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Article

From Policy to Plate: Optimizing SDG Outcomes through School Free Meals Innovation—A Case Study of Indonesia

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Abstract Indonesia's National Free Meals Programme (NFMP) faces systemic challenges of fragmented implementation across agricultural, educational, and logistical sectors. These systemic challenges are compounded by inequitable reach in its archipelagic geography, where rural infrastructure gaps exacerbate disparities. This study examines these issues through an integrated theoretical framework—combining Policy Transfer, Multi-stakeholder Governance, and Sustainable Livelihoods theories—using a mixed-methods approach that synthesises global policy benchmarks, peer-reviewed literature, and Sustainable Development Goal (SDG) alignment metrics. Key findings identify governance fragmentation, supply chain inefficiencies (notably 15–20% food spoilage in eastern regions), and digital divides as critical constraints. The research proposes a three-tiered intervention framework: (1) geospatially tailored procurement mechanisms; (2) incentivised corporate partnerships for cold-chain infrastructure; and (3) co-created R&D for climate-resilient crops. These strategies synergistically advance SDG 1 (Poverty Reduction), SDG 2 (Zero Hunger), and SDG 4 (Quality Education), demonstrating potential for farmer income gains, reduced child stunting, and improved school attendance. The study contributes to theoretical debates on adaptive policy transfer and offers Indonesia a scalable blueprint for integrated food-security transformation in archipelagic contexts.

Keywords school free meals programme; sustainable development goals; food security; Indonesia; public policy; smallholder farmers; governance; archipelagic logistics; climate resilience

1. Introduction

Indonesia's National Free Meals Programme (NFMP), or *Makan Bergizi Gratis* (MBG), represents a monumental policy effort to combat persistent stunting and poverty by providing nutritious meals to schoolchildren and vulnerable groups. Launched in 2025 under the oversight of Badan Gizi Nasional (BGN), the programme aims to synergistically advance Sustainable Development Goals (SDGs) 1 (No Poverty), 2 (Zero Hunger), and 4 (Quality Education) [1]. This effort is part of a global movement, as school feeding programmes now represent a key instrument of social protection, reaching over 400 million children worldwide according to recent benchmarks [2]. However, its potential is critically undermined by systemic fragmentation across agricultural, educational, and logistical sectors [3], a challenge exacerbated by Indonesia's unique archipelagic geography, which creates severe rural-urban and inter-island disparities [4,5].

The evolution of school feeding programmes globally provides a critical context for Indonesia's challenges. Initial phases focused on emergency relief (1950s–1970s), often creating dependency and ignoring local contexts. This was followed by a shift towards human capital development (1980s–2000s), where programmes like Mexico's PROGRESA linked nutrition to education but often operated in sectoral silos [6] and faced conceptual framing challenges [7], prompting a broader re-evaluation of school feeding as a foundational social investment [8]. The current paradigm emphasises integrated platforms (2010s–present), exemplified by Brazil's PNAE, which mandates 30% local procurement to synergise SDG 1 and SDG 2. Indonesia's NFMP seeks to adapt this integrated model but contends with a set of interconnected, context-specific challenges [3].

High stunting rates continue to present a central challenge to Indonesia's nutritional goals. While a notable and sustained positive trend has been observed, with the national rate falling

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from 30.8% in 2018 to 19.8% in 2024 [9], these rates remain far from the government's ambitious 2045 target of 5% [10,11].

This gap must be understood in the context of historical patterns [12] and is sustained by a triad of contemporary issues: ongoing micronutrient deficiencies, dietary gaps [3], acceptability problems and profound logistical inefficiencies. The latter sees maritime costs in Eastern Indonesia inflating food prices by 20–35%, where a US$7.20/ton increase in sea freight reduces regional GDP/capita by US$62.35 [5]. The pivotal role of policy environments in determining nutritional outcomes is evident in global comparative studies; for instance, research from China demonstrates how socioeconomic disparities can manifest as stunting and anaemia gaps within a national programme [13]. Similarly, documented food safety and hygiene failures in other large-scale programmes, such as India's Mid-Day Meal scheme [14], underscore a category of pervasive operational risks that also threaten the NFMP, particularly in regions with poor infrastructure. Furthermore, climate change projections indicate significant supply disruptions by 2030 [15], while cold chain gaps cause substantially higher spoilage rates in Eastern Indonesia compared to Java [5]. A deep digitalisation divide, where only 38% of rural households had home internet access in 2023, hinders technological solutions [16], and governance fragmentation across ministries increases administrative costs and creates operational inefficiencies [3]. This complex problem landscape necessitates a robust theoretical integration to diagnose failures and design solutions.

This study is guided by three complementary theoretical frameworks. Policy Transfer Theory [17] provides a macro-level lens for evaluating the adaptability of global models like Brazil's local procurement to Indonesia's archipelagic context. Multi-stakeholder Governance Theory [18] offers a meso-level lens to diagnose and solve the polycentric coordination failures between government tiers, private actors, and communities. Finally, the Sustainable Livelihoods Framework (SLF) [19] serves as a micro-level lens to ensure interventions directly build the financial, physical, natural, human, and social assets of vulnerable households. Together with Human Capital Theory [6,20,21], which frames NFMPs as long-term investments, and the Capability Approach [22,23], which defines development as the expansion of substantive freedoms, these frameworks provide a comprehensive, multi-scalar analytical tool. Despite this robust global and theoretical context, a critical research gap remains.

This study aims to fill this void by conducting a mixed-methods analysis that synthesises global policy benchmarks, peer-reviewed literature, and SDG alignment metrics to propose a cohesive and context-sensitive intervention framework. The subsequent analysis proceeds by first establishing a theoretical foundation, then detailing the mixed-methods approach, before presenting findings and their policy implications.

2. Materials and Methods

2.1. Research Design and Philosophical Underpinnings

This study employs a mixed-methods approach to evaluate Indonesia's National Free Meals Programme, integrating qualitative policy analysis with quantitative impact assessment. Prioritising problem-solving over methodological purity, it addresses Indonesia's archipelagic complexity through three interdependent phases:

- *Diagnostic Phase:* Systematic review identifying implementation gaps.
- *Comparative Phase:* Policy benchmarking against global exemplars.
- *Synthesis Phase:* SDG-alignment modelling.

The framework applies Policy Transfer Theory [17] to test the adaptability of foreign models, while Ostrom's polycentric governance principles [18] inform decentralisation strategies.

2.2. Systematic Literature Review Protocol

2.2.1. Search Strategy and Screening

Following PRISMA guidelines [24], seven databases (Scopus, Web of Science, JSTOR, ProQuest Business, ABI/INFORM, PAIS Index, EconLit) were queried using Boolean operators: ("school feeding" OR "school meals") AND ("private sector" OR "corporate partnership" OR "PPP") AND ("climate resilience" OR "sustainable procurement") AND ("SDGs" OR "Sustainable Development Goals").

Inclusion Criteria:

- Empirical studies (2010–2024) with explicit SDG alignment metrics.
- Analysis of implementation mechanisms in developing economies.
- Documentation of private-sector engagement models.

Exclusion Criteria:

- Theoretical frameworks without field validation.
- Studies conducted in high-income countries were excluded.

Initial screening of 1200+ records yielded 78 peer-reviewed articles meeting quality thresholds via the Mixed Methods Appraisal Tool (MMAT). Intercoder reliability was validated (κ = 0.85) through dual independent assessments.

2.2.2. Thematic Synthesis

Articles were categorised into four domains using NVivo 14:

- *Governance Structures:* e.g., Brazil's tripartite committees [8] and the integrated Home-Grown School Feeding Resource Framework [2].
- *Technological Innovations:* e.g., India's blockchain leakage reduction [25] and IoT (Internet of Things) food monitoring [25] and the application of unmanned aerial vehicles (UAVs) for agricultural monitoring and input delivery [26].
- *Climate Adaptation:* e.g., drought-resistant polycultures [27] and biofortification of staples [28].
- *Equity Considerations:* e.g., gender gaps in digital adoption [29].

2.3. Comparative Policy Document Analysis

2.3.1. Document Selection and Coding

Fourteen policy texts from Brazil, India, and China were analysed, including:

- Brazil's PNAE Operational Manual
- India's Mid-Day Meal Rules
- China's Nutrition Improvement Plan

A 12-variable coding matrix was applied to systematically analyse these documents. The key variables used for this analysis are presented in Table 1.

Table 1. Policy document coding matrix.

Variable Category	Examples
Governance Mechanisms	Decentralisation clauses, audit protocols
Private-sector Incentives	Tax credits, CSR mandates
Risk Management	Penalty structures, force majeure provisions

NVivo's auto-coding feature identified 347 semantic references to "smallholder inclusion" and "climate resilience", with manual verification ensuring contextual accuracy.

2.3.2. Transferability Assessment

Each policy was evaluated against Indonesia's context using Dolowitz & Marsh's [17] adaptation framework:

- *Feasibility:* Maritime logistics costs in eastern islands [5].
- *Equity Implications:* Digital literacy rates (26.3% rural access [29,30]).
- *Institutional Compatibility:* Alignment with Badan Gizi Nasional's mandate.

2.4. Analytical Framework: SDG-policy Alignment Matrix

Building on the contemporary Sustainable Livelihoods Framework (SLF) [31], which updates earlier models [19] and incorporates methodological insights from data-driven environmental analyses [32], this study applies the measurement principles of the Capability Approach [33] to develop a matrix that quantifies policy impacts across five livelihood capitals and their linkages to specific SDGs. The matrix draws on comparative evidence from global school feeding programmes [34], as detailed in Table 2.

Table 2. Livelihood capital-SDG linkages.

Capital Dimension	SDG Linkage	Metric	Data Source
Financial	SDG 1 (No Poverty)	Income uplift (%)	[35]
Physical	SDG 9 (Industry)	Spoilage reduction (%)	[5]
Natural	SDG 13 (Climate Action)	Carbon sequestration (tons/ha)	[32]
Human	SDG 4 (Education)	Attendance increase (pp)	[36]
Social	SDG 16 (Institutions)	Digital Access rate (%)	[29,30]

Validation Protocol:

- *Triangulation:* Cross-referenced matrix outputs with stochastic frontier analysis of logistics inefficiency [5].
- *Sensitivity Testing:* Adjusted weightings for Indonesian priorities (e.g., two times weighting for climate vulnerability).

2.5. Quantitative Synthesis

2.5.1. Meta-analysis

Twelve impact evaluations were synthesised using random-effects models to account for contextual heterogeneity. Key parameters:

- Stunting reduction (β coefficients)
- School attendance (percentage-point changes)
- Income elasticity for smallholder households

Cochrane's Q-test assessed heterogeneity ($I^2 = 78\%$, indicating high variability), necessitating subgroup analysis by region.

2.5.2. Stochastic Frontier Analysis (SFA)

Amin's [5] model of Indonesian maritime logistics was replicated with enhancements:

$$ln(\text{GDPpc}) = \beta_0 + \beta_1 ln(\text{FreightCost}) + \beta_2 \text{PortEfficiency} + \beta_3 \text{ColdChainGap} + v - u,$$

where:

- v = Random noise,
- u = Inefficiency term (half-normal distribution),
- ColdChainGap = Spoilage differentials (eastern vs western Indonesia), and data from 34 ports validated the model's predictive power ($R^2 = 0.91$) [5].

2.6. Theoretical Validation and Ethical Rigour

2.6.1. Polycentric Governance Application

Ostrom's [18] design principles were operationalised through:

- *Clearly Defined Boundaries:* Geographic targeting of procurement quotas.
- *Collective-choice Arrangements:* District-level mediation committees.
- *Graduated Sanctions:* Penalties for contract non-compliance.

2.6.2. Ethical Safeguards

- *Secondary Data Focus:* No primary data collection, mitigating consent issues.
- *Grey Literature Protocol:* Corporate sustainability reports (e.g., Wilmar International, 2023 [37]) and government performance documents (e.g., Ministry of Agriculture, Indonesia, 2024 [38]) underwent peer-corroboration checks.
- *Bias Mitigation:* Blind screening of literature by two researchers.

2.6.3. Ethical Approval Statement

This study constituted a desk-based policy analysis using exclusively secondary, publicly available data. No human participants were involved in the research, and no primary data collection was conducted. Therefore, ethical approval for human subject research was not required. The research adhered to the highest standards of academic integrity in the use and citation of all secondary sources.

2.7. Methodological Limitations and Mitigation

This study acknowledges several methodological limitations and the corresponding mitigation strategies, which are systematically summarised in Table 3.

Table 3. Limitations and mitigation strategies.

Limitation	Mitigation Strategy	Reference Support
Spatially fragmented data, particularly in Eastern Indonesia	Interpolation using stochastic imputation	[5]
Blockchain scalability uncertainty in low-connectivity regions	Conservative estimates (50% adoption cap)	[39]
Absence of empirical evidence for crisis-period programme performance	Scenario modelling based on the World Food Programme drought response	[2]

2.8. Conclusive Methodological Integration

This framework advances development research by:

- Theoretically integrating Ostrom's polycentricity, SLF capitals, and behavioural economics.
- Empirically grounding policy recommendations in 92 verified data sources.
- Contextually adapting global models to archipelagic constraints (e.g., deploying drone corridors for island logistics).

3. Results

This comprehensive analysis synthesises empirical outcomes from the mixed-methods investigation, addressing Indonesia's National Free Meals Programme challenges. The findings, structured around the research objectives, reveal critical implementation gaps and theoretically grounded insights validated through comparative policy assessment.

3.1. Theoretical Integration: Reconciling Governance, Livelihood, and Behavioural Frameworks

The application of multi-stakeholder governance theory reveals systemic coordination challenges within the programme's implementation landscape. Foundational barriers include Indonesia's pronounced regional disparities [4] and severe archipelagic logistics constraints, where maritime inefficiencies directly increase costs and spoilage [5]. This complex environment demands that centralised systems adapt to local contexts—such as agroecological conditions for climate resilience [15] and student dietary preferences for meal acceptance [12]. Policy analysis suggests that failures in this adaptation stem from inter-ministerial and district-level coordination gaps [3], creating risks of operational silos, redundant procedures, and uncoordinated quality assurance. In sum, the analysis underscores how fragmented governance can undermine a programme's efficiency, equity, and cultural relevance—classic polycentric governance dilemmas.

Conversely, Brazil's tripartite governance model demonstrates effective polycentric coordination in practice [8], consistent with Ostrom's principles [18]. By enabling contextual adaptation without compromising standards—such as incorporating regionally sourced fish and açai berries in Amazonian menus, while prioritising dairy and grains in the south—the model achieves high stakeholder satisfaction [8]. This locally responsive procurement is also a logical strategy to reduce systemic food waste, a documented issue in Brazil [40] and in its school feeding programme specifically [2,41], thereby validating Ostrom's principle that "nested enterprises" improve resource allocation in complex systems [18].

3.2. Sustainable Livelihoods: Addressing Capital Deficits in Archipelagic Contexts

The Sustainable Livelihoods Framework diagnosis exposed severe physical and financial capital constraints in Eastern Indonesia. Maritime logistics inefficiencies—particularly inadequate cold storage and limited berthing infrastructure—caused 15–20% perishable spoilage versus Java's 5–8% efficiency [5]. Limited financial capital constrains smallholder investments. This constraint highlights the need for interventions that build financial capital.

Globally, home-grown school feeding is proven to generate such income uplifts via structured demand [6], a potential illustrated in the Indonesian context by cooperative models [42]. These capital deficits created cyclical exclusion: smallholders lacking refrigeration could not meet safety standards, while those without formal land titles were excluded from digital procurement

platforms. An in-depth case study of Koperasi Tani Subur demonstrated how cooperatives mitigated these barriers through collective bargaining and shared resources, which strengthened farmers' bargaining power and access to certification [42]. However, participation in formal cooperatives remains low, highlighting scalability challenges.

3.3. Policy Transfer Outcomes: Adaptive Hybridisation of Global Models

The comparative analysis validated Policy Transfer Theory [17], demonstrating that successful adoption requires contextual recalibration rather than mechanical replication.

Brazil's Local Procurement Quotas have been shown to generate significant income uplifts for participating farmers through guaranteed market access, with a recent comprehensive analysis confirming these positive effects on family farmer income [40,41]. Additionally, studies highlight specific mechanisms to support smallholder participation in such procurement calls, such as bid preparation assistance [43].

However, direct implementation in Indonesia's eastern archipelago proved economically unviable due to maritime logistics constraints. Stochastic frontier analysis [5] quantified these barriers: each US$7.20/ton increase in sea freight costs reduced regional GDP per capita by US$62.35, while ports without cranes operated at 46–65% lower efficiency.

Evidence from global tech reforms reveals that success hinges on overcoming local constraints. India's digital fiscal system cut fund leakage by 17% [44], but similar digital solutions in Indonesia will be constrained by a rural-urban internet access gap [29,30]. Likewise, while Artificial Intelligence (AI) shows promise for reducing food waste in school kitchens [45], the transfer of such digital solutions to smallholder production faces distinct barriers such as land fragmentation, as seen in the adoption challenges for precision agriculture in China [46]. This highlights that technological potential is often limited by on-the-ground realities.

3.4. SDG Impact Assessment: Synergies and Spatial Disparities

A quantitative assessment of the programme's impact revealed differential progress across Sustainable Development Goals, a pattern of spatial inequity consistent with recent global analyses [2]. A synthesis of impact evaluations confirms that school feeding interventions produce a significant positive effect on school attendance. This is supported by earlier global studies [7,34], and evidence from large-scale national programmes [36] with research in marginalised zones reporting average attendance increases of 7–12 percentage points.

However, the high statistical heterogeneity observed across these studies (e.g., $I^2 = 78\%$) indicates that the magnitude of this effect is not uniform. It is strongly moderated by contextual factors such as baseline poverty levels, regional infrastructure, and the quality of local programme implementation. Consequently, the overall positive estimate represents a weighted average of diverse local outcomes, confirming the intervention's significant directional impact while underscoring that its ultimate scale is highly context dependent. This variation in context-dependent outcomes across different SDG targets is summarised in Table 4.

Table 4. SDG progress and disparities. *Source: Authors' analysis.*

SDG	Finding	Spatial Disparity
SDG 1	15% income uplift for contracted farmers	Non-contracted eastern farmers saw 0% change
SDG 2	Anaemia reduction ($\beta = 0.14$ in school-girls)	Eastern spoilage rates of 15–20%
SDG 4	7–12% attendance rise in marginalised zones	Frequent drought-related school closures in NTT (East Nusa Tenggara)

Crucially, the study identified underutilised cross-SDG synergies. Brazil's school agroforestry systems (SAFs)—integrating cassava, nitrogen-fixing cowpeas, and native trees—simultaneously advanced SDG 2 (Zero Hunger) through drought-resilient food production and SDG 13 (Climate Action) by sequestering significant biomass, a benefit of agroecological systems in Brazil [47]. These systems also have the potential to generate SDG 5 (Gender Equity) co-benefits by creating pathways for women's empowerment, for instance, through increased management roles—a type of outcome valued within the capability-based framework for expanding substantive freedoms [42,48].

3.5. Partnership Ecosystem: Tiered Engagement for Balanced Outcomes

Evidence from corporate practices in Indonesia offers proof of concept for integrating digital technologies into national food systems. For instance, Wilmar International's implementation of blockchain for supply chain traceability [39] demonstrates the potential to enhance logistical efficiency, reduce waste, and lower the carbon footprint of food distribution—directly contributing to SDG 9 (Industry, Innovation) and SDG 12 (Responsible Consumption).

This successful corporate application provides a critical reference point for adapting similar traceability technologies within the NFMP's operational framework. However, this analysis also reveals that the benefits of such corporate-led technological engagement are often coupled with equity-exclusion trade-offs—a pattern mirrored in the documented challenges of collaborative funding models in Indonesia [49]. Furthermore, the concentration of corporate social responsibility (CSR) initiatives within established commodity chains, such as palm oil, has been documented to reinforce regional investment imbalances [4], thereby excluding other regions and agricultural sectors.

4. Discussion

Based on the empirical findings and theoretical analysis presented above, the following policy implications and recommendations are proposed to optimise Indonesia's NFMP.

4.1. Governance Harmonisation

The finding of systemic fragmentation and its associated cost inefficiency [3] implies the need for structural reform.

Implication: Establish a National Nutrition Taskforce under Badan Gizi Nasional with three mandates:

a. A unified implementation protocol to eliminate redundant compliance procedures.
b. Brazil-style district committees [41] with school-industry representation.
c. Joint audits tracking both nutritional outcomes and smallholder inclusion.

4.2. Sustainable Livelihoods Capital Building

The diagnosis of severe capital deficits in Eastern Indonesia suggests a targeted capital-building initiative is required.

Implication: Launch a four-point initiative:

a. **Physical Infrastructure:** aligned with international standards for food infrastructure [50] and sustainable cold chain best practices [51]. These efforts must be complemented by mandatory "Clean Kitchen" certification, rigorously adhering to WHO WASH standards [50]. Implementing these measures is a vital and urgent response to mitigate acute food safety risks, as underscored by recent, tragic mass poisoning incidents linked to the programme [52].
b. **Financial Inclusion:** Deploying digital financial tools to enhance credit access for women in agriculture [39].
c. **Natural Capital:** Seed banks distributing drought-tolerant sorghum, proven to reduce crop failure in Eastern Indonesia [27].
d. **Social Capital:** MARA-style cooperative tax incentives to boost collective farming, a model justified by the proven economic and social benefits of cooperatives [42].

4.3. Adaptive Policy Transfer Protocol

The finding that direct policy transfer is economically unviable in the eastern archipelago implies the need for geospatial tailoring.

Implication: Develop an adaptive hybridisation protocol:

a. **Geospatial Tailoring:** Implement Brazil's 30% procurement quota [41,53] in Java with blockchain monitoring [39], while introducing clustered procurement (neighbouring district alliances) in eastern islands.
b. **Technology Sequencing:** Guided by a capability approach [23], deploy AI-blockchain hybrids in urban corridors and use asynchronous SMS/USSD platforms for low-

connectivity regions to ensure equitable access and benefits, a tiered approach aligned with digital adoption pathways for Indonesia's agricultural sector [53], access and benefits, a necessity evidenced by Indonesia's persistent rural-urban digital divide [29,30].

c. **Drone-Mediated Logistics:** Establish prioritised aerial delivery corridors for island logistics using unmanned aerial vehicles (UAVs), enhancing delivery speed and reliability [26].

4.4. SDG Synergy Acceleration

The identification of underutilised cross-SDG synergies suggests an integrated approach could amplify impact. This aligns with global evidence framing school feeding as a multi-sectoral platform for human capital development [6]. Recent Indonesian policy analyses [15] confirm the specific climate co-benefits potential.

Implication: Launch an integrated SDG accelerator:

a. **Provincial SAF Hubs:** Establish 200 model schools with polyculture gardens, prioritising drought-vulnerable regions. These hubs can incorporate proven drought-resilient crops such as sorghum, which has shown economic viability in Indonesian drylands [27], enhancing both SDG 2 and SDG 13 outcomes.
b. **Carbon Financing:** Explore mechanisms to monetise sequestration benefits, supported by robust, data-driven methodologies for quantifying landscape carbon stocks [32].
c. **Gender-Responsive Design:** Ensure 40% women's participation in SAF management training [29].

4.5. Tiered Partnership Framework

The finding of efficiency-equity trade-offs in corporate engagement necessitates balanced, graduated obligations under a multi-stakeholder governance structure that aligns public policy with private capabilities—a dynamic observed in Indonesian collaborative funding models [49]. Furthermore, the concentration of corporate social responsibility in established commodity chains like palm oil has been shown to reinforce regional investment imbalances [4], sidelining other regions and sectors. Strategic private engagement is therefore critical, particularly as technology and innovation are identified as key leverage points for modernising Indonesia's agro-value chains [53].

Implication: Implement a three-tiered framework:

a. **Tier 1 (Mandatory Foundations):** Enforce 10% smallholder subcontracting in corporate logistics bids with blockchain traceability.
b. **Tier 2 (Incentivised Value-add):** Offer 20% tax credits for CSR initiatives addressing specific gaps like nutrition education and women-focused digital literacy, using principles of behavioural economics [54] to design effective incentives and programme nudges.
c. **Tier 3 (Co-created Innovation):** Establish 50/50 government-corporate R&D funds. These would focus on priority areas identified in this study, such as the development of drought-resistant crops to enhance climate resilience [27] and the testing of saltwater-resistant drones to overcome archipelagic logistics barriers [26]. By applying Ostrom's [18] institutional principles, these funds would be structured for sustainable, collective governance.

5. Conclusions

This study has systematically addressed Indonesia's National Free Meals Programme challenges through rigorous theoretical examination, comparative policy analysis, and stakeholder-centred innovation frameworks. By bridging global insights with Indonesia's unique archipelagic context, we present a comprehensive transformation strategy that transcends historical implementation gaps while optimising Sustainable Development Goal synergies.

5.1. Theoretical Implications and Contributions

The findings of this study yield significant implications for the theoretical frameworks employed, advancing scholarly understanding of integrated food security governance.

Advancing Policy Transfer Theory

This study refines Policy Transfer Theory by demonstrating that "adaptive hybridisation" is

a more accurate descriptor than direct "transfer" in complex archipelagic contexts. Our findings reveal that successful policy adoption requires geospatial recalibration—where Brazil's procurement model succeeds in Java but requires clustered alliances in eastern islands. This challenges the theory's conventional focus on institutional compatibility alone, introducing "ecological and infrastructural compatibility" as equally critical dimensions. The tiered technology sequencing (AI-blockchain to Short Message Service (SMS) platforms) further demonstrates how digital infrastructure gradients must be incorporated into transfer frameworks.

Extending Multi-stakeholder Governance Theory

The application of Ostrom's polycentric principles [18] to Indonesia's NFMP reveals that effective governance requires not just nested enterprises but "technologically mediated nested enterprises". The empirical evidence and policy analysis highlight that ministerial fragmentation is a source of significant cost inefficiencies [3], underscoring the limitations of traditional bureaucratic coordination. Our findings suggest that digital platforms can reduce transaction costs in polycentric systems, but only when designed with accessibility safeguards for marginalised stakeholders. This extends governance theory by integrating digital mediation as a core component of contemporary multi-stakeholder coordination.

Enriching the Sustainable Livelihoods Framework

The SLF diagnosis [19] exposed how capital deficits create cyclical exclusion patterns in Eastern Indonesia. Our findings demonstrate that financial, physical, and social capitals are not merely additive but multiplicative—the absence of one undermines the effectiveness of others. For instance, smallholders lacking refrigeration (physical capital) cannot meet safety standards, excluding them from blockchain-monitored contracts (financial capital), regardless of their production capabilities. This suggests a "capital interdependence principle" that should be more explicitly incorporated into SLF applications for food security interventions.

5.2. Research Objectives and Scholarly Contributions Revisited

This study resolves Indonesia's historical NFMP gaps through two key scholarly contributions:

Polycentric Governance Integration

By applying Ostrom's institutional principles [18], we reconcile centralised quality control under Badan Gizi Nasional with district-level procurement autonomy. This structural reform is designed to eliminate the significant cost inflation and inefficiencies stemming from inter-ministerial conflicts, as identified in relevant policy analyses [3,49]. Brazil's tripartite committee model demonstrates how local actors can co-design menus while adhering to national nutritional standards, a successful integration documented in studies of its school feeding programme [8,41].

Digital Physical Hybridisation

To bridge the rural-urban digital divide, we propose asynchronous blockchain-SMS systems. This allows Java to leverage real-time AI optimisation while Eastern Indonesia uses SMS-based quality reporting—reducing exclusion risks identified by [30].

5.3. Future Research Pathways

The limitations identified in this study delineate a clear agenda for future scholarly inquiry, directly addressing the empirical and theoretical gaps uncovered.

Empirical Validation and Scaling

To build upon this foundational analysis, subsequent research should focus on field validation. A pilot study in 2–3 provinces would test the proposed partnership and technology models, generate robust, local evidence, and mitigate data fragmentation issues. Complementing this, qualitative research with key stakeholders (policymakers, implementers, schools, and nutritionists) would provide deeper insights into the programme's effectiveness and its potential to improve long-term health outcomes for young Indonesians.

Empirical Calibration of Key Performance Indicators

As a policy analysis, this study synthesises existing evidence to diagnose systemic challenges and propose a strategic framework. A critical next step is to transition from diagnostic to empirical calibration by generating precise, localised data to guide implementation and scaling. Future

research should prioritise establishing verified benchmarks for Indonesia in three areas where global proxies or fragmented data currently limit precision:

1. **Governance Efficiency Metrics:** Empirical studies are needed to quantify the administrative cost burden of inter-ministerial coordination and the efficiency gains from integrated governance models like the proposed National Nutrition Taskforce.
2. **Stakeholder Participation Baselines:** Robust surveys are required to establish accurate baselines for farmer cooperative membership and women's participation in digital platforms, providing clear metrics for tracking inclusivity.
3. **Contextual Economic Impact:** Longitudinal studies and controlled trials are essential to measure the direct income and livelihood effects of NFMP procurement contracts on Indonesian smallholders, moving beyond international analogues.

Technological Scalability and Behavioural Economics

Future research should investigate the cost-benefit thresholds for blockchain scalability in eastern Indonesia's connectivity context and examine behavioural interventions to reduce cognitive-load barriers for smallholders navigating digital platforms. The documented gender disparities in technology adoption within agricultural and digital programmes warrant a dedicated study of how supportive interventions could boost women's participation [30].

Climate Adaptation and Verification Mechanisms

To advance climate adaptation, research priorities include: (1) Crop Science: Genome-sequencing indigenous crops like manigoba to identify salt-tolerance traits, and (2) Agronomy: Investigating optimal soil-amendment strategies to address the yield instability observed in climate-resilient crops amid broader rural transformation challenges [27]. In parallel, (3) Verification: Developing robust, Intergovernmental Panel on Climate Change (IPCC)-aligned carbon accounting methodologies is essential to quantify the sequestration benefits of school-based agroforestry. Advanced data-driven scenario analysis, as applied in historic landscape systems, can inform the development of these localised verification methodologies [32]. Research in all areas should integrate agronomic and economic feasibility testing under local conditions, following models proven effective for crops like sorghum in Indonesian drylands [27].

Regulatory Harmonisation and Cultural Acceptability

Comprehensive legal analysis using legislative ethnography should codify jurisdictional overlaps and model harmonisation scenarios [55]. Such analysis aligns with broader efforts to critically reframe school feeding as a multi-sectoral instrument [56]. Concurrently, sensory acceptance trials for indigenous staples in school meals would address the cultural acceptability gaps observed in initial trials [12]. To systematically address these priorities, a detailed research agenda is proposed in Table 5.

Table 5. Research agenda for NFMP optimisation. *Source: Authors' analysis.*

Domain	Priority Questions	Methodology	Linkage to Gaps
Crisis Resilience	How to maintain operations during six-month droughts?	Agent-based modelling + stress tests	Data fragmentation during crises
Blockchain Economics	Scalability threshold for cost efficiency?	Cost-benefit analysis (five islands)	Technological scalability
Gender Equity	Can mobile nurseries boost women's tech access?	Cluster-randomised trial (20 dist.)	Gender exclusion patterns
Carbon Verification	Reliable bioindicators for sequestration?	Gas chromatography + soil sampling	Climate adaptation frontiers
Regulatory Harmonisation	How to reconcile conflicting regulations?	Legislative ethnography + scenario modelling	Governance fragmentation
Governance Efficiency	What is the exact administrative cost burden of inter-ministerial coordination, and what efficiency gains can be achieved by integrating governance models?	Time-motion studies, administrative cost tracking, and comparative case studies	Governance fragmentation

Table 5. (*Continued*)

Stakeholder Participation	What are the accurate baselines for farmer cooperative membership and women's participation in digital platforms?	Nationally representative surveys, network analysis, longitudinal tracking	Baseline data gaps
Economic Impact	What is the direct income and livelihood impact of NFMP procurement contracts on Indonesian smallholders?	Randomised controlled trials (RCTs), longitudinal income surveys	Impact data gaps

5.4. Conclusive Framework for Transformative Change

This research advances NFMP from incremental improvement to transformational change by demonstrating how Indonesia's archipelagic constraints can become catalysts for innovation rather than barriers to equity. The theoretical refinements—particularly the concepts of "adaptive hybridisation", "technologically mediated nested enterprises", and "capital interdependence"—provide scholarly foundations for rethinking food security governance in fragmented contexts globally [17]. This view is supported by parallel research highlighting the integrated policies required for sustainable agricultural transformation in similar rural contexts [57]. These foundations can be operationalised for programme design through tools like the integrated Home-Grown School Feeding Resource Framework [2,58].

By embracing evidence-based governance and context-sensitive technology transfer, Indonesia's NFMP can transition from a fragmented welfare initiative to an integrated SDG accelerator, offering replicable insights for similar archipelagic states across the Global South.

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Data Availability

Data sharing is not applicable as no new data was created. All supporting data were derived from publicly accessible sources.

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Author Contributions

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Conflict of Interest

The authors have no conflict of interest to declare. The funding sponsor had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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