

Dynamics Of MBG Partnership Formation in Complex Adaptive Systems: An Agent-Based Modeling Approach to Partnership Inequality in Indonesia

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Abstract—The Free Nutritious Meals Program (MBG) in Indonesia has experienced rapid expansion, yet significant regional disparities persist in the distribution of its business partnerships. This study investigates the dynamics of MBG partnership formation and inequality through a Complex Adaptive Systems (CAS) perspective. A hybrid Agent-Based Modeling (ABM) framework is developed, integrating mechanisms of Resource Dependence, Social Capital, Cumulative Advantage, and Relative Deprivation theories to simulate interactions among business actors, suppliers, and local institutions. The model evaluates four distinct regional scenarios: an equal access ecosystem (Jakarta), geographic inequality (Highland Papua), network dominance (Central Kalimantan), and social participation dynamics (West Sumatra). The simulation results demonstrate that equal national policies do not generate equal partnership opportunities; regions with favorable environmental and network conditions achieved 100% market capacity utilization, whereas structurally constrained regions utilized only 2.5% to 18.6% of their available capacity. The study identifies critical emergent outcomes driving this disparity, including partnership inequality traps, geographic exclusion, network clustering, adaptive survival gaps, and institutional dependence. The findings suggest that mitigating partnership inequality requires moving beyond uniform policy implementation toward region-specific interventions focused on improving information accessibility, reducing logistical barriers, and strengthening supplier networks. This study advances the literature by integrating Resource Dependence, Social Capital, Cumulative Advantage, and Relative Deprivation theories within a hybrid Agent-Based Modeling framework grounded in Complex Adaptive Systems, offering a novel computational approach for explaining partnership inequality and supporting the design of more adaptive and region-sensitive public partnership policies.

Keywords—Agent-Based Modeling, Complex Adaptive Systems, Free Nutritious Meals Program, Partnership Inequality, Regional Disparities.

I. INTRODUCTION

The Free Nutritious Meals Program (MBG) is one of Indonesia's national priority programs designed to

improve nutritional outcomes while simultaneously promoting local economic development through the involvement of suppliers, cooperatives, micro, small, and medium enterprises (MSMEs), and food service providers as program partners. Through this partnership scheme, the government seeks not only to ensure the provision of nutritious food services but also to create economic opportunities for local businesses participating in the program's supply chain (Nurjanah et al., 2026; Galloway et al., 2023).

The implementation of MBG has expanded rapidly across Indonesia. According to the National Nutrition Agency (2026), the program had reached approximately 63.86 million beneficiaries through 29,658 operational Nutrition Fulfillment Service Units (SPPGs), exceeding the national target of 28,543 units by approximately 4 percent. In addition, 15,979 SPPGs were undergoing the application and verification process, indicating strong interest among business actors to participate in the program. However, despite these achievements, substantial disparities remain in the geographical distribution of partnerships. Provinces on Java Island account for a disproportionately large share of operational SPPGs, beneficiaries, and projected economic circulation, while several provinces in Eastern Indonesia continue to record lower achievement levels relative to their targets. Highland Papua, South Papua, Central Papua, and several other remote regions remain significantly underrepresented within the MBG partnership ecosystem. These conditions suggest that equal policy provisions do not necessarily translate into equal partnership opportunities across regions (Amredika & Lestari, 2026; Makambombu, 2026).

The unequal distribution of partnership opportunities can be partially explained through Resource Dependence Theory developed by Pfeffer and Salancik (1978). The theory argues that organizations depend on external resources such as information, legitimacy, institutional support, and market access to achieve their objectives. Because these resources are not distributed equally, organizations with greater access to critical resources tend to possess stronger bargaining positions and better opportunities. Within the MBG ecosystem, businesses with better access to information, administrative support, and institutional resources may have a higher probability of becoming program partners than those operating under resource constraints.

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Differences in partnership opportunities may also be influenced by geographical conditions and spatial accessibility. Institutional Proximity Theory proposed by Kirat and Lung (1999), further developed by Boschma (2005) and Torre and Rallet (2005), argues that geographical, organizational, and social proximity facilitate access to information, knowledge, and economic opportunities. Businesses located near economic centers generally have better access to information, supplier networks, and supporting infrastructure than businesses operating in remote regions. In contrast, enterprises located in frontier, outermost, and underdeveloped areas often face higher logistical barriers, limited supplier availability, and restricted access to economic networks. These disadvantages may reduce their ability to participate successfully in the MBG partnership system.

The role of social relationships is further explained by Social Capital Theory. Bourdieu (1986) conceptualizes social capital as resources embedded within durable social networks that can be mobilized to achieve economic advantages. Coleman (1988) emphasizes the role of social structures in facilitating collective action, while Putnam (1993, 2000) argues that social networks enhance access to information, cooperation, and institutional resources. Woolcock (2001) further highlights the importance of social connections in improving access to development opportunities. Within the MBG partnership system, businesses possessing broader networks and stronger relationships with government agencies, suppliers, and community organizations may obtain information and support more effectively than businesses with weaker social connections.

Initial differences in resources and networks may subsequently evolve into larger inequalities through cumulative processes. Cumulative Advantage Theory introduced by Merton (1968) explains how early advantages tend to generate additional advantages over time. DiPrete and Eirich (2006) demonstrate that relatively small differences in initial conditions can become amplified through positive feedback mechanisms, while Rigney (2010) emphasizes the self-reinforcing nature of cumulative inequality. Within the MBG ecosystem, businesses with previous experience in government procurement, stronger reputations, and better operational capabilities may find it easier to secure future partnership opportunities, thereby reinforcing existing disparities.

Unequal access may also affect perceptions of fairness and participation decisions. Relative Deprivation Theory proposed by Gurr (1970) argues that dissatisfaction emerges when individuals perceive a gap between expected and actual opportunities. Similarly, Hirschman (1970) suggests that actors who perceive institutions as unfair may respond through voice, loyalty, or exit. In the context of MBG, perceptions of unequal access to information, bureaucratic processes, and partnership opportunities may discourage potential participants from engaging with the program, thereby contributing to persistent disparities.

Although recent studies have demonstrated the usefulness of Agent-Based Modeling (ABM) for examining complex interactions among heterogeneous actors, social networks, resources, and institutional conditions, limited attention has been given to integrating these mechanisms within public food

partnership programs. Recent research has shown that ABM can capture dynamic interactions and emergent outcomes in complex agri-food systems (Alonso-Adame et al., 2024), while other studies have applied ABM to examine network interactions and behavioral dynamics among organizational actors (Pires et al., 2024) and inequality and participation barriers in collective institutions (Joshi et al., 2024). However, research investigating how resource accessibility, institutional proximity, social networks, cumulative advantages, and participation behavior interact dynamically to generate partnership inequality remains limited, particularly in the context of Indonesia's MBG program.

From a systems perspective, MBG can be viewed as a Complex Adaptive System in which partnership outcomes emerge from continuous interactions among businesses, suppliers, local institutions, government agencies, and regional environments. Partnership formation is therefore not solely determined by individual business characteristics but also by adaptive behaviors, network interactions, resource competition, and institutional conditions that evolve over time.

Therefore, this study aims to develop an Agent-Based Modeling (ABM) framework grounded in Complex Adaptive Systems theory to examine the dynamics of MBG partnership formation. Specifically, the study investigates how information accessibility, institutional proximity, resource availability, social networks, and adaptive interactions among actors contribute to unequal partnership opportunities across different regions of Indonesia. By identifying the mechanisms underlying partnership inequality, the study seeks to provide insights for designing more inclusive and equitable MBG implementation strategies.

II. LITERATURE REVIEW

A. Resource Dependence Theory

Resource Dependence Theory (RDT) explains that organizations depend on external resources to achieve their objectives and that such dependencies shape organizational strategies and interorganizational relationships (Pfeffer & Salancik, 1978; Jiang et al., 2023). Because critical resources are not distributed equally, organizations with greater access to essential resources may possess stronger bargaining positions and broader opportunities. Within the MBG partnership ecosystem, differences in access to information, supplier networks, and institutional support may influence the likelihood of business actors becoming program partners. RDT therefore provides a useful framework for understanding how unequal resource accessibility contributes to disparities in partnership formation and sustainability.

B. Social Capital Theory

Social Capital Theory emphasizes the role of social relationships and networks in facilitating access to information, opportunities, and resources. Bourdieu (1986) defines social capital as resources embedded within durable social networks, while Coleman (1988) highlights the role of social structures in facilitating coordinated action. Putnam (1993, 2000) further argues that trust, reciprocity, and civic engagement enhance collective outcomes, and Woolcock (2001) distinguishes between bonding, bridging, and linking social capital. In

the context of MBG partnerships, businesses with stronger network connections may obtain information regarding partnership opportunities more quickly and gain greater access to support systems, increasing their probability of successful participation.

C. Cumulative Advantage Theory

Cumulative Advantage Theory explains how small differences in initial conditions can generate substantial inequalities over time. Merton (1968) describes this process as the Matthew Effect, whereby actors who gain early advantages tend to accumulate additional advantages in subsequent stages. DiPrete and Eirich (2006) further demonstrate that positive feedback mechanisms reinforce success, while Rigney (2010) highlights how inequality becomes self-reinforcing. Within the MBG ecosystem, businesses with prior experience, stronger capabilities, and established networks may find it easier to secure partnership opportunities, resulting in persistent disparities among participants.

D. Relative Deprivation Theory

Relative Deprivation Theory argues that participation behavior is influenced not only by actual opportunities but also by perceptions of fairness. Davies (1962) and Gurr (1970) suggest that dissatisfaction emerges when expectations exceed perceived opportunities. Hirschman (1970) further proposes that individuals may respond to dissatisfaction through loyalty, voice, or exit, while Tilly (1978) emphasizes the role of perceived inequality in shaping collective responses. Within MBG partnerships, perceptions of unequal access to information and opportunities may discourage participation among potential partners, thereby contributing to uneven partnership development across regions.

E. Complex Adaptive Systems and Agent-Based Modeling

The MBG partnership ecosystem can be viewed as a Complex Adaptive System (CAS), where outcomes emerge from interactions among heterogeneous actors operating under changing environmental conditions. According to Holland (1992), CAS consists of adaptive agents whose behaviors evolve through learning, interaction, and feedback mechanisms. Rather than being centrally controlled, system-level outcomes emerge from

decentralized decision-making processes and interactions among actors.

Within the MBG ecosystem, partnership formation is influenced by interactions among business actors, suppliers, supervisors, local institutions, and regional environments. Factors such as information accessibility, supplier availability, compliance behavior, network strength, and logistic barriers interact dynamically to shape participation outcomes. Consequently, partnership inequality should not be viewed solely as the result of individual characteristics but also as an emergent property of a complex system.

Agent-Based Modeling (ABM) provides an appropriate methodological approach for examining these dynamics. Epstein and Axtell (1996) demonstrate that complex social patterns can emerge from interactions among simple agents, while Axelrod (1997) and Bonabeau (2002) show that adaptation, learning, and social influence can generate collective outcomes that are difficult to predict using traditional analytical methods. In this study, ABM is employed to simulate how Information Accessibility (IA), Logistic Barriers (LB), Supplier Availability (SA), Supervisor Availability (SupA), Compliance Probability (CP), Learning Radius (LR), and Market Capacity (MC) interact to influence MBG partnership formation and inequality across different regional contexts.

F. Conceptual Framework

The present study combines Resource Dependence Theory, Social Capital Theory, Cumulative Advantage Theory, and Relative Deprivation Theory within a Complex Adaptive Systems (CAS) perspective to explain the dynamics of MBG partnership formation and inequality. These theoretical perspectives are operationalized through a Hybrid Agent-Based Modeling (ABM) framework consisting of agent attributes, Sugarscape mechanisms, network interactions, and social pressure mechanisms. The interaction of these components generates emergent outcomes related to partnership formation, partnership sustainability, partnership inequality, and regional participation disparities. The conceptual framework of the study is illustrated in Figure 1.

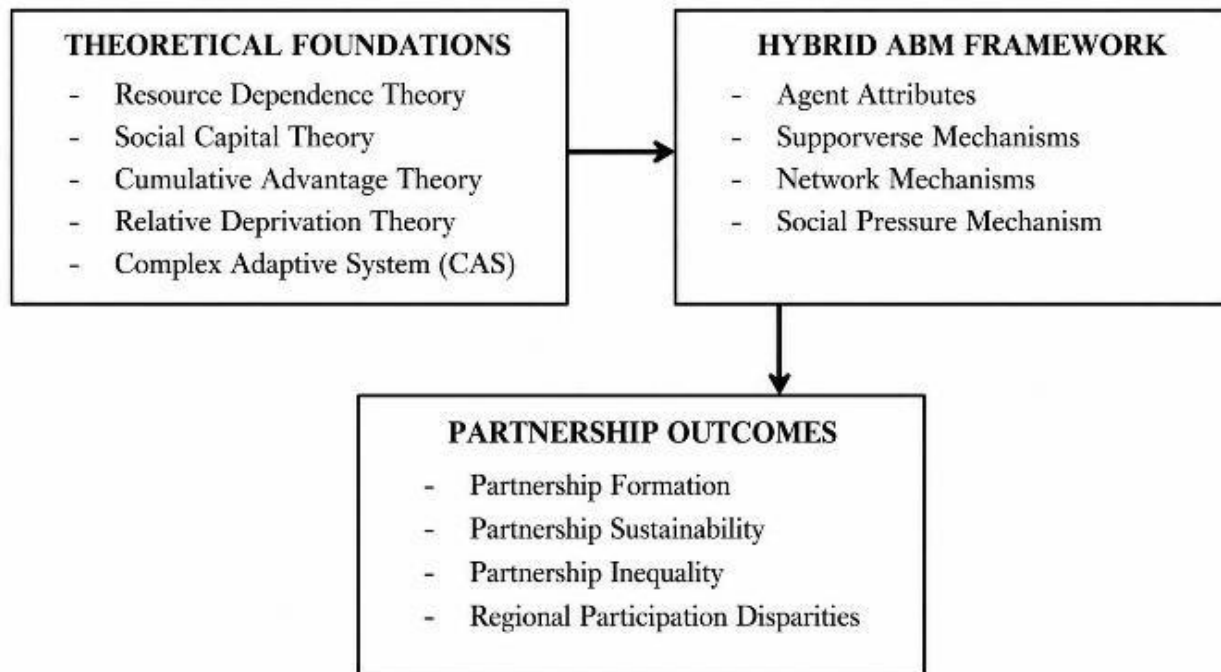


Figure 1.
Conceptual framework

G. Theoretical Foundation

Table 1 presents the theoretical foundations that underpin this study. Each theory offers a complementary perspective for understanding the factors influencing partnership formation, participation, and inequality

within the MBG program. Collectively, these theories provide a comprehensive conceptual basis for analyzing partnership dynamics and developing the proposed simulation model.

Table 1.
Theoretical Foundation

Theory	Key Scholars	Main Argument
Resource Dependence Theory	Pfeffer & Salancik (1978)	Organizations depend on external resources to achieve objectives.
Social Capital Theory	Bourdieu (1986); Coleman (1988); Putnam (1993, 2000); Woolcock (2001)	Social networks facilitate access to information and opportunities.
Cumulative Advantage Theory	Merton (1968); DiPrete & Eirich (2006); Rigney (2010)	Early advantages accumulate over time.
Relative Deprivation Theory	Davies (1962); Gurr (1970); Hirschman (1970); Tilly (1978)	Perceived inequality influences participation behavior.
Complex Adaptive Systems	Holland (1992); Miller & Page (2007)	System outcomes emerge from interactions among adaptive agents.
Agent-Based Modeling	Epstein & Axtell (1996); Axelrod (1997); Bonabeau (2002); Gilbert (2008)	Simulates interactions among heterogeneous actors.

As presented in Table 1, Resource Dependence Theory proposed by Pfeffer and Salancik (1978) explains that partnership opportunities in the Makan Bergizi Gratis (MBG) program are influenced by actors' access to information, resources, and institutional support. Social Capital Theory developed by Bourdieu (1986), Coleman (1988), Putnam (1993, 2000), and Woolcock (2001) highlights that the strength of social networks determines the extent to which actors participate in partnerships. Cumulative Advantage Theory introduced by Merton (1968) and further developed by DiPrete and Eirich (2006) and Rigney (2010) explains how differences in initial resources and opportunities

accumulate over time, leading to persistent partnership inequalities. Relative Deprivation Theory proposed by Davies (1962), Gurr (1970), Hirschman (1970), and Tilly (1978) suggests that perceived inequality may discourage participation and generate resistance among disadvantaged actors. Furthermore, Complex Adaptive Systems theory by Holland (1992) and Miller and Page (2007) explains that partnership patterns emerge dynamically through interactions among adaptive stakeholders. Finally, Agent-Based Modeling, developed by Epstein and Axtell (1996), Axelrod (1997), Bonabeau (2002), and Gilbert (2008), provides a computational

approach to simulate partnership formation, adaptation, and inequality within the MBG partnership ecosystem.

H. Previous Studies and Research Gaps

Previous studies have provided important insights into partnership development, stakeholder participation, geographic proximity, social networks, and inequality, yet several research gaps remain. Recent research on public-private partnerships has demonstrated that stakeholder engagement varies across public, private, and public-private partnership projects, highlighting the importance of understanding the structure of interactions among multiple stakeholders (Uddin et al., 2023). Research on geographic proximity has also shown that spatial relationships with partners can influence partnership outcomes depending on partner capabilities and local intermediary conditions (Park & Choi, 2023), extending the earlier proximity perspective of Boschma (2005). Similarly, recent reviews of social networks emphasize the interaction between social capital, network structures, and access to resources in shaping entrepreneurial outcomes (van Burg et al., 2022), while research on cumulative advantage demonstrates how differences in resources and network positions can reinforce inequalities over time (Ross-Hellauer et al., 2022). In addition, recent systematic evidence shows that Agent-Based Modeling (ABM) can capture heterogeneous agents, dynamic interactions, social networks, and the emergence of inequalities within complex systems (Nie et al., 2022). However, these approaches have rarely been integrated to examine how resource accessibility, geographic and institutional conditions, social networks, participation behavior, and adaptive interactions jointly generate partnership inequality within a government food partnership program. This gap is particularly relevant in the context of Indonesia's MBG program, where partnership opportunities emerge from interactions among business actors, suppliers, institutions, and diverse regional environments. Building on these gaps, the present study integrates these mechanisms into a Complex Adaptive Systems (CAS)-based Agent-Based Modeling (ABM) framework to explain the emergence of partnership inequality within the MBG partnership ecosystem.

III. METHODOLOGY

A. Research Design

This study employs a quantitative simulation approach using Agent-Based Modeling (ABM) to examine the dynamics of MBG partnership formation and inequality across different regional contexts in Indonesia. The study adopts a Complex Adaptive Systems (CAS) perspective, which views partnership outcomes as emergent phenomena resulting from interactions among heterogeneous actors operating within diverse institutional, social, and geographical environments. Unlike conventional statistical approaches that focus on linear relationships among variables, ABM enables the analysis of adaptive behavior, feedback mechanisms, and dynamic interactions that shape partnership formation and sustainability over time.

B. Agent-Based Modeling Framework

The MBG partnership ecosystem is represented through a hybrid Agent-Based Modeling framework that integrates Sugarscape, Network, and Social Pressure

mechanisms. The Sugarscape mechanism captures resource competition and environmental constraints that influence partnership opportunities. The Network mechanism represents information diffusion, social interactions, and network accessibility among business actors. The Social Pressure mechanism captures behavioral imitation, trust in the program, and participation decisions that emerge through interactions among agents.

Through these mechanisms, the model simulates how individual decisions and environmental conditions collectively generate partnership outcomes at the system level.

C. Agents and Environment

The model consists of prospective partners, active partners, and local institutions.

Prospective partners represent business actors considering participation in the MBG program and make decisions regarding registration based on available opportunities and environmental conditions. Approved agents become active partners responsible for production, distribution, reporting, and operational activities. Local institutions function as supporting actors that improve information accessibility, facilitate supplier availability, provide supervision, and conduct monitoring and evaluation activities. The interactions among these agents create a dynamic environment in which partnership opportunities and outcomes continuously evolve.

D. Model Variables

The simulation incorporates environmental variables and agent-level attributes that influence partnership formation and sustainability within the MBG ecosystem. The variables included in the model are presented in Table 2.

Table 2.
Model Variables and Descriptions

Variable	Symbol	Description
Information Accessibility	IA	Ease of access to MBG program information
Logistic Barriers	LB	Distribution and transportation constraints
Supplier Availability	SA	Availability of suppliers and raw materials
Supervisor Availability	SupA	Availability of supervisors, mentoring, and monitoring support
Compliance Probability	CP	Probability of compliance with MBG regulations and reporting requirements
Learning Radius	LR	Learning range and information diffusion among agents
Market Capacity	MC	Maximum partnership capacity within a region
Policy Strictness	τA	Government approval threshold

In addition to environmental variables, each agent possesses behavioral attributes that affect registration, approval, and survival outcomes. These attributes are presented in Table 3.

Table 3.
Agent Attributes

Attribute	Symbol	Description
Compliance	C	Level of compliance with program regulations
Efficiency	E	Operational efficiency
Coverage	CV	Extent of service coverage
Consistency	CS	Consistency of service delivery
Distribution	D	Distribution capability
Trust in Program	T	Confidence in the MBG program
Network Strength	NS	Strength of institutional and partnership networks

The variables included in the model are presented in Table 2. The calibration procedure used to determine the parameter values for these variables is described in the following section.

E. Parameter Calibration

The environmental parameters used in the simulation were calibrated using secondary data obtained from the Indonesian Central Bureau of Statistics (BPS, 2023), official reports of the National Nutrition Agency regarding the implementation of the MBG program, and regional characteristics identified in previous studies on logistics accessibility and partnership development. These data were used to represent differences in information accessibility, logistical barriers, supplier availability, supervision support, compliance conditions, and regional market capacity across the selected scenarios.

Table 4.
Simulation Scenarios

Scenario	Region	Description
S1	Jakarta	Represents an equal-access ecosystem characterized by high information accessibility, low logistical barriers, strong supplier availability, and extensive supervision support.
S2	Highland Papua	Represents a geographically disadvantaged region with severe logistical barriers, limited supplier availability, and low information accessibility.
S3	Central Kalimantan	Represents a network-dominance environment where strong institutional networks and prior advantages influence partnership opportunities.
S4	West Sumatra	Represents a social participation environment where moderate resource conditions interact with trust, participation behavior, and social influence dynamics.

These four regions were purposively selected to represent contrasting environmental conditions within the Indonesian MBG partnership ecosystem rather than to serve as statistical representatives of all provinces. Jakarta was selected as the benchmark of a highly developed urban ecosystem with high information accessibility, well-established supplier networks, strong institutional support, and relatively low logistical barriers. Highland Papua represents the opposite extreme, where geographical isolation, limited infrastructure, and severe logistical constraints substantially restrict partnership opportunities. Central Kalimantan was selected to represent a network-

To ensure comparability among regions, all environmental indicators were normalized to a scale ranging from 0 to 1, where higher values represent more favorable conditions for partnership formation, except for Logistic Barriers (LB), where higher values indicate greater transportation and distribution constraints. The market capacity (MC) parameter was determined based on the estimated regional partnership capacity under the MBG implementation framework.

Behavioral thresholds governing agent registration, approval, adaptation, and survival were calibrated through iterative simulation. Parameter values were repeatedly adjusted until the simulation generated stable outcomes that reflected the contrasting regional characteristics represented by each scenario. This calibration process ensured that the model reproduced realistic differences in partnership participation, approval rates, and capacity utilization while maintaining consistency with observed MBG implementation patterns.

F. Simulation Scenarios

The regional parameter values presented in Table 5 represent the results of the calibration process described in the previous section and reflect the relative differences in environmental conditions among the selected regions.

To examine how regional conditions influence MBG partnership formation and sustainability, four simulation scenarios were developed based on distinct environmental characteristics observed within the MBG ecosystem. Each scenario represents different levels of information accessibility, logistical constraints, supplier availability, supervision support, and compliance conditions. The scenarios are summarized in Table 4.

dominance ecosystem because partnership formation in the region is influenced primarily by institutional coordination, organizational linkages, and accumulated local networks rather than by industrial concentration alone. West Sumatra represents a social participation ecosystem, where community engagement, trust, and collaborative interactions among local actors play a more prominent role in supporting partnership formation. Collectively, these four scenarios capture contrasting ecosystem conditions that enable the model to examine how differences in regional environments generate unequal partnership outcomes within the MBG program.

Table 5.
Regional Scenario Parameters

Scenario	IA	LB	SA	SupA	CP	LR	MC
Jakarta	0.90	0.15	0.95	0.90	0.85	0.05	804
Highland Papua	0.30	0.95	0.20	0.32	0.23	1.00	199
Central Kalimantan	0.65	0.50	0.70	0.53	0.50	1.00	549
West Sumatra	0.50	0.75	0.50	0.42	0.66	1.00	236

G. Data Analysis

The model was implemented using MATLAB and executed under each simulation scenario. During each simulation cycle, agents progress through stages of opportunity evaluation, registration, approval, operational activities, learning and adaptation, supervision, and audit monitoring. Simulation outputs were analyzed by comparing registration rates, approval rates, survival rates, capacity utilization, partnership inequality, and regional participation disparities across scenarios. The resulting emergent patterns were subsequently interpreted using the Complex Adaptive Systems perspective to explain how interactions among agents and environmental conditions generate unequal partnership opportunities within the MBG ecosystem.

IV. FINDINGS AND DISCUSSION

A. Equal Access Ecosystem (Jakarta)

To examine how different regional environments influence MBG partnership formation, the simulation was executed under four representative regional scenarios. Each scenario reflects distinct combinations of information accessibility, logistical barriers, supplier availability, institutional support, and social participation dynamics. The first scenario represents Jakarta as an equal access ecosystem, where businesses operate under highly favorable conditions characterized by extensive information access, well-developed infrastructure, strong supplier networks, and effective institutional support. This scenario serves as the benchmark for evaluating the optimal performance of the MBG partnership ecosystem before comparing it with regions facing more challenging structural conditions.

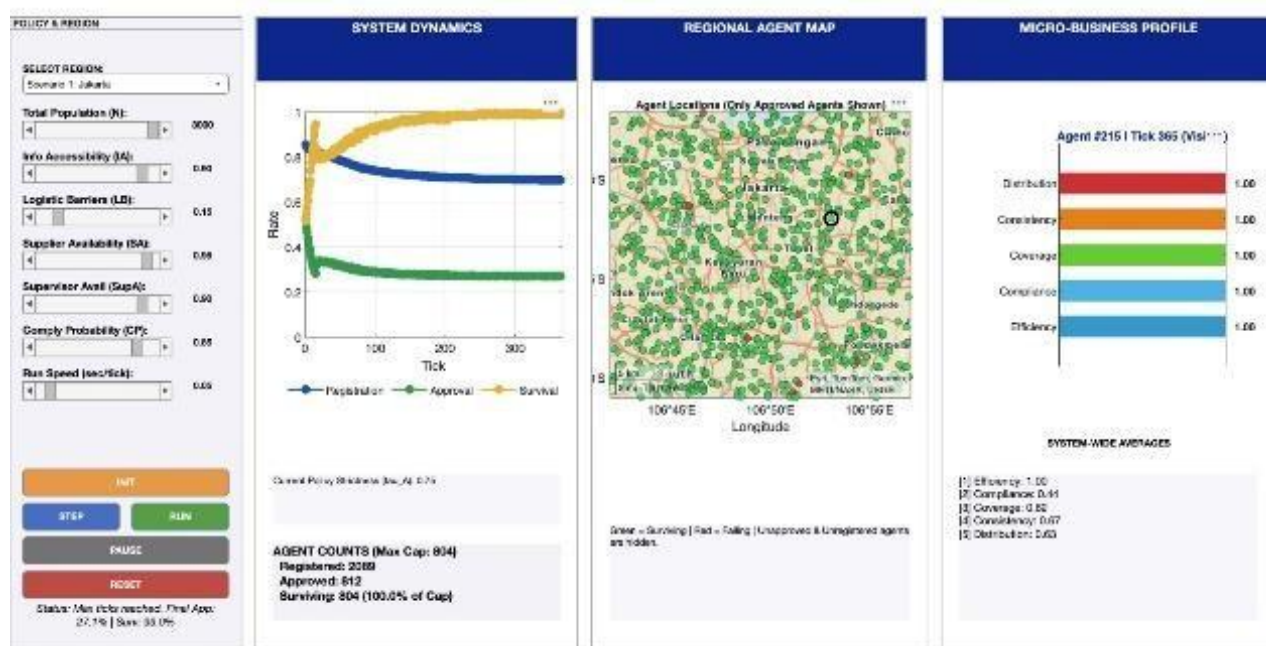


Figure 2.
Scenario 1

Figure 2 illustrates the simulation outputs for Scenario 1 (Equal Access Ecosystem – Jakarta). The left panel shows the environmental parameters applied in the simulation, including information accessibility, logistical barriers, supplier availability, supervisory support, compliance probability, and market capacity. The second panel depicts the system dynamics by displaying the cumulative numbers of registered, approved, and surviving agents throughout the simulation. The regional agent map visualizes the spatial distribution of agents, where green dots indicate active

(surviving) partners, red dots indicate failed agents that exited the partnership system, and gray dots denote inactive business agents that did not successfully participate in the MBG ecosystem. The right panel summarizes the operational profile of a representative micro-business agent based on its performance attributes during the simulation.

Scenario 1 corresponds to an equal access ecosystem characterized by high information accessibility, low logistical barriers, and strong supplier availability. The simulation produced 867 registered agents, 862

approved partners, and 804 surviving partners, resulting in full utilization of the regional market capacity (MC = 804). These results indicate that favorable environmental conditions significantly increase participation, approval, and long-term partnership sustainability. Under conditions where access to information and resources is widely available, most eligible actors are able to successfully enter and remain within the MBG partnership ecosystem.

The findings support Resource Dependence Theory proposed by Pfeffer and Salancik (1978), which argues that access to critical resources influences organizational opportunities and performance. The results also align with Social Capital Theory developed by Bourdieu (1986), Coleman (1988), and Putnam (1993, 2000), as strong information flows and network accessibility facilitate participation and partnership success. From a Complex Adaptive Systems perspective (Holland, 1992),

the interaction between favorable environmental conditions and adaptive agent behavior generated positive feedback mechanisms that enabled the partnership ecosystem to reach its maximum capacity.

B. Geographic Inequality (Highland Papua)

Following the equal access scenario, the second simulation examines Highland Papua to represent a geographically constrained regional ecosystem. The environmental settings in this scenario reflect the challenges commonly experienced by remote areas, including limited infrastructure, high transportation costs, low information accessibility, restricted supplier networks, and reduced supervisory support. From a Complex Adaptive Systems perspective, these conditions create a less favorable environment for agent interaction and adaptation, enabling the simulation to capture how structural disadvantages contribute to unequal partnership opportunities within the MBG ecosystem.

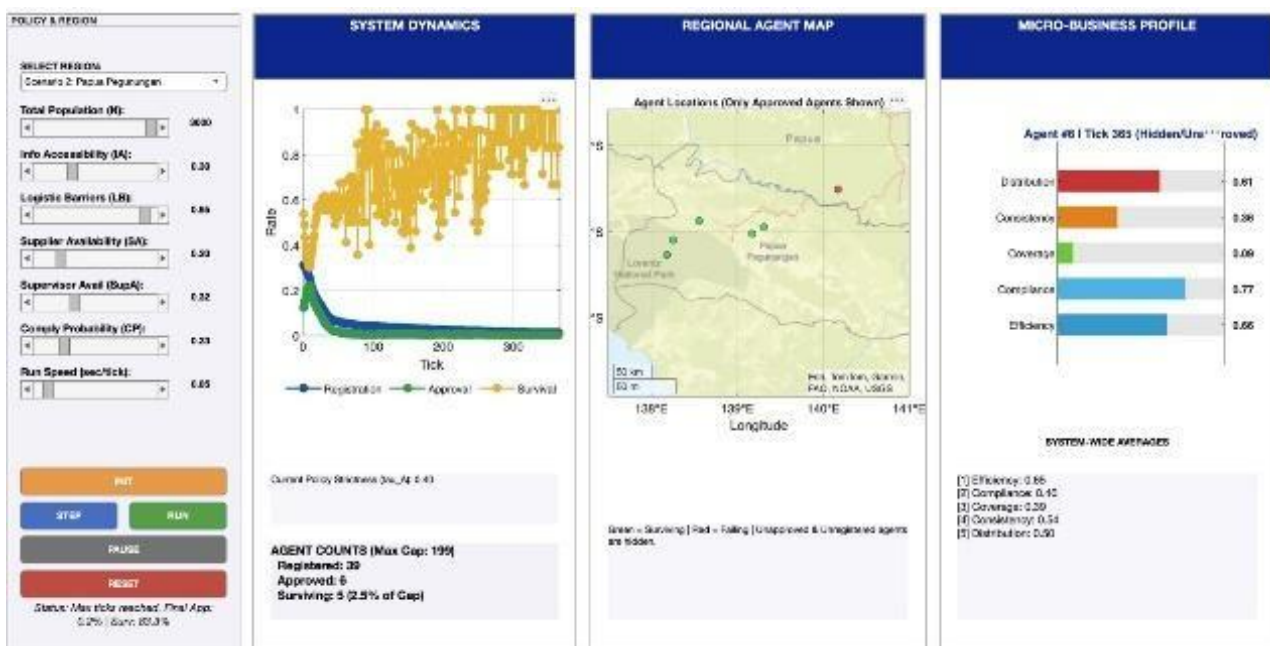


Figure 3.
Scenario 2

Figure 3 illustrates the simulation outputs for Scenario 2 (Geographic Inequality – Highland Papua). The left panel shows the environmental parameters applied in the simulation, reflecting limited information accessibility, severe logistical barriers, restricted supplier availability, and relatively weak supervisory support. The second panel depicts the system dynamics by displaying the cumulative numbers of registered, approved, and surviving agents throughout the simulation. The regional agent map visualizes the spatial distribution of agents, where green dots indicate active (surviving) partners, red dots represent failed agents that exited the partnership system, and gray dots denote inactive business agents that did not successfully participate in the MBG ecosystem. The right panel summarizes the operational profile of a representative micro-business agent based on its performance attributes during the simulation.

Scenario 2 corresponds to a geographically disadvantaged ecosystem characterized by limited information accessibility, severe logistical barriers, and restricted supplier availability. The simulation generated

only 39 registered agents, of which six were approved as MBG partners and five remained active until the end of the simulation period. Despite having a market capacity of 199 partnerships, only 2.5% of the available capacity was utilized, representing the lowest performance among all simulation scenarios. These findings indicate that structural barriers significantly constrained partnership formation and sustainability within the region, resulting in the utilization of only 2.5% of the available partnership capacity despite considerable unmet market potential.

The results suggest that geographical constraints play a critical role in shaping partnership opportunities. High logistical barriers, limited supplier availability, and restricted access to information reduced both participation and approval rates, preventing potential partners from entering and surviving within the MBG ecosystem. This finding supports Resource Dependence Theory proposed by Pfeffer and Salancik (1978), which argues that unequal access to critical resources affects organizational opportunities and performance. The

results also reflect the mechanism described by Cumulative Advantage Theory (Merton, 1968; DiPrete & Eirich, 2006), where regions facing initial disadvantages continue to experience lower participation and partnership outcomes over time. From a Complex Adaptive Systems perspective (Holland, 1992), these environmental constraints generated a pattern of geographic exclusion, limiting the ability of agents to adapt and participate effectively despite the existence of unused partnership capacity.

The extremely low capacity utilization observed in Highland Papua suggests that structural constraints cannot be addressed solely through uniform national policies. The simulation indicates the existence of a minimum infrastructure threshold that must be achieved before the MBG partnership ecosystem can operate effectively. This threshold includes adequate transportation connectivity, sufficient local supplier availability, reliable supervision and mentoring mechanisms, and improved access to program information. Without these enabling conditions,

increasing the number of partnership opportunities alone is unlikely to improve regional participation, as business actors remain constrained by fundamental logistical and institutional barriers. Therefore, infrastructure strengthening and capacity-building interventions should precede or accompany partnership expansion in structurally disadvantaged regions.

C. Network Dominance (Central Kalimantan)

The third simulation investigates Central Kalimantan as a regional ecosystem characterized by network dominance. Although environmental conditions are more favorable than those in geographically disadvantaged regions, partnership formation is largely shaped by the distribution of institutional networks, accumulated experience, and social connections among business actors. From a Complex Adaptive Systems perspective, repeated interactions among agents enable existing advantages to reinforce future partnership opportunities, allowing the simulation to capture how network structures influence participation patterns and generate partnership concentration within the MBG ecosystem.

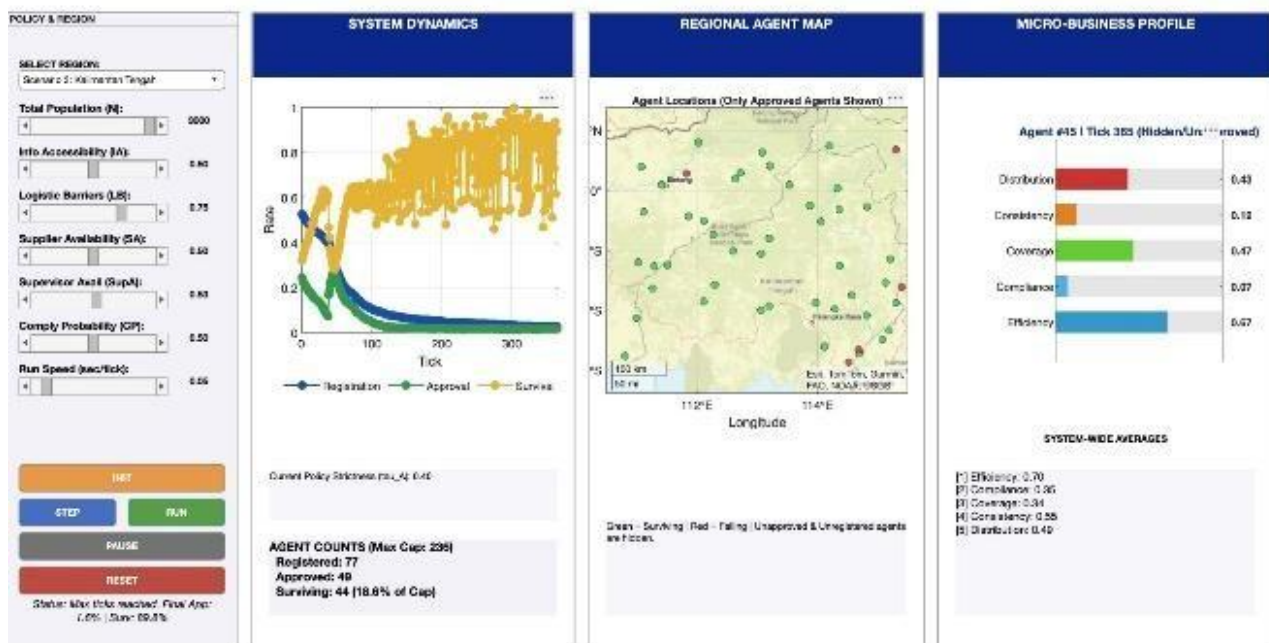


Figure 4.
Scenario 3

Figure 4 illustrates the simulation outputs for Scenario 3 (Network Dominance – Central Kalimantan). The left panel shows the environmental parameters applied in the simulation, reflecting moderate information accessibility, balanced logistical barriers, relatively strong supplier availability, and institutional support. The second panel depicts the system dynamics by displaying the cumulative numbers of registered, approved, and surviving agents throughout the simulation. The regional agent map visualizes the spatial distribution of agents, where green dots indicate active (surviving) partners, red dots represent failed agents that exited the partnership system, and gray dots denote inactive business agents that did not successfully participate in the MBG ecosystem. The right panel summarizes the operational profile of a representative micro-business agent based on its performance attributes during the simulation.

Scenario 3 corresponds to a network-dominance ecosystem characterized by strong institutional networks, prior experience, and accumulated advantages among participating actors. The simulation generated 77 registered agents, 49 approved partners, and 44 surviving partners at the end of the simulation period. Although the number of participants was relatively low, approved partners demonstrated a high survival rate, indicating that actors who successfully entered the system possessed sufficient resources and capabilities to maintain their participation. Only 18.6% of the available market capacity was utilized, suggesting that partnership opportunities were concentrated among a limited group of actors rather than being broadly distributed throughout the region.

The results indicate the emergence of network clustering, where partnership opportunities tend to accumulate among actors with stronger connections and

greater institutional access. This finding supports Social Capital Theory proposed by Bourdieu (1986), Coleman (1988), and Putnam (1993, 2000), which emphasizes the importance of social networks in facilitating access to information and opportunities. The findings also align with Cumulative Advantage Theory developed by Merton (1968) and further elaborated by DiPrete and Eirich (2006), suggesting that actors possessing early advantages are more likely to secure additional opportunities over time. From a Complex Adaptive Systems perspective (Holland, 1992), repeated interactions among agents generated a concentration of opportunities among well-connected participants, producing a self-reinforcing pattern of partnership success despite relatively low overall participation.

D. Social Participation Dynamics (West Sumatra)

The final simulation scenario examines West Sumatra as a regional ecosystem characterized by dynamic social participation. Rather than relying solely on resource availability or institutional advantages, partnership formation in this scenario is strongly influenced by social interactions, trust in the MBG program, and the diffusion of participation behavior among agents. From a Complex Adaptive Systems perspective, repeated interactions and positive feedback mechanisms encourage additional business actors to participate, allowing the simulation to capture how social dynamics reinforce partnership growth and improve the sustainability of the MBG partnership ecosystem.



Figure 5.
Scenario 4

Figure 5 illustrates the simulation outputs for Scenario 4 (Social Participation Dynamics – West Sumatra). The left panel shows the environmental parameters applied in the simulation, reflecting moderate resource availability, adequate information accessibility, balanced logistical conditions, and active participation dynamics. The second panel depicts the system dynamics by displaying the cumulative numbers of registered, approved, and surviving agents throughout the simulation. The regional agent map visualizes the spatial distribution of agents, where green dots indicate active (surviving) partners, red dots represent failed agents that exited the partnership system, and gray dots denote inactive business agents that did not successfully participate in the MBG ecosystem. The right panel summarizes the operational profile of a representative micro-business agent based on its performance attributes during the simulation.

Scenario 4 corresponds to a social participation ecosystem characterized by moderate resource availability, adequate information accessibility, and active participation dynamics. The simulation generated 1,475 registered agents, representing the highest registration level among all scenarios. Of these

applicants, 550 were approved as MBG partners and 549 remained active until the end of the simulation period. The region achieved full utilization of its market capacity ($MC = 549$), indicating that partnership opportunities were rapidly absorbed by participating actors. These findings suggest that favorable participation dynamics can significantly increase interest in the program and support long-term partnership sustainability.

The results demonstrate that information accessibility and positive participation behavior play important roles in stimulating partnership growth. Although logistical barriers remained moderate, adequate supplier availability and favorable perceptions of the program encouraged a large number of agents to register and participate. This finding is consistent with Relative Deprivation Theory proposed by Gurr (1970) and Hirschman (1970), which suggests that participation decisions are influenced by perceptions of opportunity and fairness. When actors perceive opportunities as accessible and attainable, participation tends to increase. From a Complex Adaptive Systems perspective (Holland, 1992), high participation generated reinforcing social effects that encouraged additional actors to join the

system, ultimately allowing the partnership ecosystem to reach its maximum operational capacity.

E. Cross-Scenario Comparison and Emergent Outcomes

The comparison of simulation results reveals substantial disparities in partnership formation and sustainability across regions. Jakarta and West Sumatra achieved full utilization of their respective market capacities, whereas Highland Papua utilized only 2.5% of available capacity and Central Kalimantan utilized 18.6%. These differences indicate that partnership opportunities are not distributed evenly across regions, even when all actors operate within the same national MBG framework. Environmental conditions, resource accessibility, social networks, and participation dynamics collectively influence the ability of business actors to enter and remain within the partnership ecosystem.

Several emergent outcomes were observed across the simulation scenarios. First, a partnership inequality trap emerged as regions with favorable conditions accumulated substantially more partnership opportunities than disadvantaged regions. Second, geographic exclusion was observed in Highland Papua, where severe logistical barriers and limited supplier availability significantly restricted participation. Third, network clustering emerged in Central Kalimantan, where partnership opportunities tended to concentrate among actors possessing stronger institutional and social connections. Fourth, an adaptive survival gap appeared as stronger actors consistently demonstrated higher survival rates than weaker participants. Finally, the simulation revealed a pattern of institutional dependence, indicating that partnership sustainability was strongly influenced by information accessibility, supplier availability, supervision support, and regional environmental conditions.

These findings support the argument that partnership inequality within the MBG ecosystem cannot be explained by a single factor. Resource Dependence Theory explains how unequal access to critical resources influences participation opportunities, while Social Capital Theory highlights the importance of networks and information flows in shaping partnership success. Cumulative Advantage Theory explains how early advantages become reinforced over time, creating persistent disparities among actors and regions. Relative Deprivation Theory helps explain differences in participation behavior arising from perceptions of opportunity and accessibility. Collectively, these findings reinforce the Complex Adaptive Systems perspective, which views partnership inequality as an emergent outcome generated through continuous interactions among agents and their surrounding environments rather than as the direct result of any single variable.

The simulation outcomes are broadly consistent with the early implementation of the MBG program reported by the National Nutrition Agency (2026), which indicates that operational SPPGs and partnership activities remain concentrated in regions with stronger infrastructure and institutional capacity, particularly on Java, while several provinces in Eastern Indonesia continue to experience lower implementation coverage. Although the present simulation is not intended to reproduce exact empirical values, the observed regional disparities demonstrate that the Hybrid ABM framework captures the general patterns of partnership development observed during the early stages of MBG implementation, thereby providing preliminary support for the model's predictive validity.

Table 6.
Comparison of Simulation Results Across Scenarios

Scenario	Registered	Approved	Survived	Capacity Utilization
Jakarta	867	862	804	100%
Highland Papua	39	6	5	2.5%
Central Kalimantan	77	49	44	18.6%
West Sumatra	1,475	550	549	100%

V. CONCLUSION

This study examined the dynamics of MBG partnership formation using a Complex Adaptive Systems (CAS) perspective and a Hybrid Agent-Based Modeling (ABM) framework. The simulation results demonstrate that partnership opportunities are distributed unevenly across regions and are strongly influenced by differences in information accessibility, logistical barriers, supplier availability, supervision support, and social interactions among actors. Regions characterized by favorable environmental conditions, such as Jakarta and West Sumatra, achieved substantially higher levels of registration, approval, and partnership sustainability than regions facing structural constraints, such as Highland Papua. These findings indicate that equal national policies do not necessarily generate equal partnership opportunities across different regional contexts.

The simulation further revealed several emergent outcomes, including partnership inequality traps, geographic exclusion, network clustering, adaptive survival gaps, and institutional dependence. These outcomes were reflected in concrete regional conditions, such as limited supplier availability, severe logistical bottlenecks, restricted information accessibility, unequal concentration of partnership opportunities among well-connected actors, and insufficient supervision support in structurally disadvantaged regions. Together, these mechanisms emerged through the interaction of heterogeneous agents operating under different environmental conditions, demonstrating that partnership inequality is not the result of a single factor but rather a consequence of complex interactions among resources, networks, participation behavior, and regional characteristics. The findings support Resource Dependence Theory, Social Capital Theory, Cumulative Advantage Theory, and Relative Deprivation Theory,

while also confirming the usefulness of the Complex Adaptive Systems perspective in explaining how partnership inequalities develop and persist over time.

From a practical perspective, the results suggest that reducing partnership inequality within the MBG ecosystem requires more than uniform policy implementation. From a practical perspective, the findings suggest that the National Nutrition Agency should prioritize policies aimed at improving information accessibility, reducing logistical bottlenecks, strengthening local supplier networks, expanding supervision and mentoring support, and designing region-specific interventions for structurally disadvantaged areas. Addressing these specific constraints is expected to reduce partnership inequality and improve the effectiveness of MBG implementation across diverse regional contexts. Such measures can help create a more inclusive partnership ecosystem and increase the participation of business actors in regions that currently face significant structural barriers.

This study contributes to the literature by integrating multiple theoretical perspectives within a Hybrid Agent-Based Modeling framework to examine partnership formation and inequality in a large-scale public program. By demonstrating how individual decisions, environmental conditions, and social interactions collectively generate emergent outcomes, the study provides a deeper understanding of the mechanisms underlying unequal partnership opportunities and offers a foundation for future research on adaptive policy design and partnership development within complex public-sector ecosystems.

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