ADDRESSING THE HIDDEN HUNGER AMONG CHILDREN THROUGH MICRONUTRIENT SUPPLEMENTATION: THE ROLE OF NATIONAL POLICIES IN SCHOOL FEEDING

Ni Putu Wulan Purnama Sari[1], Adrino Mazenda[2*], Michael Kemboi[3], Minh-Hoang Nguyen[4], Quan-Hoang Vuong[4,5]

[1] Faculty of Nursing, Widya Mandala Surabaya Catholic University, East Java, Indonesia

[2] Faculty of Economic and Management Sciences, School of Public Management and Administration, University of Pretoria, Hatfield, South Africa

[3] Department of Political Science, University of Nairobi, Kenya

[4] Centre for Interdisciplinary Social Research, Phenikaa University, Hanoi, Vietnam

[5] Adjunct Professor, University College, Korea University, Seoul, South Korea

[*]Corresponding author: adrino.mazenda@up.ac.za (Adrino Mazenda)

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Abstract

Background: Overnutrition, undernutrition, and micronutrient deficiency present a major global public health challenge due to food insecurity. Micronutrient deficiencies are prevalent among children and result in impaired intellectual growth. Policy guidelines at the national level are essential for the success of micronutrient supplementation programs for children during school feeding.

Aim: This study aims to analyze how various national policies guiding the school meal programs—such as those related to school feeding, nutrition, health, food safety, agriculture, and the private sector—associate with the implementation of in-school micronutrient supplementation among countries with school meals programs.

Methods: The Bayesian Mindsponge Framework, combining the reasoning strengths of Mindsponge Theory and inference advantages of Bayesian analysis, was employed on a dataset of 126 government representatives who manage large-scale school meal programs in 126 different countries.

Results: Findings showed that school feeding policies were positively associated with in-school micronutrient supplementation, while nutrition policy had a negative association with these practices. Both associations were only moderately reliable. Policies on health, food safety, agriculture, and the private sector had ambiguous relationships with micronutrient supplementation among countries implementing school meal programs.

Conclusions: Findings highlight the evidence of school feeding policy's positive association with micronutrient supplementation in school meal programs, indicating effective policy guidance on these practices. There is a need to re-assess the implemented nutrition policy due to its negative association with these practices. Enhancing and strengthening the national policies on health, food safety, agriculture, and the private sector may increase their potencies in supporting in-school micronutrient supplementation among countries implementing school meal programs.

Keywords: school feeding; policy analysis; food insecurity; micronutrient supplementation; Bayesian Mindsponge Framework.

"On the second day, Kingfisher weakened and could not stand without shaking.
He tried to eat some vegetables, but they just tasted so bland.

—In "No-Fish Dietary"; *Wild Wise Weird* (Vuong, 2024).

1. Introduction

Globally, there is a pressing need to address the triple burden of malnutrition, which manifests through the coexistence of undernutrition (stunting and wasting), micronutrient deficiencies (often termed as hidden hunger), and overnutrition (overweight and obesity) within the same population, especially among school-aged children. The global statistics estimate that 149 million children under five are stunted (too short for age), 45 million wasted (too thin for height), 37 million overweight, and nearly half of the deaths of children under five years of age are linked to undernutrition (WHO, 2024). In low- and middle-income countries, the three elements of the triple burden of malnutrition can be found simultaneously with poverty, poor dietary choices, and a lack of knowledge about what constitutes the most nourishing foods as the contributing factors to this global burden on public health (Prentice, 2023).

Hidden hunger represents one of the three elements of the triple burden of malnutrition that poses a significant yet less visible threat to global public health. As opposed to overt malnutrition, hidden hunger is characterized by the lack of essential micronutrients, such as zinc, iron, folate, iodine, Vitamin A, vitamin D, and vitamin B12, which are critical for growth and overall well-being (Vishwakarma & David, 2021; Mehboob, 2022; Kiani et al., 2022). This form of malnutrition affects more than two billion people worldwide, especially in developing countries where there is limited diet diversity and reliance on low-cost staple foods (Lowe, 2021). Considering that hidden hunger often remains unnoticed and only surfaces through the diagnosis of deficiency symptoms (Majumder, Datta, & Datta, 2019), children are particularly vulnerable. In growing children, hidden hunger contributes to malfunctioning in a child's intellectual and growth impairment, perinatal complications, and health concerns such as stunting, wasting, vitamin diseases, congenital heart disease, degenerative diseases related to aging, and increased child morbidity and mortality (Kiani et al., 2022; Zaheer, Akhtar, & Sharif., 2023).

Global estimates indicate that of the 372 million children affected by micronutrient deficiencies, 99 million of them live in South Asia, 98 million in sub-Saharan Africa, and 85 million in East Asia and the Pacific (Stevens et al, 2022). Besides, among the five million children who die each year from preventable diseases such as malaria, diarrhea, and respiratory infections, half of these deaths are linked to undernutrition, including micronutrient deficiencies (Palmer, Bedsaul-Fryer, & Stephensen, 2024). However, in instances where children are adequately nourished, they are able to attain their full cognitive and motor developmental potential and contribute to positive societal repercussions (Mattei & Pietrobelli, 2019). Additionally, maintaining proper amounts of macronutrients and micronutrients are key to children's physiological growth while preventing diseases (Savarino, Corsello, & Corsello, 2021).

Thus, to attain the benefits that come with optimal development and to avert the negative implications of hidden hunger, comprehensive policies related to school meal programs encompassing areas of school feeding, nutrition, health, food safety, agriculture, and the private sector have been established at the national level to ensure that children receive adequate nutrition (Kroth, Geremia, & Mussio, 2020; Toro et al., 2023; GCNF, 2022a; Verguet et al., 2023). As part of these national policies' implementation, many countries have implemented school meal programs aimed at improving micronutrient intake among children, thereby addressing the hidden hunger.

In Lebanon, for instance, the distribution of snacks through an emergency school feeding program was linked to improved dietary diversity and food security among children (Jamaluddine et al., 2022). Similarly, an analysis of nutritional adequacy over a two-day period in Japan, comparing days with and without school lunches, revealed that nutrient deficiencies were significantly higher on days without school lunches for most macro- and micro-nutrients (Horikawa et al., 2020). Also, in India, the use of school-based double-fortified salt provided through the midday meal addressed iron deficiency in rural Bihar, leading to an improvement in the anemic status of children (Krämer, Kumar, & Vollmer, 2018). This shows that initiatives such as school-feeding programs are not standalone but intersect with health policies to facilitate micronutrient supplementation. In the same way, health policies in the form of micronutrient powder intervention not only decrease the prevalence of anemia in young children but also contribute to an increase in diet diversity (Zhang et al., 2024). However, in certain instances, such as Kenya, low dietary diversity in terms of low consumption of fruits and animal products among children in the lunch program in Kilifi County resulted in low micronutrient intake (Mungai et al., 2024). This suggests that dietary diversity is essential in school meal programs to address low micronutrient intake.

Further, the emphasis of national policies is also on nutrition-specific interventions through multisectoral involvement and collaboration to address the growing micronutrient deficiencies in children (Wali, Agho, & Renzaho, 2023; Yazdanpanah et al., 2023). Notably, private sector engagement in addressing micronutrient deficiencies is key to the success of food fortification initiatives and the implementation of nutritional policies that promote healthy diets in the Eastern Mediterranean Region (Ali et al., 2021). In similar resource-constrained contexts, nutrition education initiatives coupled with agricultural interventions have proven effective in treating vitamin deficiencies and improving both the availability and diversity of food (Rufati & Awalia, 2023).

Given the critical role of national policies in enhancing micronutrient supplementation and their potential to address the hidden hunger among school-aged children, there is an urgent need for a detailed analysis of the national policies guiding school meal programs. Therefore, this study intends to offer insights into how these interventions could be optimized by examining how national policies impact in-school micronutrient supplementation. In doing so, this study seeks to contribute to the development of more effective strategies for combating hidden hunger among children.

2. Method

2.1. Theoretical Foundation

This study employed the mindsponge theory (MT) as its theoretical framework. The term 'mindsponge' serves as a metaphor for comparing the mind to a sponge that eliminates incompatible values while assimilating new ones that resonate with its fundamental values (Vuong & Napier, 2015). Initially, the mindsponge mechanism of the human mind was developed to explain the dynamics of acculturation and global thinking of managers and organizations (Vuong & Napier, 2015). Currently, MT has been enhanced by integrating detailed worldviews, Shannon's information theory (Shannon, 1948), and principles derived from quantum mechanics (Rovelli, 2018; Keppens, 2018; Rovelli, 2016), making it a granular interaction thinking theory which proposes an entropy-based notion of value to explain better the complexity of individual's, organization's, and system's information processes and behaviour (Vuong & Nguyen, 2024a, 2024b).

MT conceptualizes the brain as a mechanism for collecting and processing information, driven by specific goals and priorities determined by systemic needs. When examined through the framework of information processing, MT provides a dynamic viewpoint on the cognitive operations of the human brain (Vuong, 2023). The information-processing mechanism of MT posits that various elements can play a role in the accumulation of knowledge, which in turn affects one's psychology and behaviour (Vuong et al., 2022). Human behaviour is shaped by various mental products which influence his actual actions (Davies & Gregersen, 2014). The optimization process of information within MT leads to human behaviour that engages with external stimuli accordingly (Nguyen et al., 2023). Therefore, human mental products and behaviour are influenced by exposure to various information available in the environment.

In MT, an information unit is a possible alternative, a fundamental component of information processing that can be used synonymously with concepts like ideas and values (Davies & Gregersen, 2014; Vuong & Nguyen, 2024a, 2024b). Information availability pertains to the tangible presence of information in the environment, whereas information accessibility concerns one's ability to perceive and retrieve this information when it exists. According to the theory, the subjective cost-benefit judgment in the mind's information multi-filtering processes is considered the key point determining information absorption and ejection processes (Vuong & Napier, 2015; Vuong, 2023; Mantello et al., 2023). The subjective cost-benefit assessments are structured to optimize perceived gains while effectively reducing perceived limitations (Vuong et al., 2023; Vuong et al., 2021). The processes undertake subjective evaluations of costs and benefits to achieve the core objectives of the system, i.e., enhancing survival, facilitating growth, and ensuring reproduction while also adhering to its fundamental priorities (Vuong, 2023).

In MT, the mind is an information collection-cum-processor. While this definition is typically applied to the mental processes of the human mind, it can also extend to a wide range of biological and social systems (Vuong, 2023). MT shows a high credibility to be used in studies of the mind at a collective level, at household and national level in particular (Duong et al., 2024; Vuong et al., 2022; Vuong et al., 2021). In this study, a nation is conceptualized as an information collection-cum-processor, or a collective mind. MT employs a granular worldview to elucidate the intricate interactions of information units within the mind, which are defined as the possible alternatives perceived by the mind. These information units, whether newly acquired or pre-existing, interact, cohabit, and connect within the mind to establish a mindset, a set of core values (i.e., information units that are deemed important for prolonging the existence of the system) (Vuong & Nguyen, 2024b).

In the current study, implementing in-school micronutrient supplementation practices in school feeding programs can be deemed an outcome of the nation's information processes. For these practices to emerge and persist within the mind (i.e., implemented within the nation's school feeding programs), there are several conditions need to be met. First, the information regarding micronutrient supplementation needs to be available and accessible to the nation. In other words, the nation needs to have access to the knowledge, manpower, and resources that enable the implementation of such practices. Second, the information needs to be justified as beneficial so it can pass through the multi-filtering system of mind (or the nation). The multi-filtering system is mainly based on the mindset to determine whether the information is beneficial, neutral, or costly to the whole system. If the information is deemed beneficial after interacting with the mindset, it will be given a higher probability of being stored and used within the mind (i.e., upheld and implemented within the nation). If it is deemed costly, the information will be discarded. If it is deemed neutral, the information is kept within the mind's buffer zone for later evaluation.

The current study focuses on examining the second condition. In other words, it attempts to examine the types of core values within the mindset of a nation that can be associated with the implementation of in-school micronutrient supplementation practices in school feeding programs. In a nation, laws, policies, and standards play a pivotal role in guiding the national school meal programs to achieve their objectives so that they can be viewed as the mind's core values or constituents of the mindset. School meal programs have three basic objectives, including nutrition, education, and value transfer (Kretschmer, Spinler,

& Van Wassenhove, 2014), which often require the involvement of national laws, policies, or standards related to school feeding, nutrition, health, food safety, agricultural issues, and private sectors as guidelines and useful for legal protection. Therefore, by examining the associations between the presence of these laws, policies, or standards and the implementation of in-school micronutrient supplementation practices, the current study is expected to provide insights into how these interventions could be optimized by examining how national policies impact in-school micronutrient supplementation.

2.2. Model Construction

2.2.1. Dataset

This study utilized a dataset of 126 government representatives who managed large-scale school meal programs in 126 different countries. The dataset is about the results of a global survey on school meal programs in 2021, which can be accessed publicly at the Global Child Nutrition Foundation (GCNF) Global Survey of School Meal Programs database (GCNF, 2022b). GCNF is a non-political and non-profit entity. GCNF global survey was partly funded by the United States Department of Agriculture (USDA). This survey asked about national or large-scale school feeding programs (or school meal or school nutrition programs), including programs that are managed or administered by the national, regional, or local government, as well as large-scale school-based feeding programs that are managed by a non-governmental entity but in coordination with the national government. It also includes programs that do not involve the government but reach a substantial proportion of students in the country.

A standardized questionnaire was used in data collection. This instrument was developed by GCNF. This survey included 11 sections. Four sections contain national-level questions, meaning that the respondents only need to complete these sections once for each country. The remaining seven sections contain program-level questions, meaning that the respondents completed these sections separately for each large-scale school feeding program in each country. Compared to the 2019 GCNF Global Survey of School Meal Programs, this 2021 global survey gathered updated information regarding 1) the scope of school feeding in each country in the most recently completed school year (2020-2021), 2) government financing of, and involvement in, school feeding, 3) nutrition-, education-, and gender-related aspects of school feeding, 4) agricultural and private sector engagement, 5) related health and sanitation topics, and 6) the impact of emergencies. Among all variables, there were only seven variables employed in the current study's statistical analysis to achieve the study objective (see Table 1).

No demographic data was released on the GCNF Global Survey of School Meal Programs database, making the general characteristics of respondents remain confidential. The data of focal point contact information included country's name, survey started date, respondent's name, institution/department/office, job title, email, telephone number, and other contact options; Ministry/Agency and other contact options; was collected for GCNF administrative purposes only and were not be made publicly available in its database.

2.2.2. Variable Selection and Rationale

In the current study, we extracted seven variables from the GCNF dataset to be employed in statistical analysis (see Table 1). To measure six types of national policies, we employed variables of *SchoolFeedingPolicy, NutritionPolicy, HealthPolicy, FoodSafetyPolicy, AgricuturePolicy,* and *PrivateSectorPolicy,* which reflect the presence of any national laws, policies, or standards related to school feeding practices in the country. To measure in-school micronutrient supplementation practices, we employed the variable *MicronutrientSupp,* which reflects the presence of any nutritional supplements or micronutrient powders included in the school meals program. Table 1 below explains the variables' description in detail.

Table 1. Variable Description

Variable's Name	Description	Data Type	Value
SchoolFeedingPolicy	The presence of any national school feeding laws, policies, or standards related to school meals program.	Binary	1 = Yes 0 = No
NutritionPolicy	The presence of any national nutrition laws, policies, or standards related to school meals program.		
HealthPolicy	The presence of any national health laws, policies, or standards related to school meals program.		
FoodSafetyPolicy	The presence of any national food safety laws, policies, or standards related to school meals program.		
AgriculturePolicy	The presence of any national agriculture laws, policies, or standards related to school meals program.		
PrivateSectorPolicy	The presence of any national private sector laws, policies, or standards related to school meals program.		
MicronutrientSupp	The presence of any nutritional supplements or micronutrient powders included in the school feeding program.		

2.2.3. Statistical Model

In this study, we positioned the types of national policies as predictors of in-school micronutrient supplementation practices among countries implementing school meal programs. We formulated the analytical model (see Figure 1) based on the theoretical foundation of MT as presented below:

$$MicronutrientSupp \sim \text{normal}\left(\log\left(\frac{\mu_i}{1-\mu_i}\right), \sigma\right) \quad (1)$$

$$\log\left(\frac{\mu_i}{1-\mu_i}\right) = \beta_0 + \beta_1 * SchoolFeedingPolicy_i + \beta_2 * NutritionPolicy_i + \beta_3 * HealthPolicy_i + \beta_4 * FoodSafetyPolicy_i + \beta_5 * AgriculturePolicy_i + \beta_6 * PrivateSectorPolicy_i \quad (2)$$

$$\beta \sim normal(M, S) \quad (3)$$

The probability around the mean $\log\left(\frac{\mu_i}{1-\mu_i}\right)$ is determined by the shape of the normal distribution, where the width of the distribution is specified by the standard deviation of σ. μ_i indicates the probability that country i will implement any nutritional supplements or micronutrient powders included in school meal programs. $SchoolFeedingPolicy_i$, $NutritionPolicy_i$, $HealthPolicy_i$, $FoodSafetyPolicy_i$, $AgriculturePolicy_i$, and $PrivateSectorPolicy_i$ are the types of national policies guiding the school meal programs in country i. The model has an intercept β_0 and six coefficients, β_1-β_6. 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 below.

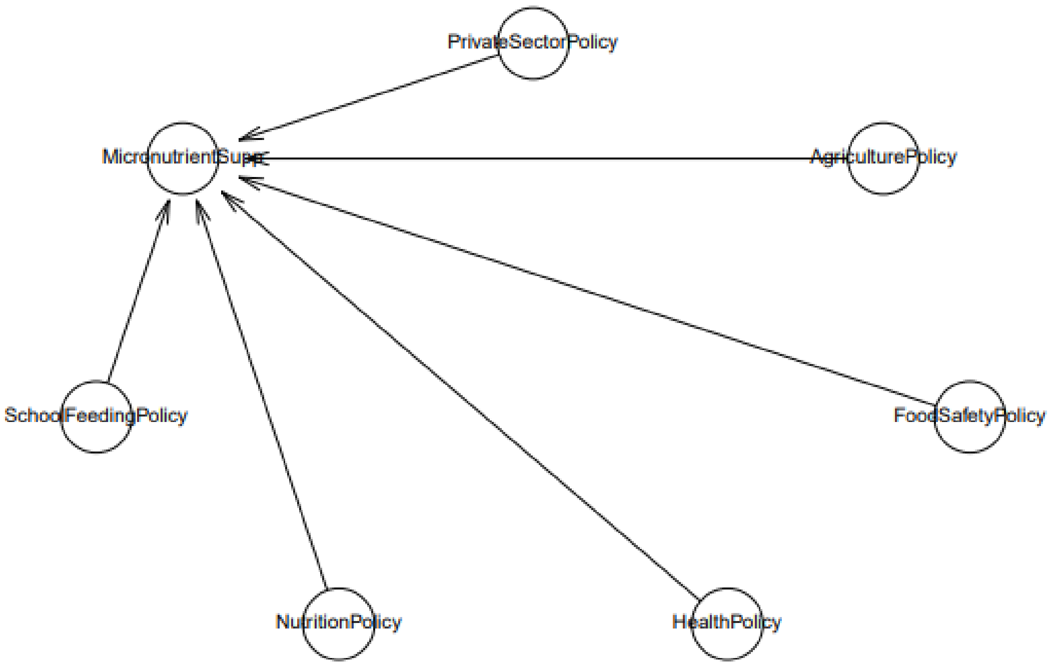

Figure 1. Model 1’s logical network

2.2.4. Data Analysis and Validation

Bayesian Mindsponge Framework (BMF) analytics was employed in the current study for several reasons (Nguyen et al., 2022; Vuong, Nguyen, & La, 2022). First, the analytical method integrates the logical reasoning capabilities of MT with the inferential advantages of Bayesian analysis, exhibiting a high degree of compatibility (Nguyen et al., 2022). Second, Bayesian inference is a statistical approach that treats all the properties (including the known and unknown ones) probabilistically (Csilléry et al., 2010; Gill, 2015), enabling reliable prediction of parsimonious models. Nevertheless, utilizing the Markov chain Monte Carlo (MCMC) technique still allows Bayesian analysis to deal effectively with various intricate models, such as multilevel and nonlinear regression frameworks (Dunson, 2001). Third, Bayesian inference has various advantages over the frequentist approach. One notable advantage is the ability to utilize credible intervals for result interpretation instead of relying solely on the dichotomous decision based on *p*-values (Halsey et al., 2015; Wagenmakers et al., 2018). The Bayesian analysis was performed on R using the **bayesvl** open-access package, which provides good visualization capabilities (La & Vuong, 2019).

In Bayesian analysis, selecting the appropriate prior is required during the model construction process. Due to the exploratory nature of this study, uninformative priors or a flat prior distribution were used to provide as little prior information as possible for model estimation (Diaconis & Ylvisaker, 1985). The Pareto-smoothed importance sampling leave-one-out (PSIS-LOO) diagnostics were employed to check the models' goodness of fit (Vehtari & Gabry, 2019; Vehtari, Gelman, & Gabry, 2017). LOO is computed as follows:

$$LOO = -2LPPD_{loo} = -2\sum_{i=1}^{n} \log \int p(y_i|\theta)p_{post(-i)}(\theta)d\theta$$

$p_{post(-i)}(\theta)$ is the posterior distribution calculated through the data minus data point i. The k-Pareto values are used in the PSIS method to compute the LOO cross-validation in the R **loo** package. Observations with k-Pareto values greater than 0.7 are often considered influential and problematic for accurately estimating LOO cross-validation. When a model's k values are less than 0.5, it is typically regarded as being fit.

If the model fits well with the data, we will proceed with the convergence diagnoses and results interpretation. In the current study, we validated the convergence of Markov chains using statistical values and visual illustrations. Statistically, the effective sample size (*n_eff*) and the Gelman–Rubin shrink factor (*Rhat*) can be used to assess the convergence. The *n_eff* value represents the number of iterative samples that are not auto-correlated during stochastic simulation, while the *Rhat* value is referred to as the potential scale reduction factor (Brooks & Gelman, 1998). If *n_eff* is larger than 1000, it is generally considered that the Markov chains are convergent, and the effective samples are sufficient for reliable inference (McElreath, 2018). As for the *Rhat* value, if the value exceeds 1.1, the model does not converge. The model is considered convergent if *Rhat* =

1. Visually, the Markov chains' convergence was also validated using trace plots, Gelman–Rubin–Brooks plots, and autocorrelation plots.

Data and code snippets of this statistical analysis were deposited at https://zenodo.org/uploads/12742823 for transparency and public evaluation.

3. Results

Before interpreting the results of BMF analytics, it is necessary to evaluate how well Model 1 fits the data. As can be seen in Figure 2, we found no value exceeding the 0.4 threshold; the recommended value is below the 0.7 threshold. This indicates a good fit signal between the model and the data.

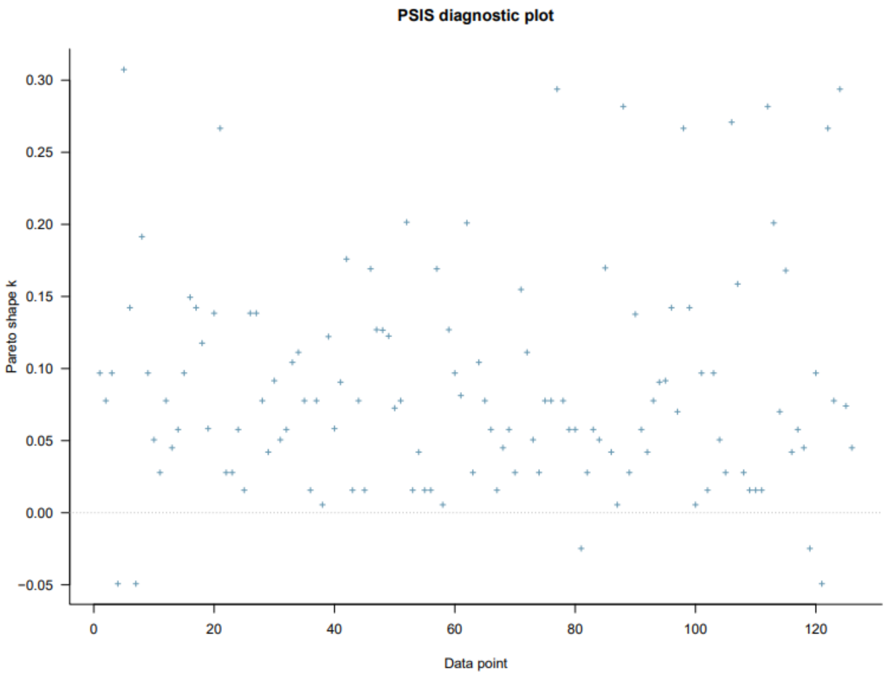

Figure 2. Model 1's PSIS-LOO diagnosis

The posterior distribution statistics of Model 1 are shown in Table 2. All *n_eff* values are greater than 1000, and *Rhat* values are equal to 1, so it can be assumed that Model 1's Markov chains are well-convergent. Table 2 below explains the posterior distribution statistics of Model 1, as illustrated in Figure 1.

Table 2. Estimated results of Model 1

Parameters	Mean	SD	n_eff	Rhat
a_MicronutrientSupp	0.23	0.09	7147	1
b_SchoolFeedingPolicy_ MicronutrientSupp	0.12	0.10	7903	1
b_NutritionPolicy_ MicronutrientSupp	-0.12	0.10	9924	1

b_HealthPolicy_ MicronutrientSupp	0.00	0.09	11473	1
b_FoodSafetyPolicy_ MicronutrientSupp	-0.03	0.09	10424	1
b_AgriculturePolicy_ MicronutrientSupp	-0.02	0.09	12341	1
b_PrivateSectorPolicy_MicronutrientSupp	0.02	0.11	13207	1

The convergence of Markov chains is also reflected in the trace plots of Figure 3. In particular, after the 2000th iteration, all chains' values fluctuate around the central equilibrium.

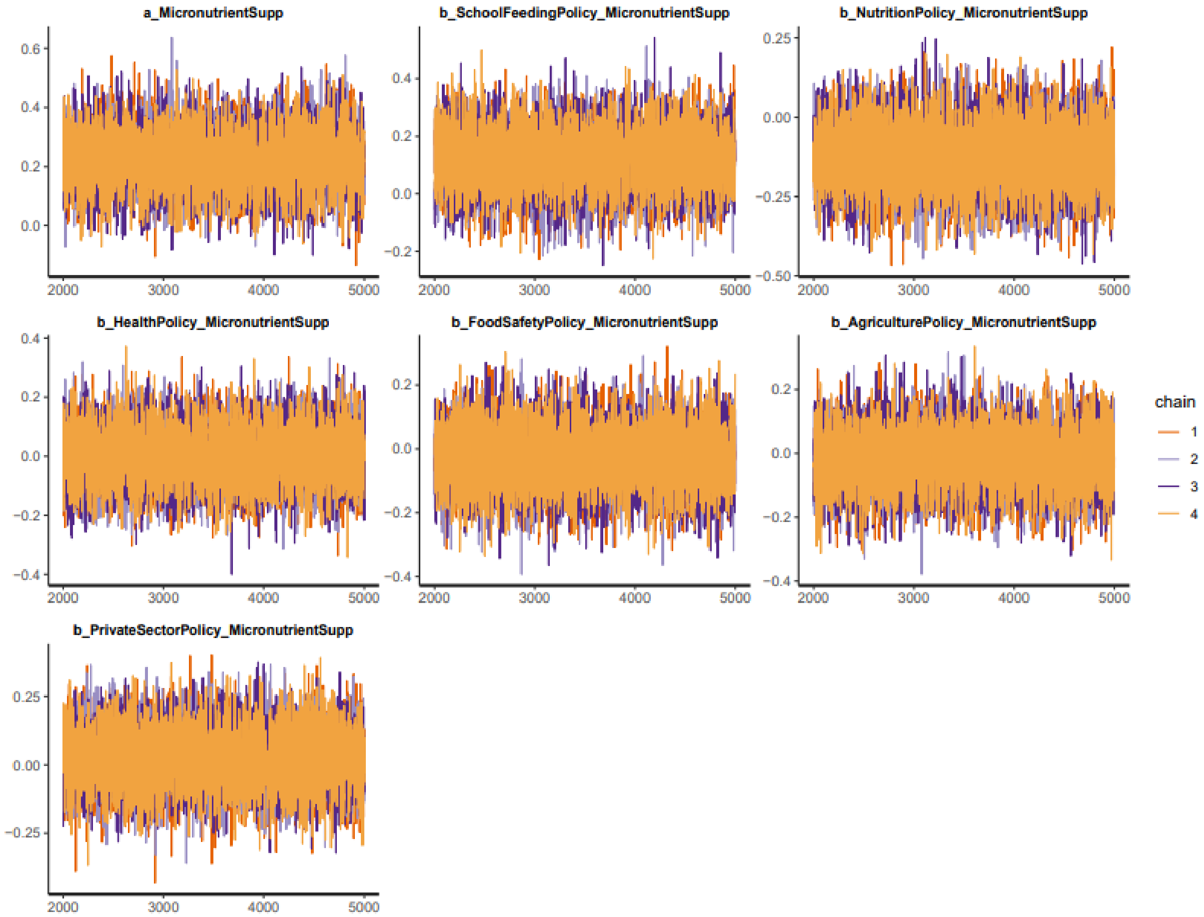

Figure 3. Model 1's trace plots

The Gelman-Rubin-Brooks plots and autocorrelation plots also show that the Markov chains have good convergence. Gelman-Rubin-Brooks plots are used to evaluate the ratio between the variance between Markov chains and the variance within chains. The y-axis demonstrates the shrinkage factor (or Gelman-Rubin factor), while the x-axis illustrates the iteration order of the simulation. In Figure 4, the shrinkage factors of all parameters rapidly decrease to 1 before the 2000th iteration (during warm-up). This manifestation indicates that there are no divergences between Markov chains.

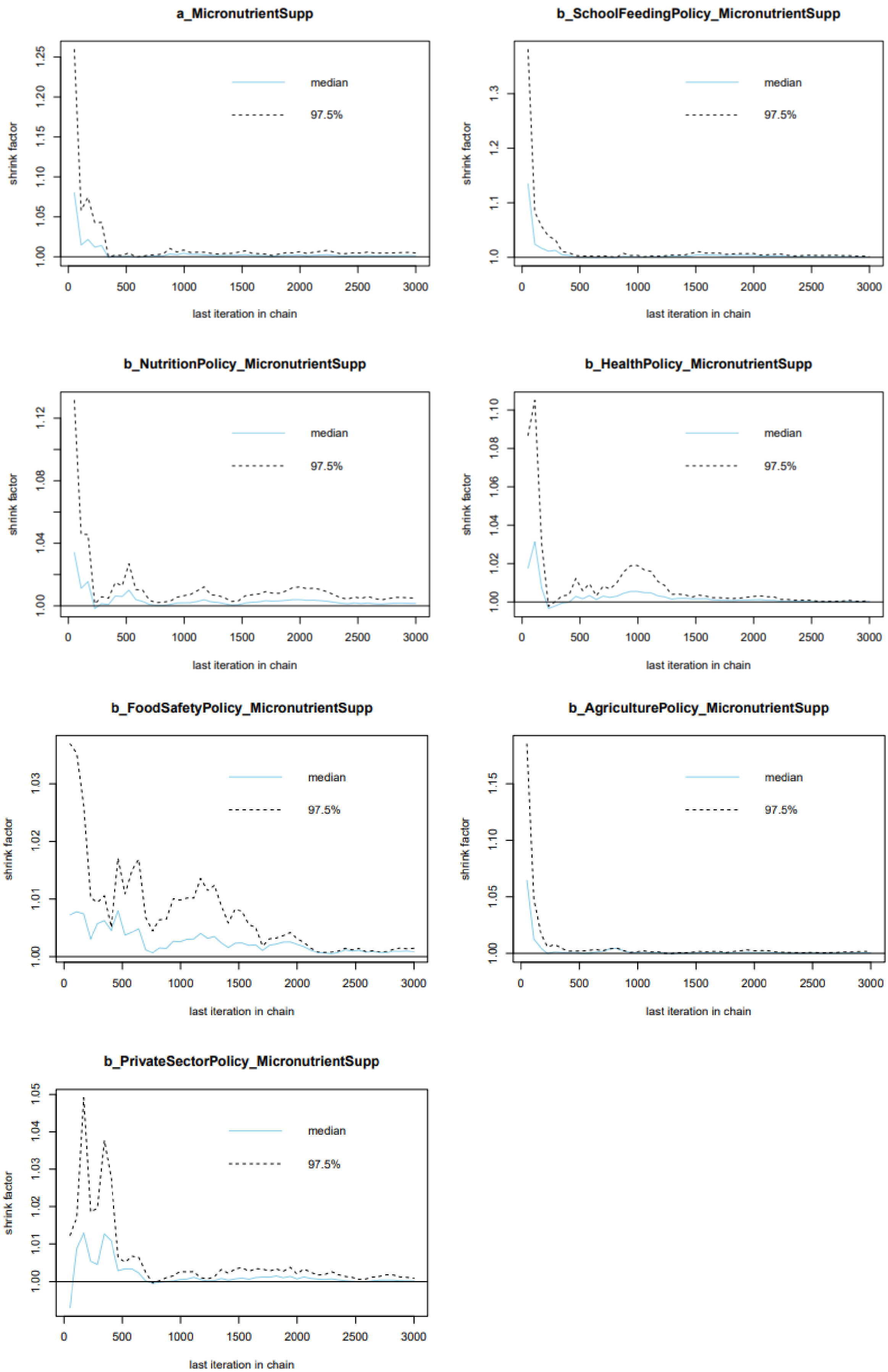

Figure 4. Model 1's Gelman-Rubin-Brooks plots

The Markov property refers to the memory-less property of a stochastic process. In other words, iteration values are not auto-correlated with the past iteration values. Autocorrelation plots are used to evaluate the level of autocorrelation between iteration values. The plots in Figure 5 show the average autocorrelation of each Markov chain along the y-axis and the delay of these chains along the x-axis. Visually, after several delays (before 5), the autocorrelation levels of all Markov chains swiftly drop to 0, indicating that the Markov properties are preserved and the Markov chains converge well.

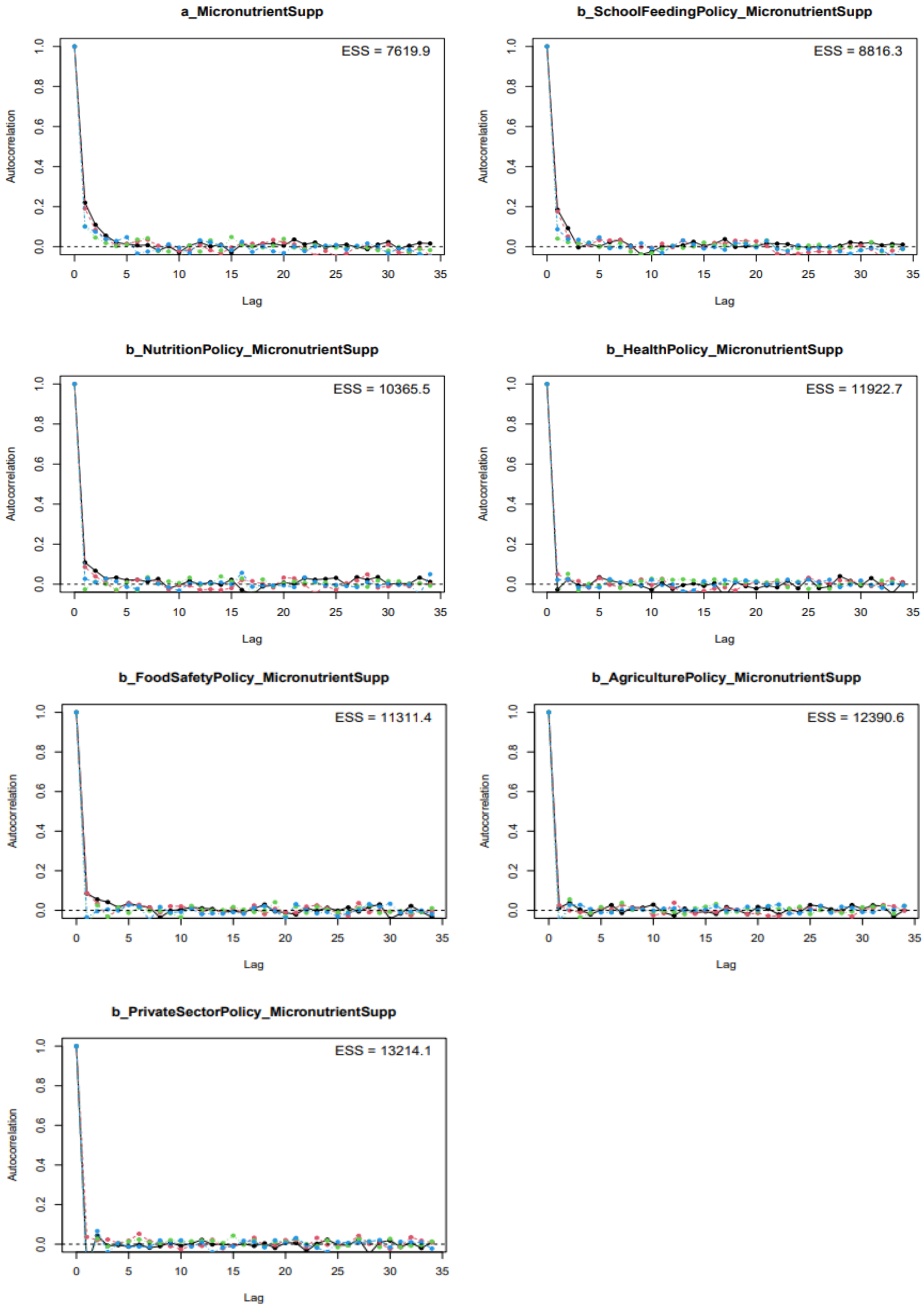

Figure 5. Model 1's autocorrelation plots

Since all the diagnostics confirm the convergence of Markov chains, the simulated results are eligible for interpretation. The estimated results of Model 1 show that among the six types of national policies, only school feeding policies were positively associated with in-school micronutrient supplementation, while nutrition policy had a negative association with these practices. Both associations were only moderately reliable. Policies on health, food safety, agriculture, and the private sector had ambiguous relationships with micronutrient supplementation among countries implementing school meal programs.

Figure 6 below illustrates the estimated posterior distributions of coefficients. The mean values reflect the points where the coefficients have the highest probability of occurrence. The Highest Posterior Density Interval (HPDI) of *b_SchoolFeedingPolicy_MicronutrientSupp* is almost fully located on the positive side of the x-axis, while that of *b_NutritionPolicy_MicronutrientSupp* is almost fully situated on the negative side. These distributions signify the moderate reliability of the positive association between *SchoolFeedingPolicy* and *MicronutrientSupp* and the negative association between *NutritionPolicy* and *MicronutrientSupp* because a proportion of their HPDI 95% still locate on the positive and negative side of the x-axis, respectively.

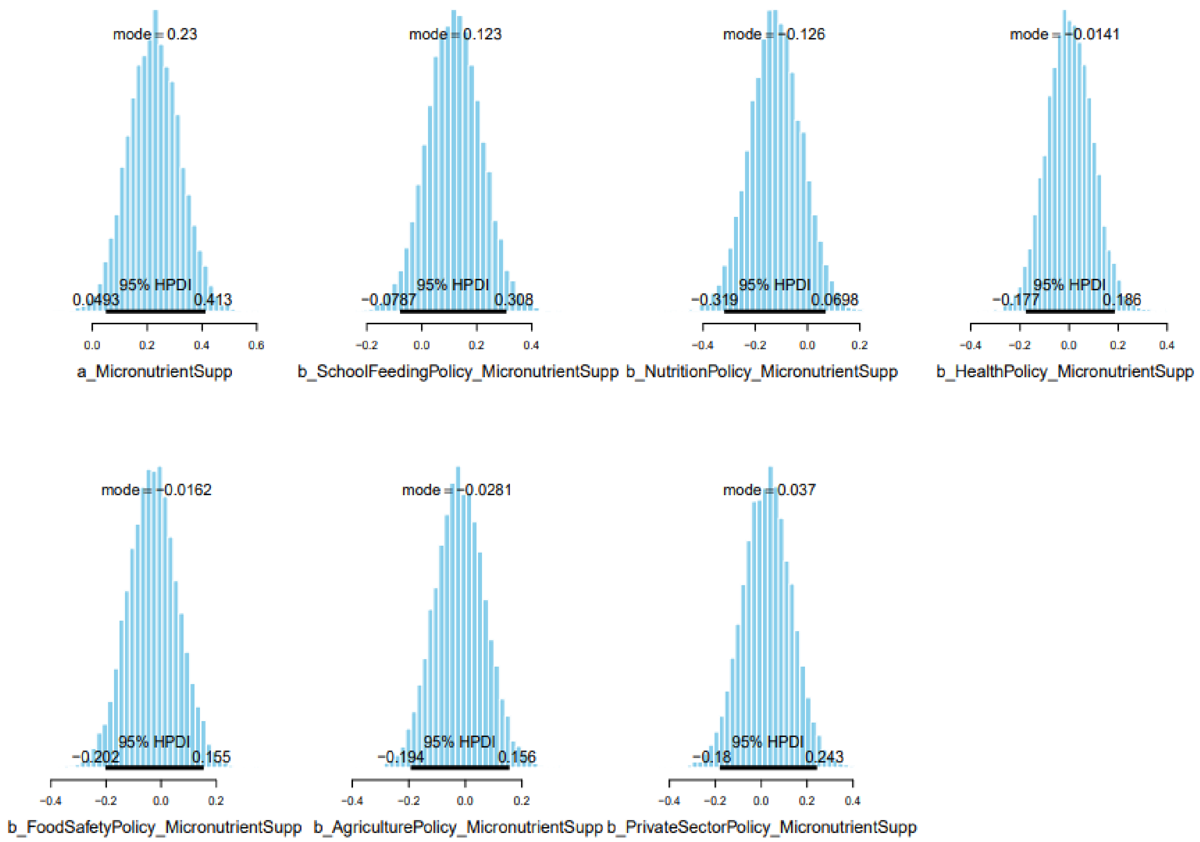

Figure 6. The estimated posterior distributions with HPDI at 95%

4. DISCUSSION

Micronutrient supplements are divided into macro minerals, trace minerals, and fat-soluble vitamins. Consuming food with adequate micronutrients normally improves individuals' balanced diets. Micronutrient deficiency or hidden hunger can be addressed by integrating micronutrient supplementation within a broader framework that emphasizes dietary diversity, food security, and community engagement. Policymakers should ensure that supplementary interventions complement rather than replace comprehensive nutrition strategies.

This study aims to analyze the relationship between different government interventions, including national policies guiding the school meal programs, to generate an understanding of how these policies affect children's micronutrient supplementation at school. The study employed the Bayesian Mindsponge Framework to analyze the association between national policies on school feeding, nutrition, health, food safety, agriculture, and the private sector with the implementation of micronutrient supplementation practices in school meal programs.

Strengthening the School Feeding Policy, the Essential Connection with In-school Micronutrient Supplementation

The findings indicate that the school feeding policies have improved the supplementation of vitamins and minerals, thus improving the balanced diet of school-aged children. A study in China assessing the success of school feeding programs in improving child nutrition and development indicates that government interventions have reduced malnutrition rates among rural students (Ren et al., 2023; Yan et al., 2022; Wang et al., 2019). Ren et al. (2023) found that school feeding programs supplemented vitamins, iron, and manganese, improving school performance and reducing urban-rural health disparities. However, a US study found negative outcomes on cognitive performance and health outcomes despite school feeding intervention programs (Dave, et al.2024). School children faced iron deficiency anemia, causing academic disadvantages. Supplementary programs addressed this by offering food with dietary sources of nonheme iron, including nuts, beans, vegetables, and fortified grain products (Zimmerman et al., 2024). Further research is needed to assess the cost-effectiveness and sustainability of these programs (Choedon et al., 2024).

Findings suggest that school feeding policy effectively guides and supports the implementation of in-school micronutrient supplementation as part of the national school meal programs. MT views school feeding policy as core values deeply embedded in the collective mind of a nation, serving as essential benchmarks for the acceptance or rejection of new information or values related to micronutrient supplementation (Vuong, 2023). MT views micronutrient supplementation practices in school meal programs as a product of the nation's information processing system. For these practices to emerge and be sustained within the national framework, the information regarding in-school micronutrient supplementation must first be available and accessible to the nation. The information regarding micronutrient supplementation practices includes knowledge and human resources, the internal and external driving forces to catalyze micronutrient supplementation practices, the available budget, access to technology and experts, etc.

These elements enable a conformity assessment, or benchmarking, following regulated national policies, which are regarded as the nation's core values.

When micronutrient supplementation practices align with these core values after a rigorous benchmarking process—where the school feeding policy acts as a multi-filtering system—these practices can be effectively implemented and maintained in school meal programs. This alignment results in a strong, positive correlation between school feeding policy and in-school micronutrient supplementation. Given the significant role of micronutrient supplementation in reducing the malfunction risk of child's intellectual and growth impairment, perinatal complications, and health concerns such as stunting, wasting, vitamin diseases, congenital heart disease, degenerative diseases related to aging, and increased child morbidity and mortality (Kiani et al., 2022; Zaheer, Akhtar, & Sharif., 2023), legal protection and adherence to national policies or standards are essential. This study underscores that school feeding policy helps guide, support, and protect the micronutrient supplementation practices in school meal programs.

Evaluating and Advancing the Nutrition Policy, the Vital Potency to Support In-School Micronutrient Supplementation

The findings indicate a negative relationship between nutrition intervention and micronutrients, such as copper. Studies in the US show that interventions by the government persistently strengthen policies to reduce consumption of goods lacking essential vitamins and minerals (Laird et al., 2014). The support of vitamins plays an important role in growth, bone health, and fluid balance and in risk groups such as children, pregnant women, and the elderly (Eggersdorfer et al., 2018). Contrary to these views, the United States Department of Agriculture (2024) argued that routine supplementation of micronutrients, such as cereals and chicken roast, for chronic disease prevention is not recommended due to insufficient scientific evidence. When nutrition challenges evolve, new approaches to fortification are required. Eating fruits, vegetables, whole grains, cereals, lean meats, and reduced-fat dairy products enables children to acquire the vitamins and minerals they need at the right level and balance (Choedon et al, 2024).

The negative associations observed in the study could be attributed to potential food wastage in school meal programs, where efforts to meet nutritional demands might result in plate waste due to lower consumption of fortified foods by students (Burgaz et al., 2023; Nguyen, van den Berg, & Nguyen, 2023). Likewise, studies by Chaudhary et al. (2020) and Alonge et al. (2024) indicated that increased food production and the provision of readily available healthy foods positively impacted nutrition, although they also noted concerns about obesity and non-communicable diseases among children. However, other research has shown that food fortification can reduce nutrient deficiencies and improve the nutritional status of children (Pike et al., 2021; Rowe, 2020). This improvement may be linked to the availability of healthy nutritional foods provided through school nutrition programs (Bundy, 2005; Grigsby-Duffy et al., 2022). Furthermore, Chaudhary et al. (2020) argued that school food programs and related interventions have the potential to improve dietary behaviors, attitudes, and anthropometric outcomes in young children while also promoting healthy eating habits. As a result, schools have the capacity to implement long-lasting changes that create a healthier learning environment for children, enhancing both their short- and long-term health (Chaudhary et al., 2020).

MT views the negative association between nutrition policy and in-school micronutrient supplementation practices as an unconformity between the new information on micronutrient supplementation and the nutrition policy as the mindset of the nation. This condition may exist potentially due to the incapabilities of meeting the following condition: The information regarding the in-school food fortification practices is justified as costly for the nation based on the nutrition policy, so it cannot pass through the multi-filtering system of the mind. The National Health Institute (2024) has argued that routine supplementation of micronutrients for chronic disease prevention is not recommended due to a lack of scientific evidence, so this lack of available scientific information related to micronutrient supplementation for children catalyze this negative association. Micronutrient supplementation for children may not be a favorable practice from the perspective of nutrition policy.

Advancing the Policies on Health, Food Safety, Agricultural, and Private Sectors; the possible Interconnected Role in Micronutrient Supplementation by Driving Innovations in Micronutrient Enrichment

Health and food safety interventions have ambiguous association with the provision of food containing adequate vitamins and trace minerals. Studies in Russia show a complex connection suggesting that unhealthy diets cause non-communicable diseases (Kodentsova & Risnik, 2020; Idrisov et al., 2015). Deficiencies in multiple micronutrients are common among the Russian population, with vitamin D, B vitamins, and carotene being particularly low (Kodentsova et al., 2017). Similar findings indicate that micronutrient supplementation is widespread, with 25-40% of individuals in developed nations regularly consuming supplements (Ströhle & Hahn, 2013). Most countries face challenges in coordinating several micronutrient deficiency control interventions, risking both deficiencies and potential toxicity. However, nutritional surveys show that recommended micronutrient intakes are not always met among groups like pregnant women, young children, and the elderly (Spiegler, 2024; Hoeft et al., 2012). This gap has significant implications for health and healthcare costs (Hockamp et al., 2024).

A study showed that the agriculture intervention programs are failing to provide sufficient ascorbic acid, meat, poultry, and seafood, which improve nonheme iron absorption, whereas phytate present in grains and beans (Mahdavi-Roshan, Gheibi & Pourfarzad, 2022). Although some countries are revising such interventions, they still lack detailed strategies for nutritional security (Beattie & Sallu, 2021). There is a need to focus on developing a precision nutrition strategy that incorporates genetic, genomic, and lifestyle factors to address the issues of hidden hunger (Tam et al., 2020). The success of this approach is determined by technical understanding, advocacy, political leadership, and accountability (Benson, 2021). The agriculture intervention programs have reduced investments in sustainable agricultural practices that could enhance the availability of diverse, nutrient-rich foods such as nuts and beans (Fan et al., 2023). This neglect can perpetuate cycles of dependency on external aid rather than fostering local food production and resilience.

The findings show an ambiguous relationship between private sector policies and micronutrient supplementation. Worldwide hidden hunger indicators are showing improvement from 1995-2011, except in Africa, with reductions primarily in zinc and vitamin A deficiencies (Minja et al., 2024). Similar findings by Ritchie, Reay, & Higgins (2018) indicate extensive nutrient deficiencies in calcium, vitamins A, B12, folate, and lysine, with more concentrated deficiencies in iron, zinc, and vitamin B6. Public-private partnerships (PPPs) are playing a crucial role in addressing micronutrient deficiencies through food fortification initiatives in Africa (Ferreira et al., 2024). The Strengthening African Processors of Fortified Foods (SAPFF) Program has demonstrated the importance of engaging and motivating the food industry to comply with national fortification standards (Durotoye et al., 2022). Thus, the effective coordination of PPPs has led to large-scale food fortification, with fortified vegetable oil and wheat flour reaching over 70% of the population (Mideksa et al., 2024). However, companies prioritize financial gains, making it difficult to promote products that do not align with dietary guidelines, which may not be suitable for all populations and are not profitable (Gillespie et al., 2022). This engagement can complicate the public discourse on nutrition, shifting focus away from holistic dietary solutions towards commercial products.

MT views this ambiguous association as a result of the nation's information processing. When information on in-school micronutrient supplementation practices interacts with the national mindset—particularly policies on health, food safety, agricultural, and private sectors—it is perceived as neutral. Consequently, this information is kept in a buffer zone and is awaiting further evaluation. This situation may arise from insufficient information on micronutrient supplementation practices in school meal programs, including details about opportunities and challenges in relation to these policies.

5. Study Limitations

This study is not without limitations. The nature of the cross-sectional study has made the changing value of the variables studied unmeasurable over time. This study may portray a certain situation at one time to show a pattern of events but may not show the dynamic changes of the situation in the field. The questionnaire used is a self-reported questionnaire by design. It might be less objective for measuring variables. A qualitative study employing in-depth interviews among policymakers and stakeholders or parties involved in school feeding program execution is needed to fully understand the impacts of various national policies on in-school micronutrient supplementation practices. Moreover, research using more objective measurements of the policy implementation and micronutrient supplementation is also recommended to validate the current study's findings.

6. Conclusions

School feeding policy has a positive association with the in-school micronutrient supplementation practices among countries implementing school meal programs. This policy effectively guides, supports, and protects the implementation these practices as part of the national school meal programs in implementing countries. In the other hand, the nutrition policy has a negative association with micronutrient supplementation. A reassessment and enhancement of nutrition policy is necessary to identify problematic clauses and make positive adjustments that can support these practices during school feeding. Policies on health, food safety, agricultural, and private sectors have ambiguous relationships with in-school micronutrient supplementation. Enhancing and strengthening these policies could potentially increase their positive impacts on micronutrient supplementation practices in school meal programs.

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