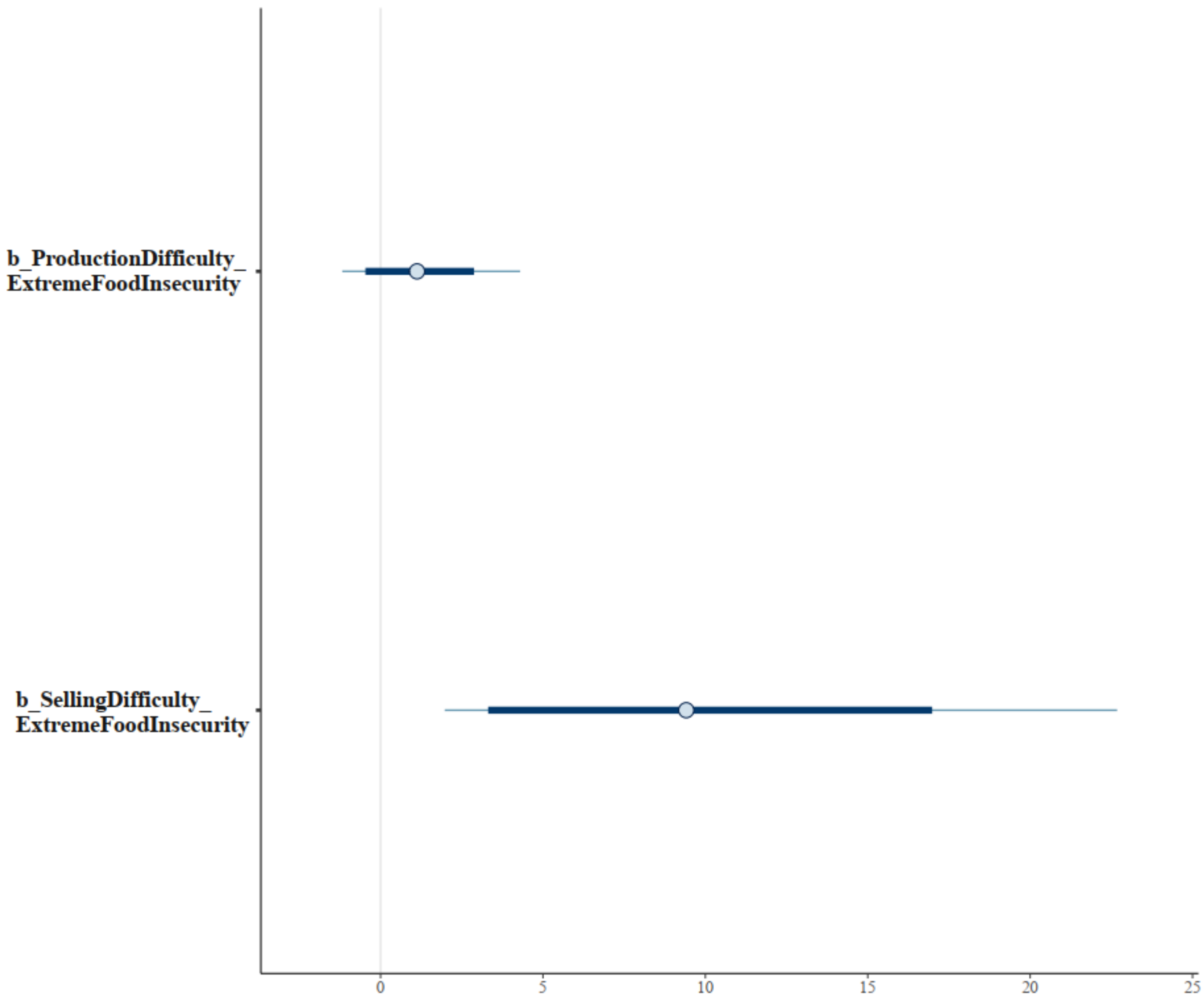

Figure 9: Model 3's posterior distributions

3.2. Reasons behind the livestock production and selling difficulties

In the survey of DIEM, when the respondents reported that their households had produced livestock or both livestock and crops for consumption and sale in the past 12 months, they were asked questions associated with the production and sale of livestock, including the difficulties. Specifically, households facing production and selling difficulties were asked about their main challenges when producing and selling livestock. The respondents' answers are presented in the current section to specify the reasons behind the livestock production and selling difficulties of livestock smallholder households.

3.2.1. Livestock production difficulties

According to Figure 10, the primary challenges to raising livestock are finding feed (35%) and controlling livestock diseases (33%). The challenges associated with buying feed are caused by a number of problems, including a lack of supply, high pricing, and insufficient market access. On the other side, livestock diseases have a serious negative impact on animal health, which results in decreased output, higher rates of mortality, and financial hardship for farmers.

Other factors, such as limited pasture access (9%), difficulty accessing veterinary services (7%), difficulty in accessing veterinary inputs (5%), and other variables related to labor, security, and access to the livestock market (11%) also contribute to these challenges (Figure 10). For livestock farmers, these issues pose considerable obstacles that harm their productivity and profitability.

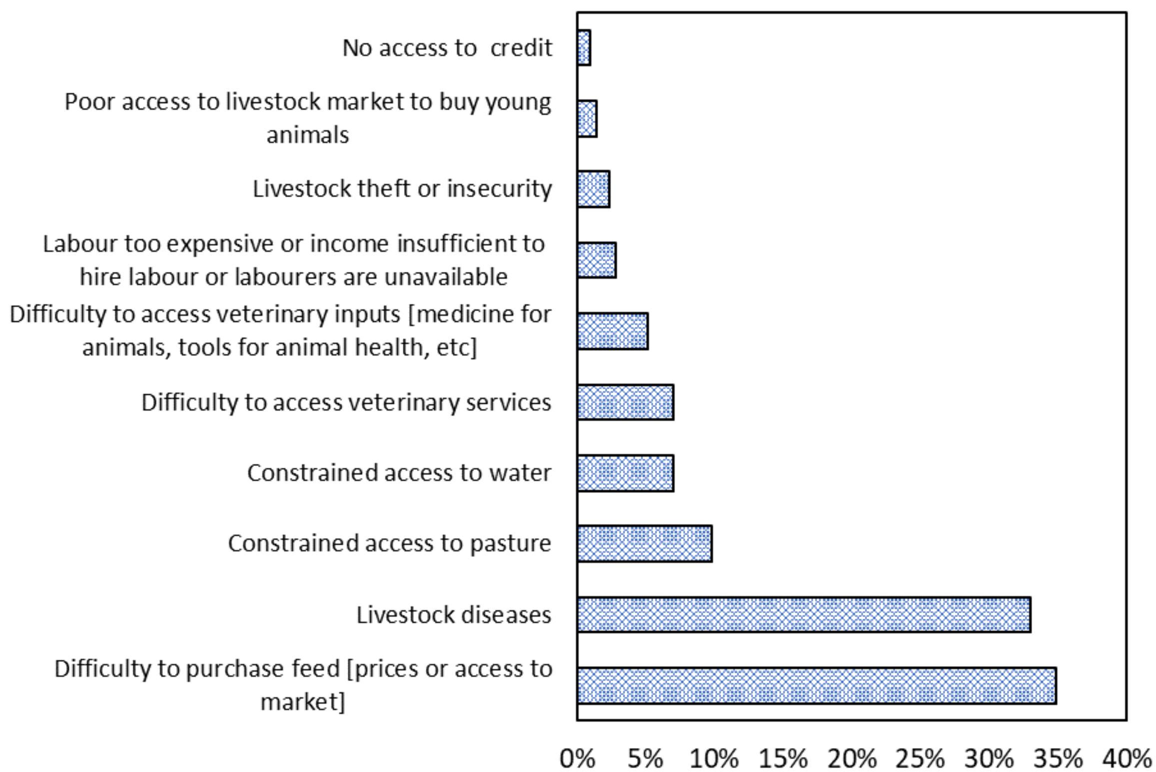

Figure 10: Main Factors Affecting Livestock Production Challenges

3.2.2. Livestock sales difficulties

According to Figure 11, the main factors contributing to difficulties in livestock selling are higher marketing costs (24%) and low prices (23%). Higher marketing costs include transportation, storage, and promotion of livestock products. These costs can significantly impact the profitability of livestock selling and pose challenges for farmers in finding buyers or accessing profitable markets. Farmers may face financial difficulties and struggle to cover their production costs when prices are too low.

Other factors influencing livestock trading difficulties include local customers or regular traders not buying as much as usual (18%), damage or losses resulting from delays or inability to access markets physically (13%), difficulties processing products other than closure of slaughterhouses (lack of access to processing inputs, equipment) (8%), closure of slaughterhouse or difficulties accessing slaughterhouse (4%) and others as well. (Figure 11).

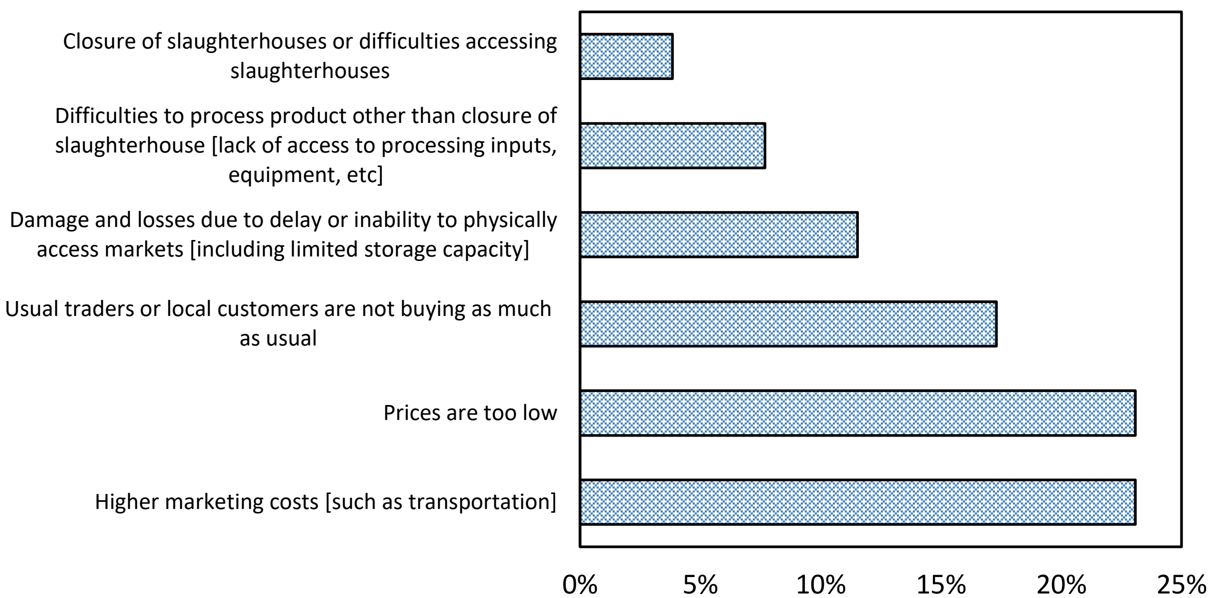

Figure 11: Main Factors Affecting Livestock Trading Challenges

4. Discussion

Employing the Bayesian Mindsponge Frameworks analytics on the dataset of DIEM, we found that livestock production and selling difficulties are crucial factors contributing the food insecurity in the Philippines. Specifically, the three most prominent reasons behind the selling difficulties are market accessing costs, low selling prices, and low demand for livestock products. Meanwhile, those production difficulties are feed purchasing difficulties, livestock diseases, and limited access to pasture.

The effects of production and selling difficulties on different severity of food insecurity vary. Specifically, production and selling difficulties contribute equally to the households' likelihood of eating less healthy and nutritious food. However, the production difficulties have smaller impacts on the likelihood of skipping meals and even ambiguous impacts on the likelihood of not eating for a whole day compared to the effects of selling difficulties. These differences can be explained with more details from the information-processing perspectives and the underlying reasons for production and selling difficulties.

As explained above, to acquire food, the household must exchange information with the surrounding environment by producing livestock or trading them for other types of food. Difficulty producing or selling livestock can adversely affect the households' food security. However, households facing selling problems are more vulnerable to food insecurity (i.e., skipping meals) and extreme food insecurity (i.e., not eating for a whole day) than those facing production difficulties for their dependence on the market.

Smallholder farmers are often poor, having limited capital and land and therefore relying on direct sales of livestock products like milk, eggs, and dung for the generation of capital regularly, as well as sporadic sales of live animals, wool, meat, feathers, and hides (Ahuja, 2013). It is reported that Asian countries have been experiencing a chronic feed shortage and are heavily dependent on the importation of feed and feed additives; therefore, any changes to trade or price volatility will affect the animal and feed industry and ultimately compromise food security (Ahuja, 2013).

Besides livestock trading, the market also plays a crucial (or even indispensable) role in the livestock production of households. While the importance of the market for livestock sales is clear, livestock production is also significantly influenced by the products and services purchased from the market. Without access to the market, feed, medicines, and veterinary services cannot be acquired, intensifying the largest production problems (e.g., difficulty in purchasing feed and livestock diseases). In particular, the challenge of livestock diseases is in line with those who postulated that, unlike in developed countries, livestock diseases are a challenge commonly attributed to poor control as most are preventable (Grace et al., 2015). Although market access is useful for solving production problems, it requires the participants to have sufficient capital.

When households fall into food insecurity (i.e., skipping meals) and extreme food insecurity (i.e., not eating for a whole day) situations, it also means that their saving has been depleted significantly. Such saving depletion subsequently makes them rely more on the market, expecting to sell livestock for money. However, why do the household not consume their own livestock products?

According to the Mindsponge Theory, a system is more likely to optimize behaviors based on its priority, which is greatly influenced by the perceived availability and accessibility of resources. In this case, the households' priority should be prolonging their existence.

Livestock products are generally more nutritious than crop-based products (Rizvi et al., 2021), making them more expensive. With a given amount of money, households can sustain their existence for longer by consuming crop-based food (i.e., rice) than livestock products. Therefore, households with limited resources and choices might consider fasting or starving as a survival strategy to wait until the livestock products can be sold (Nguyen et al., 2023; Vuong, 2022a, 2022b). Acosta et al. (2021) and Bahta (2022) consistently reported that livestock sales were used as a coping strategy against drought and climate shock for household income and consumption support. Other studies postulated that except for functions or times of extreme need, the farmers hardly ever eat or sell their livestock but keep them as a source of wealth (Nuvey et al., 2022). With this reasoning approach, the varying impacts of production and selling difficulties on various households' food insecurity situations can be explained.

Given the sensitivity of livestock smallholder households to the market, especially those with limited saving resources, we propose the following recommendations to alleviate food insecurity:

- The livestock market should be regulated to balance the prices of livestock products and products and services needed for livestock production.
- The information exchanging mechanism (e.g., information dissemination channels, product transportation, and service provision) should be bolstered to create more livestock demand and increase the supply of products and services required for livestock production.
- Credit-supporting systems should be implemented and expanded to reach poor livestock smallholder households. Balana and Oyeyemi (2022) postulated that certain smallholders' lack of participation in the credit market might not be due to their inability to receive credit but rather to their risk aversion or lack of access to relevant information about available loan sources and their terms.

The current study is not without limitations (Vuong, 2020). Although the total number of observations of the dataset is adequate, the number of respondents who produce livestock is limited, reducing the representativeness of the current study results. Further studies with larger sample sizes should be conducted to validate the current study's findings. Although we provided detailed reasons underlying the production and selling difficulties of the households, we could not examine how much these reasons affect the households' food insecurity situations due to the limited sample size.

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