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Regional Food Supply System Planning: A System Dynamics Analysis of Broiler Chicken Supply and Price Stabilization Policies in Indonesia

Avif Haryana [1,2], Suprayogi [1], Rachmawati Wangsaputra[1] and Rajesri Govindaraju[1]

***Abstract*.** Price instability in Indonesia's broiler sector is not only an industry-level supply chain problem but also a food supply planning issue with regional relevance, as broiler meat is an important source of affordable animal protein. Despite repeated government interventions, including reference prices, final stock day-old chicks (FS DOC) supply regulation, hatching egg culling, and early culling of breeder hens, live bird prices frequently have remained below production cost. This study developed an explanatory system dynamics model to examine how recurrent live bird price instability emerges endogenously from the structure of the broiler food supply system. The model integrates downstream broiler meat demand, slaughterhouse activity, live bird market dynamics, integrator and non-integrator grow-out production, FS DOC allocation, cold storage, the grandparent stock (GPS) and parent stock (PS) breeding subsystem, and grandparent stock day-old chicks (GPS DOC) import determination. The main novelty lies in a dual-control structure that combines long-term capacity correction through demand-driven GPS DOC import adjustment and short-term operational control through hatchery setting adjustment. Baseline simulation broadly and qualitatively reproduced the recurrent pattern of live bird price fluctuations and prolonged periods of price pressure relative to production cost. Scenario analysis indicated that hatchery setting adjustment is the strongest short-run leverage point, because it moderates excess FS DOC realization before surplus propagates downstream to live bird and broiler meat markets. Demand-driven GPS DOC import adjustment has limited short-run influence because of long biological delays but remains important for aligning long-term breeding capacity with downstream requirements. Within the modeled system, cold storage operates as a residual downstream buffer rather than the primary source of stabilization. Overall, the findings suggest that broiler price stabilization should be treated as a multi-horizon food supply planning problem that requires coordinated control of upstream breeding capacity, hatchery operations, market absorption, and downstream buffering.

***Keywords*.** system dynamics; regional food supply planning; broiler supply system; live bird price; FS DOC; GPS DOC import; hatchery setting adjustment; price stabilization.

1. Introduction

Regional food supply planning is concerned with how food production, distribution, market infrastructure, and consumer demand are coordinated across space to ensure stable access to affordable food while protecting producer livelihoods. Mui et al. (2021) argue that regional food planning should address equity, institutional coordination, and the vulnerability of actors within the food system, which is relevant to independent broiler farmers, who bear high production risks

[1] Graduate Program of Industrial Engineering, Bandung Institute of Technology, Bandung, Indonesia. * (Corresponding author email: vifhary@gmail.com.)
[2] Ministry of Trade of Indonesia, Jakarta, Indonesia

when live bird prices fall below production costs. Further, Zhong et al. (2021) emphasize the importance of comprehensive food system planning that integrates production, distribution, markets, and consumption. This perspective suggests that broiler supply planning should connect upstream decisions, such as GPS DOC imports, parent stock capacity, and FS DOC allocation, with downstream slaughterhouse absorption and consumer demand. Similarly, Keegan et al. (2024) highlight that regional food system resilience depends on supply chain coordination, adaptive capacity, and governance mechanisms that allow the system to respond to shocks and imbalances.

Ensuring stable access to affordable animal protein is therefore a key concern in regional food supply planning, particularly in developing and emerging economies where food price volatility affects household welfare, producer livelihoods, and market coordination (Beal et al., 2023). In Indonesia, broiler meat is one of the most important sources of affordable animal protein for both household and non-household consumers. However, the broiler supply system faces a persistent structural problem: live bird prices at the farm gate frequently fluctuate and fall below both the government reference price and production costs, particularly during periods of oversupply. For independent farmers, this instability threatens business survival, because they bear the full risk of purchasing FS DOC and feed, raising broilers, and selling harvested birds in the live bird market. Repeated price collapses have eroded farmers' margins and led many independent farmers to exit the industry (Kimberly & Sitorus, 2023; Nugroho, 2020)).

Further, live bird price instability in Indonesia's broiler industry reflects a regional food supply chain issue, because it emerges from misalignment between where and when broilers are produced, how they are distributed, and how effectively regional markets can absorb supply. Downstream broiler meat demand, slaughterhouse absorption, live bird procurement, FS DOC allocation, PS and GPS breeding capacity, and GPS DOC import decisions are interconnected across different decision horizons. A disruption or misalignment in one part of the system may be transmitted to other parts through inventories, prices, margins, and delayed production responses. Therefore, stabilizing live bird prices requires more than output-market price intervention. It requires an integrated understanding of how food demand, production planning, breeding capacity, market absorption, and supply-control policies interact over time (Solano-Blanco et al., 2023).

Stakeholders in Indonesia's poultry industry have identified oversupply and price pressure as the main problems facing the broiler sector, an observation that is consistent with previous studies (Nugroho, 2020; Salim et al., 2020; Suganda et al., 2024). In response, the government has implemented several supply- and price-stabilization policies, including setting reference prices, regulating FS DOC supply, controlling the availability of hatching eggs, and early culling of breeding stock when surplus conditions emerge. More recently, the Ministry of Agriculture Regulation No. 10 of 2024 has emphasized the importance of national production planning, supply–demand balance, the development of a national poultry information system, and stronger oversight. Nevertheless, sharp declines in the price of live birds continue to occur. This suggests that the problem should not be understood merely as a temporary deviation from market equilibrium but as the outcome of a systemic structure involving production decisions, inventory adjustment, actor behavior, and delayed supply responses.

This structural pressure is further illustrated by the cost–price pattern shown in Table 1. Over the period 2017–2021, average annual live bird prices were below the estimated cost of goods sold (COGS) in four of the five observed years, indicating recurrent pressure on farm-level gross margins. Only in 2018 did the average annual live bird price slightly exceed the estimated COGS. At the same time, GPS DOC imports remained substantial, suggesting that upstream biological capacity was maintained despite weak farm gate price performance in most years. Taken together, these trends suggest that live bird price instability is shaped by the structure of the supply chain rather than merely by temporary market fluctuations.

Table 1. Annual Trends in GPS DOC Imports, Estimated Production Costs, Live Bird Prices, and Gross Margins in Indonesia, 2017–2021 (Source: Kementerian Pertanian RI, (2025), and calculated data based on a preliminary study)

Year	GPS DOC Import (Pcs)	Average FS DOC Price (Rp/Pcs)	FS DOC cost per kg live bird (Rp/ kg) *	Average Feed Price (Rp/kg)	Feed cost per kg live bird (Rp/kg)*	Other cost at 10% (Rp/kg)*	COGS (Rp/kg)	Average Live Bird Price (Rp/kg)	Gross Margin (Rp/kg)
			= (3)/average HW		= FCR x (5)		=(4)+(6)+(7)		=(9)-(8)
1	2	3	4	5	6	7	8	9	10
2017	660,024	6,466	3,592	8,266	11,986	1,731	17,309	17,254	-55
2018	750,200	7,250	4,028	8,592	12,459	1,832	18,319	19,901	1583
2019	756,214	7,900	4,389	9,041	13,109	1,944	19,442	17,876	-1566
2020	720,243	7,839	4,355	9,263	13,431	1,976	19,762	17,476	-2286
2021	506,363	8,759	4,866	9,682	14,038	2,100	21,005	19,541	-1463

*Based on assumed feed conversion ratio (FCR) = 1.45 and average harvest weight (HW) = 1.8 kg.

The Indonesian broiler supply system has several structural characteristics that make price stabilization difficult. First, broiler production is organized through a multi-layered breeding structure, from GPS and PS breeding to FS DOC production and live bird farming. While PS and FS production are carried out domestically, the upstream supply of GPS still depends on imported GPS DOC. Consequently, today's decisions regarding GPS imports and breeding capacity affect FS DOC and live bird supply only after a sequence of biological, operational, and administrative lead times. This makes upstream capacity planning critical for downstream market stability but difficult to adjust in response to short-term demand changes (Suganda et al., 2024).

Second, the industry is characterized by heterogeneous actors with different levels of control over inputs, production, and market channels. This condition is consistent with Saptana & Ilham (2020), who showed that independent broiler farmers face an asymmetric market position, with oligopolistic pressure in input markets and oligopsonistic pressure in output markets. Independent farmers and other non-integrator actors purchase FS DOC and feed from input markets dominated by large corporations but sell harvested birds in an output market that is highly sensitive to daily supply surpluses. Integrators, by contrast, have more allocation options because part of their production can be directed to internal slaughterhouses, fresh meat markets, cold storage, or processed products. This difference creates risk asymmetry: production surpluses can be redirected by integrators to alternative channels, whereas for independent farmers surplus is often immediately translated into downward pressure on harvest prices. This pressure can be further exacerbated when harvested birds from integrators or their contract growers spill over into the open live bird market.

Empirical studies on broiler farming also show that farmers' income and business viability are highly sensitive to price fluctuations and production performance. Nurlaelah et al. (2022) found that during the pandemic, partnership systems were still affected by supply chain disruptions, income changes, and price fluctuations, while Wantasen et al. (2021) showed that broiler farms operating under partnership models were sensitive to output price declines, operating cost increases, and production decreases. This evidence indicates that farmers' margins should be treated not only as an economic outcome but also as a behavioral variable that influences chick-in decisions and future supply formation.

From a policy perspective, live bird price stabilization cannot be separated from upstream input structures and national production planning. Paramayudha & Budhisatrio (2024) emphasize that Indonesia's broiler competitiveness and export opportunities remain constrained by input market issues, particularly the availability of feed maize and the GPS DOC import procedures. This suggests that stabilizing live bird prices requires more than output-market price intervention. This interpretation is consistent with supply-chain modelling evidence from Unveren & Luckstead (2020), which shows that broiler industry outcomes are shaped by vertical and horizontal linkages among feed inputs, breeder farms, hatcheries, grow-out farms, processing plants, value-added processing, and final markets. In the Indonesian context, this implies that price stabilization requires an integrated understanding of production planning, GPS DOC import policy, FS DOC allocation, feed costs, hatchery decisions, slaughterhouse absorption, cold storage utilization, and downstream broiler meat demand. Thus, broiler price stabilization lies at the intersection of food supply planning, data governance, coordination among business actors, and the protection of independent farmers.

This study developed a system dynamics model to analyze the endogenous mechanisms through which the structure of Indonesia's broiler supply system generates recurrent live bird price fluctuations and prolonged price pressure. The model was not designed to predict weekly live bird prices with precision but to explain how decision structures that appear rational at the actor level may generate instability at the system level. From a regional planning perspective, the model provides a framework for understanding how food demand, production capacity, market absorption, and supply-control policies interact across regions and decision horizons. By integrating downstream broiler meat demand, slaughterhouse activity, live bird market dynamics, integrator and non-integrator grow-out production, FS DOC allocation, cold storage, GPS–PS breeding capacity, and GPS DOC import determination, the model supports planning-oriented evaluation of policy levers for stabilizing supply, protecting farmer viability, and strengthening the resilience of regional broiler food supply systems.

The main contribution of this study lies in the development of a system dynamics model that endogenizes upstream breeding capacity formation, integrates the FS DOC, live bird, and broiler meat markets, and introduces a dual-control structure within the breeding and hatchery system. The first control mechanism operates over a longer horizon through demand-driven GPS DOC import and breeding capacity decisions. The second operates over a shorter horizon through hatchery setting adjustment and FS DOC realization. By representing these mechanisms within a unified feedback framework, this study positions broiler price stabilization as a multi-horizon food supply planning problem rather than merely as a reference price policy issue. Although the model is formulated at the national aggregate level, the mechanisms represented are relevant for regional food supply planning because supply imbalance, market absorption, price pressure, and producer viability are ultimately experienced across territorial food markets.

2. Literature Review

Regional food supply planning requires an integrated understanding of how food demand, production capacity, distribution, market absorption, and policy interventions interact over time. In developing and emerging economies, the stability of strategic food commodities should be treated as a planning and governance concern, as food price movements affect consumer affordability, producer viability, and regional market coordination. Broiler meat is particularly relevant in this context, because it is one of the most affordable sources of animal protein and is closely linked to household consumption, non-household demand, slaughtering capacity, cold storage, and upstream input planning (Ibayi et al., 2025; Thi Dien et al., 2023). Food systems studies have emphasized that food policy problems are complex and interlinked, while Indonesian staple protein studies have shown that poultry production is closely connected to feed supply, chicken production, consumer demand, and food security planning (Queenan et al., 2022; Vanany et al., 2021).

A system dynamics perspective is useful for examining such planning problems, because it explains how system behavior emerges from feedback relationships, stocks and flows, accumulations, nonlinearities, delays, and decision rules. From this perspective, system behavior is generated by the internal structure of feedback relationships, accumulations, delays, and decision rules that shape actors' responses over time, rather than solely by external disturbances (Richardson, 2025; Sterman, 2000). In food and agricultural systems, this perspective is important because supply responses are rarely instantaneous. Production decisions are often based on current or perceived prices, while the resulting output becomes available only after biological, operational, or administrative delays. These delays can create a temporal mismatch between the decision to expand production and the actual market condition when additional supply arrives.

This mechanism is closely related to commodity price cycles. When prices rise, producers tend to expand production or increase chick-in decisions. However, if the additional supply reaches the market after demand conditions have changed, the system may experience overshooting, surplus accumulation, price decline, production contraction, and a subsequent cycle of supply adjustment. System dynamics studies of commodity markets have shown that such cycles may arise from delayed supply responses, inventory adjustments, and decision rules based on imperfect information (Glöser-Chahoud et al., 2016; Sterman, 2000). Therefore, price instability in biological supply systems should be understood as a dynamic planning problem involving feedback, expectations, and adjustment delays, rather than merely as a market-clearing problem.

In broiler supply systems, delays occur across several biological, operational, and information-processing stages. Biological delays include GPS maturation, PS maturation, laying periods, hatching egg production, incubation, and broiler rearing periods. Operational delays occur in hatchery setting adjustment, DOC allocation, procurement, slaughtering, cold storage utilization, and distribution. Information delays arise because actors respond to perceived demand, perceived price, inventory conditions, and expected margins rather than to perfectly observed real-time conditions. These delay structures are consistent with system dynamics modelling principles, which emphasize the role of material delays, information delays, and adjustment processes in generating dynamic behavior (Bala et al., 2017; Sterman, 2000). In the broiler industry, such delays are also reinforced by the biological structure of poultry breeding and production, from upstream genetic stock and breeding capacity to final stock broiler production (Neeteson et al., 2023). Consequently, broiler price stabilization requires a multi-horizon planning perspective that links long-term breeding capacity decisions with short-term operational control and downstream buffering.

Previous system dynamics studies on food and poultry systems provide important foundations, but they differ in their model boundaries and policy purposes. Early food supply chain models used system dynamics to analyze demand, production, inventory, and distribution relationships in food systems (Minegishi & Thiel, 2000). Vo & Thiel (2011) applied system dynamics to poultry supply chain dynamics during a sanitary crisis, highlighting the relevance of feedback and delays in poultry supply responses. Shamsuddoha (2015, 2022) developed poultry supply chain models to address sustainable production and forward supply chain integration, while Gafi & Javadian (2018) used system dynamics to evaluate policy options for improving chicken industry supply chain performance. These studies demonstrated the usefulness of system dynamics for representing poultry supply chains, but they generally focused on operational efficiency, sustainability, crisis response, or aggregate production performance rather than on the interaction between breeding capacity, FS DOC allocation, live bird price formation, and broiler meat market absorption.

Qualitative system dynamics and livestock value-chain studies have further shown that poultry systems are shaped by actor structures, market power, smallholder constraints, and policy entry points. Cuevas Garcia-Dorado et al. (2021) used causal loop diagrams to identify reinforcing dynamics that limit inclusiveness in the broiler value chain, while Aboah & Enahoro (2022) showed that drivers of change in poultry farming systems can shift across the production cycle. Ariffin et al. (2024) combined actor-network theory and system dynamics to understand poultry supply chains as evolving networks of human and non-human actors. These studies have broadened the literature beyond narrow production analysis. However, most remain qualitative, actor-oriented, or food-security-oriented and do not explicitly simulate price instability across interconnected DOC, live bird, and meat markets.

The Indonesian broiler sector adds further complexity because live bird price instability is shaped by both market dynamics and actor structures. Suganda et al. (2024) showed that actor contestation in Indonesia's broiler supply chain is influenced by control over FS DOC, feed, downstream access, and market power. Kimberly & Sitorus (2023) further showed that broiler supply chains involve multiple operational stages, including farms, company agents, slaughterers, markets, restaurants, and consumers, and are affected by input and output price fluctuations. Paramayudha & Budhisatrio (2024) emphasize that Indonesia's poultry competitiveness is constrained by input-market issues, including feed maize availability and GPS DOC import procedures. These studies provide important evidence on actor relationships, input constraints, and market structure, but they do not show how these structures generate recurrent price behavior through endogenous feedback mechanisms. Table 2 summarizes selected previous studies and clarifies how this study differs from previous work.

Table 2. Selected Previous Studies and Research Gaps

Previous studies	**Main focus of previous studies**	**Remaining gap addressed in this study**
Mui et al. (2021); Zhong et al. (2021); Keegan et al. (2024); Beal et al. (2023)	Regional food planning, food system resilience, institutional coordination, food access, stakeholder interaction, and the relationship between food systems and human welfare	Limited use of simulation to examine broiler price stabilization as a regional food supply planning problem involving supply–demand imbalance, actor vulnerability, and multi-level coordination
Minegishi and Thiel (2000); Vo and Thiel (2011); Shamsuddoha (2015, 2022); Gafi and Javadian (2018); Unveren and Luckstead (2020)	System dynamics and supply chain modelling of food and poultry systems, including feedback, delays, inventory, production, distribution, crisis response, sustainability, trade-policy effects, and supply chain performance	Limited representation of GPS-PS breeding capacity, GPS DOC import decisions, hatchery setting adjustment, and FS DOC transmission to live bird prices in an endogenous price-stabilization framework

Previous studies	Main focus of previous studies	Remaining gap addressed in this study
Vanany et al. (2021); Suganda et al. (2024); Kimberly and Sitorus (2023); Paramayudha and Budhisatrio (2024)	Indonesian staple protein and broiler studies, including corn supply, feed mills, chicken production, consumer demand, actor contestation, input constraints, GPS DOC import procedures, and competitiveness	Limited integration of FS DOC allocation, farmer margin, live bird price formation, broiler meat demand, slaughterhouse absorption, and upstream capacity planning in a single dynamic simulation model
Cuevas Garcia-Dorado et al. (2021); Aboah and Enahoro (2022); Ariffin et al. (2024); Queenan et al. (2022)	Livestock value-chain governance and qualitative system dynamics, including actor structure, market power, smallholder constraints, inequality, policy leverage points, and food system interactions	Limited quantitative simulation of how actor structures, capacity decisions, inventory pressure, market absorption, and price adjustment generate recurrent price behavior over time

The synthesis of selected previous studies indicates four main research gaps. First, studies on regional food planning and food system resilience have emphasized coordination, equity, actor vulnerability, and governance, but have rarely translated broiler supply instability into a planning-oriented simulation framework for price stabilization. Second, system dynamics and broiler supply chain models have demonstrated the importance of feedback, delays, inventory, production, and distribution but have not sufficiently represented GPS as a slow-moving biological capacity source whose effects are transmitted through PS capacity, hatching eggs, FS DOC realization, and live bird supply. Third, Indonesian staple protein and broiler studies have provided evidence on feed supply, chicken production, consumer demand, actor contestation, input constraints, and GPS DOC import procedures but have not integrated FS DOC allocation, farmer margin, live bird price formation, broiler meat demand, slaughterhouse absorption, and upstream capacity planning in a single dynamic simulation model. Fourth, livestock value-chain governance and qualitative system dynamics studies have explained actor structures, market power, smallholder constraints, and policy leverage points but have rarely operationalized these structures in a quantitative simulation model that shows how actor behavior, capacity decisions, inventory pressure, market absorption, and price adjustment interact over time.

This study addresses these gaps by developing a system dynamics model of the Indonesian broiler supply system that integrates upstream breeding capacity, FS DOC allocation, live bird market dynamics, broiler meat demand, slaughterhouse absorption, cold storage, and price formation within a single feedback framework. The model introduces a dual-control structure that distinguishes long-term biological capacity planning through demand-driven GPS DOC import and breeding capacity decisions from short-term operational control through hatchery setting adjustment and FS DOC realization. By linking upstream biological capacity, operational FS DOC control, downstream market absorption, and farmer margin dynamics, this study advances a planning-oriented system dynamics framework for analyzing price instability in a multi-tier biological food supply system. It also positions live bird price stabilization as a regional food supply planning and multi-horizon control problem rather than merely a matter of reference prices or short-term supply correction.

3. Methodology

This study employed a system dynamics methodology following the iterative modeling process proposed by Sterman (2000). The process consisted of problem articulation, dynamic hypothesis development, simulation model formulation, model testing and validation, and policy design and evaluation. These stages were not treated as a strictly linear sequence but as an iterative process in which insights from model formulation, testing, and policy simulation were used to refine the problem definition, model boundary, assumptions, and feedback structure (Martinez-Moyano & Richardson, 2013).

The first step was problem articulation. In this stage, the study defined the problem of interest, model purpose, system boundary, time horizon, and reference modes. The problem of interest was formulated around the instability of live bird prices and the imbalance between broiler supply and demand in the Indonesian broiler supply chain. The model's purpose was to explain how upstream breeding decisions, FS DOC allocation, broiler rearing, slaughterhouse absorption, cold storage, and downstream broiler meat demand interact over time to generate price and supply dynamics. The data used in this stage were collected from both secondary and primary sources as part of the preliminary study. The primary data were collected through surveys, discussions, and interviews with the Ministry of Trade team and stakeholders in the poultry industry. Interviews and discussions were conducted in 2020 with two major poultry integrator companies in Indonesia. Interviews were also conducted at two GPS breeding farm sites in Subang and Purwakarta, with three to four participants at each site, including directors, managers, and operational staff from the respective breeding companies. The interview instrument covered the main symptoms of the problem, actor roles, supply-chain structure, policy issues, data availability, and perceived causes of price instability. The information obtained in this stage was used primarily for problem articulation, supply-chain mapping, identification of key variables, and preliminary formulation of the system boundary and dynamic issues to be examined in the model. Secondary data consisted of empirical studies, ministerial publications, and government agency reports, which provided information on key variables such as live bird prices, broiler meat prices, DOC prices, supply indicators, and relevant policy variables.

The second step was dynamic hypothesis development. After defining the problem of interest, reference modes, and model boundary had been defined, the study developed a dynamic hypothesis to explain the feedback mechanisms that could generate the observed behavior. This stage used a causal loop diagram (CLD) to represent the hypothesized causal relationships, feedback loops, delays, and interactions among the main components of the broiler supply system. The dynamic hypothesis was developed based on information obtained from the literature review, policy documents, discussions with government officials, and interviews with poultry industry actors and poultry sector experts. Interviews with poultry industry actors were conducted in March 2022 in Cianjur and in November 2024 in Cianjur and Bogor. Poultry sector expert input was obtained through a series of semi-structured individual interviews with three selected experts from the poultry industry: an owner of an integrated poultry business, an academic specializing in livestock systems, and a practitioner-consultant with expertise in poultry breeding. A semi-structured interview protocol was used to explore perceived causal relationships, key feedback processes, dominant delays, operational decision rules, and the structural sources of price instability. The information obtained from these interviews was used to refine the causal loop structure, confirm or revise the assumed direction of causality, identify important time delays, and assess the structural plausibility of the proposed feedback mechanisms. Expert judgement was translated into model assumptions in the form of hypothesized causal links, delay structures, and decision rules, which were then compared with documentary evidence and retained in the model only when they were consistent with both the empirical context and the overall system logic.

This approach is consistent with the procedure used by Zarghami (2024), which showed that a CLD can be developed and confirmed through a group model-building (GMB) process involving three purposively selected experts. In that study, the experts were involved in reviewing the list of causal factors, developing causal relationships through exploratory workshops, and confirming the CLD through a confirmatory workshop. This approach is also consistent with Cuevas Garcia-Dorado et al. (2021), who developed a CLD based on stakeholder interviews and policy documents. Based on this process, the dynamic hypothesis was represented as a CLD using Vensim PLE 10.4. The output of this step was a conceptual model showing the main feedback mechanisms related to demand perception, FS DOC requirement, hatchery setting, broiler production, live bird inventory, slaughterhouse procurement, price adjustment, and upstream breeding-capacity planning.

The third step was simulation model formulation. After the dynamic hypothesis had been represented conceptually through the CLD, the model was translated into a formal stock and flow diagram (SFD) and simulation equations using the academic version of Powersim Studio 10. This step specified the stocks, flows, auxiliary variables, parameters, decision rules, nonlinear relationships, and delay functions required to operationalize the conceptual structure. Parameter values and equation structures were derived from a combination of system dynamics modelling techniques and data obtained in the previous stages. The formal model was designed to preserve stock-flow consistency, dimensional consistency, and an endogenous explanation of the main dynamic behavior.

The fourth step was model testing and validation. After the simulation model had been formulated, model testing and validation were conducted as complementary confidence-building activities. In line with system dynamics methodology, validation in this study was not treated as an attempt to prove that the model is true in an absolute sense but as a process of establishing sufficient confidence that the model is structurally sound, behaviorally credible, and useful for its intended purpose. Model testing was therefore treated as an integral part of the broader validation process. Structural validity was assessed by examining whether the model boundary, causal relationships, stock-and-flow structure, parameter assumptions, and decision rules were consistent with the literature, relevant regulations, empirical evidence, and expert knowledge. Expert judgment was incorporated through interviews conducted in May 2026 to assess whether the model adequately represents the operational logic of the broiler supply chain and the policy mechanisms embedded in the model. Dimensional consistency was checked to ensure that all equations used compatible units, such as birds per week, kilograms per week, rupiah per kilogram, and weeks. Behavioral validity was assessed by comparing simulated outputs with the reference modes of price fluctuation and supply pressure, with emphasis on the model's ability to reproduce the principal dynamic patterns of instability rather than exact point-by-point historical values. Taken together, these testing and validation procedures were intended to establish the model as a credible basis for policy analysis and for understanding the structural drivers of system behavior (Bala et al., 2017; Sterman, 2000).

The fifth step was policy design and evaluation. After the model had passed the testing and validation procedures required for its intended purpose, it was used to design and evaluate policy scenarios. Policy design in this study was not limited to changing parameter values but also involved modifying decision rules and structural mechanisms that influence supply planning and price dynamics. The policy scenarios were formulated based on the model structure, the identified leverage points, and policy issues raised during the preliminary study and expert interviews. The scenarios included hatchery setting adjustment, demand-driven GPS DOC import correction, and combined policy intervention. Each scenario was simulated and compared with the baseline condition using selected performance indicators, including live bird price stability, deviation from reference price, and farmer margin. The evaluation focused on the dynamic effects of each policy over time, the short-term and long-term trade-offs, and the robustness of the policy outcomes under selected sensitivity assumptions.

After the model had been tested and sufficient confidence in its structure and behavior had been established, it was used as a basis for designing and evaluating alternative policies. Model testing provided the basis for establishing confidence in the model structure and behavior. Once this confidence had been established, the model was used to design and evaluate alternative policies. Within the system dynamics framework, policy design is not limited to changes in parameter values. It also involves formulating new strategies, structures, and decision rules to improve system performance. Sterman (2000) emphasized that system behavior is determined by its feedback structure. Accordingly, high-leverage policies are generally directed toward dominant feedback loops, including improvements in stock-and-flow structures, reductions in delay, better information quality at critical decision points, or changes in actors' decision-making processes. Consistent with this view, Bala et al. (2017) explained that a tested system dynamics model can support scenario development, policy option selection based on simulated performance indicators, and policy robustness assessment under parameter and structural uncertainty. Therefore, in this study, policy simulations were conducted by comparing the performance of several intervention scenarios, assessing the sensitivity of results to key model assumptions, and evaluating the short- and long-term implications of the proposed policy alternatives (Bala et al., 2017; Sterman, 2000).

This study followed several core principles of system dynamics modeling. First, system behavior was assumed to arise from the underlying system structure, consistent with the principle that structure drives behavior. Accordingly, the model emphasized endogenous feedback loops rather than treating observed behavior as primarily driven by external shocks. Second, the model maintained stock-flow consistency to represent accumulation processes and the dynamic consequences of inflows and outflows over time. Third, nonlinear relationships were incorporated to capture more realistic system responses, particularly where changes in one variable do not produce proportional changes in another. The model also explicitly represents delays and bounded rationality in decision-making, recognizing that actors respond to perceived information, adjustment times, and operational constraints (Sterman, 2000). Finally, the model was developed with clear objectives, explicit system boundaries, dimensional consistency, transparent assumptions, and tests of model structure and behavior. These elements are consistent with best practices in system dynamics modeling (Martinez-moyano & Richardson, 2013).

4. Result
4.1 Problem Articulation

Indonesia's broiler supply chain consists of upstream, farming, slaughtering, distribution, and consumption segments. The upstream segment includes GPS and PS hatcheries, feed mills, and suppliers of medicines and vaccines, while the farming segment consists of independent, corporate, and partnership farmers. The downstream segment includes collectors, slaughterhouses, distributors, traditional and modern markets, processing industries, hotels, restaurants, catering services, and household consumers. This structure is consistent with Kimberly & Sitorus (2023), who reported that broiler chicks in North Sumatra are sourced from supply companies, delivered to farms over approximately 28 to 35 days and then distributed through company agents, slaughterhouse operators, markets, restaurants, or directly to consumers. In line with system dynamics modelling principles, the model boundary is not intended to represent the entire broiler industry in full detail. Instead, it was designed to capture the key feedback structures that generate supply–demand imbalances, live bird price fluctuations, and supply-control responses from downstream to upstream. The model therefore represents the national broiler system at an aggregate level, covering final consumers, the broiler meat retail market, slaughterhouses, the live bird market, integrator and non-integrator farming segments, the FS DOC market, PS-GPS breeding, and GPS DOC import policy as part of the endogenous system mechanism.

The Indonesian broiler supply chain is characterized by heterogeneous actors. Integrators control multiple segments, including breeding, feed, farming, slaughterhouses, and cold storage, whereas independent farmers purchase inputs from the market and sell harvested birds through the live bird market. This difference creates asymmetric exposure to price risk: integrators can redirect part of their surplus to internal slaughtering facilities or cold storage, while independent farmers are more directly exposed to downward pressure on farm gate prices. These actor differences were incorporated into the model because production decisions and price risk exposure vary between independent farmers, partnership farmers, and vertically integrated companies. The structure of Indonesia's broiler supply chain is shown in Figure 1.

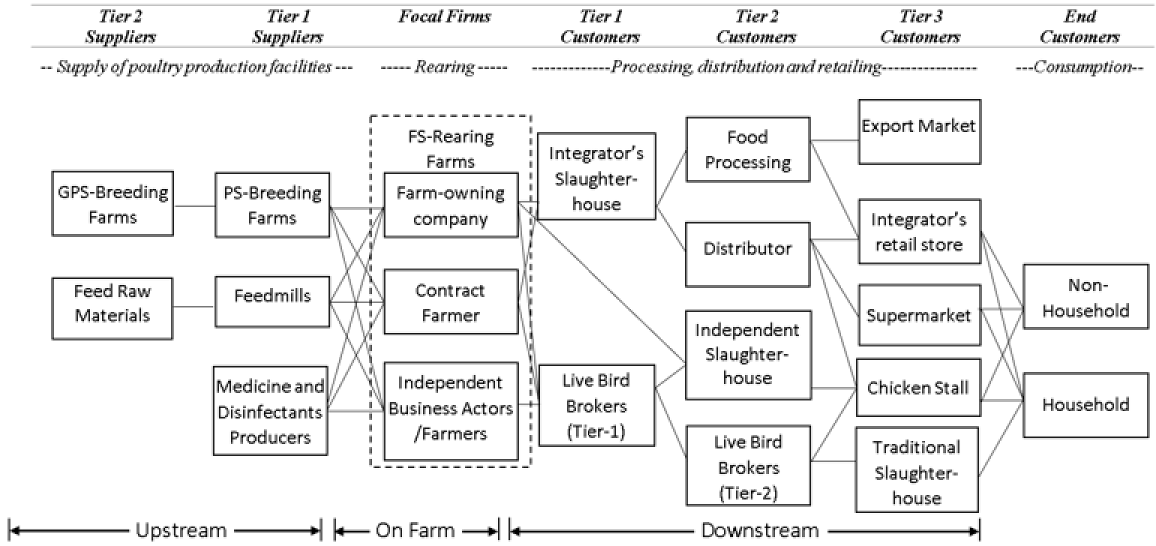

Figure 1. Broiler supply chain structure in Indonesia. (Source: preliminary study)

This distinction is important because empirical studies show that business patterns influence farmers' risk exposure and decision rules. In the partnership system, core companies generally provide DOC, feed, medicines, technical assistance, and marketing, while farmers provide housing, labor, electricity, and water (Nurlaelah et al., 2022; Susanti, 2023). However, business feasibility remains affected by changes in output prices, operational costs, and production performance (Barus et al., 2024; Wantasen et al., 2021).

The broiler supply chain has characteristics that generate industrial dynamics through feedback, accumulation, and delays. FS broilers can be harvested within a relatively short period, but a multi-layered breeding structure determines the supply of FS DOC. Broiler breeding follows a breeding pyramid from pure line, great-grandparent stock, grandparent stock, and parent stock to final stock (Neeteson et al., 2023). In the Indonesian context, PS and FS production are carried out domestically, whereas GPS supply still depends on imported GPS DOC. Therefore, today's GPS import decisions affect FS DOC and live bird supply only after a relatively long sequence of biological and administrative delays.

Within this structural context, independent farmers face a persistent economic problem: live bird prices frequently fall below production costs, resulting in recurrent negative margins and business losses. Because independent farmers have limited control over FS DOC supply, feed prices, slaughterhouse access, and downstream market absorption, they are highly exposed to short-term oversupply in the live bird market. When surplus occurs, they have fewer alternatives than integrators to redirect output to internal slaughterhouses, cold storage, or processed-product channels. Consequently, live bird price instability extends beyond farm-level income loss and becomes a regional food supply planning issue in Indonesia. If independent farmers continue to exit the industry, regional production capacity, market diversity, and the resilience of local broiler supply may weaken. Therefore, live bird price instability should be understood as a structural coordination problem that links farmer viability, regional production planning, upstream breeding control, and downstream absorption capacity.

4.2 Reference Modes

Reference modes describe the primary behavioral pattern of key variables over time, including fluctuations, trends, and cycles relevant to the problem under study. In system dynamics modeling, they provide the basis for developing dynamic hypothesis and serve as a benchmark for model development and validation. The reference modes in this study capture the pattern of live bird prices and their position relative to production costs and reference prices set by the goverment. These variables were selected because they link the interests of farmers, breeders, slaughterhouses, and consumers. The reference modes that were developed based on the problem articulation stage are shown in Figure 2.

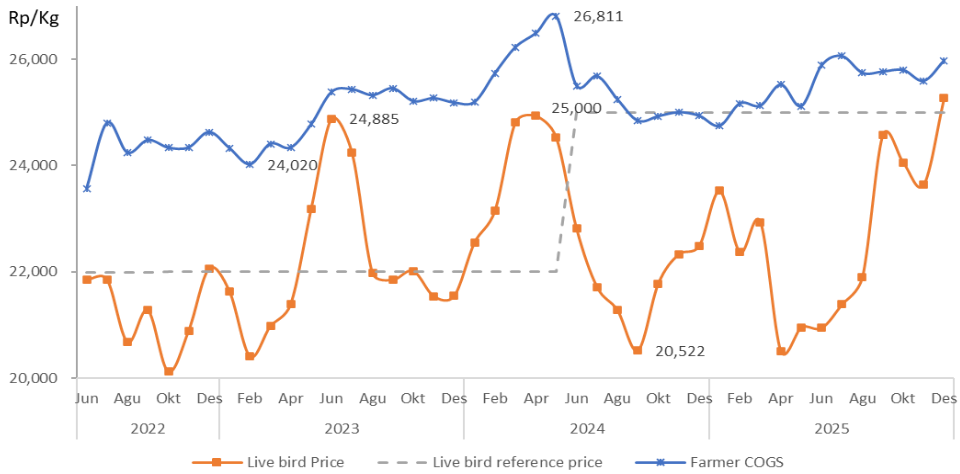

Figure 2. Monthly reference modes of live bird price, live bird reference price, and farmer cost of goods sold (COGS), June 2022–December 2025 (Rp/kg live bird) (BAPANAS, 2024; Kementerian Pertanian RI, 2025).

4.3 Dynamic Hypothesis Development

The dynamic hypothesis of this study was that live bird price fluctuations emerge from the interaction of several balancing loops operating in the FS DOC market, independent farmers' chick-in decisions, the live bird market, the broiler meat market, and the breeding control mechanism. In the CLD, the open market loop (B1) to the broiler meat price adjustment loop (B5) represents market and operational adjustment mechanisms that endogenously shape price and supply dynamics, while loops B6 and B7 represent the control mechanisms that constitute the main novelty of the conceptual model. The model feedback structure, which underlies the dynamic hypothesis and the novelty of the conceptual model, is presented in Figure 3.

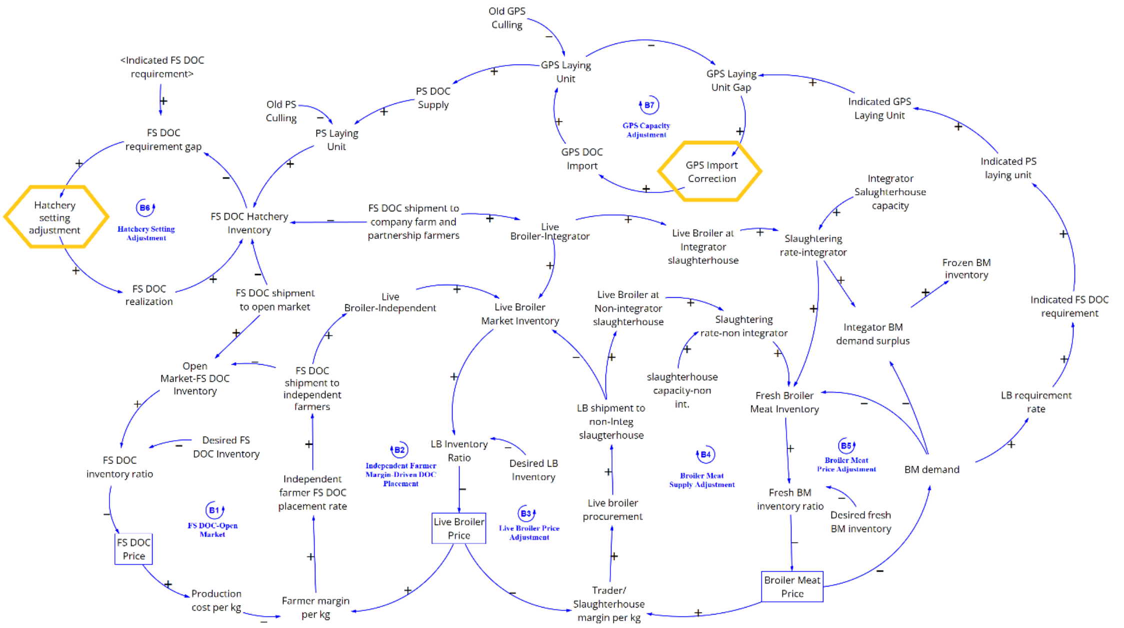

Figure 3. Causal loop diagram of the Indonesian broiler supply chain system highlighting the dual control structure of breeding capacity and hatchery setting adjustment.

First, the FS DOC Open Market loop (B1) explains the adjustment of FS DOC prices in response to FS DOC inventory conditions in the open market. When the open-market FS DOC inventory increases relative to the desired FS DOC inventory, the FS DOC inventory ratio rises and puts downward pressure on FS DOC prices. A decline in FS DOC prices reduces per-kilogram production costs for independent farmers, thereby increasing their margins. Higher margins encourage an increase in the independent farmers' FS DOC placement rate and FS DOC shipments to independent farmers. The increase in these shipments eventually reduces FS DOC inventory in the open market. Thus, B1 represents a balancing mechanism in the cultivation input market. However, lower FS DOC prices may also stimulate higher chick-in decisions, which subsequently affect live bird supply in the following weeks.

Second, the Independent Farmer Margin-driven DOC Placement loop (B2) describes how independent farmers' chick-in decisions respond to changes in margins. Higher live bird prices or lower production costs increase independent farmers' margins, which in turn encourage higher FS DOC placement. After the growing delay, this increase in FS DOC placement generates additional live broilers from independent farmers and increases live broiler market inventory. As live bird inventory rises relative to the desired level, live bird prices decline, and farmer margins decrease. Although this loop serves as a balancing mechanism, it may generate oscillatory behavior because chick-in decisions are based on current margin signals. At the same time, their effects on supply only appear after the growing period.

Third, the Live Broiler Price Adjustment loop (B3) describes how live bird prices adjust to inventory pressure in the live bird market. When live broiler market inventory rises relative to the desired inventory level, the live bird inventory ratio increases and exerts downward pressure on live bird prices. Changes in live bird prices, in turn, affect the margins of procurement actors, including traders and slaughterhouses. These margin changes influence live broiler procurement and shipments to non-integrator slaughterhouses. Higher procurement and shipments reduce stock pressure in the live bird market, whereas lower procurement increases it. Therefore, B3 functions as a price and procurement correction mechanism in the live bird market. However, because live birds have limited storability and procurement decisions are constrained by slaughterhouse capacity, this correction may be delayed in alleviating stock pressure.

Fourth, the Broiler Meat Supply Adjustment loop (B4) describes how broiler meat supply adjusts through live bird procurement and slaughter mechanisms. When trader or slaughterhouse margins increase, live bird procurement rises, which increases live bird shipments to non-integrator slaughterhouses and also increases the non-integrator slaughtering rate. A higher slaughtering rate increases broiler meat inventory. As broiler meat inventory rises, the broiler meat inventory ratio changes, and shortage pressure decreases. This loop, therefore, functions as a balancing mechanism on the broiler meat supply side, as the increase in fresh broiler meat supply eventually reduces upward pressure on prices and slaughtering margins.

Fifth, the Broiler Meat Price Adjustment loop (B5) describes how broiler meat prices adjust to changes in inventory and demand. When broiler meat inventory rises above the desired level, the inventory ratio increases, exerting downward pressure on prices. Lower broiler meat prices may stimulate demand, whereas higher prices may suppress it. Changes in demand, in turn, influence live bird requirements and upstream FS DOC requirements. Therefore, B5 connects the broiler meat market to upstream production-requirement signals. This loop is important because pressure in the broiler meat market can be transmitted upstream to live birds, FS DOC, PS, and GPS requirements.

Sixth, the Hatchery Setting Adjustment loop (B6) serves as a short-term operational control mechanism within the FS DOC hatching subsystem. When the indicated FS DOC requirement increases while available FS DOC inventory remains insufficient, the FS DOC requirement gap widens. This gap triggers a hatchery-setting adjustment, which is the decision to increase or decrease the number of FS hatching eggs to be set for incubation. An increase in hatchery setting adjustment raises FS DOC realization after the hatching delay and subsequently increases FS DOC hatchery inventory. Conversely, when FS DOC inventory increases and the requirement gap narrows, the pressure to increase hatchery setting decreases. Therefore, B6 functions as an operational control mechanism that aligns FS DOC realization with downstream requirements before an imbalance in FS DOC develops into an imbalance in live bird supply.

Seventh, the GPS Capacity Adjustment loop (B7) represents a long-term capacity-control mechanism by adjusting GPS DOC imports. Downstream demand is translated into the indicated FS DOC requirement, then into the indicated PS laying unit, the indicated GPS laying unit, and ultimately the GPS laying unit gap. When the actual GPS capacity is lower than the indicated capacity, the GPS capacity gap widens, triggering a GPS import correction. This correction increases GPS DOC imports, which subsequently increase the GPS laying unit after a biological delay. The increase in the GPS laying unit then reduces the capacity gap. Although this loop functions as a balancing mechanism, it operates over a long time horizon because it involves GPS maturation, PS DOC production, PS maturation, FS hatching egg production, FS DOC hatching, and FS growing. Therefore, B7 should not be treated as an instrument for responding to weekly fluctuations but as a mechanism for long-term capacity design.

With this structure, the novelty of the conceptual model lies in integrating two control mechanisms that operate across different time horizons. B6 controls FS DOC realization operationally through hatchery setting adjustment, whereas B7 controls long-term biological capacity through GPS DOC import correction. These two control mechanisms complement the market loops B1–B5, which endogenously shape price and supply dynamics. If B6 is too weak or delayed, FS DOC surplus may develop into live bird surplus. If B7 is not aligned with downstream requirements, GPS and PS capacity may remain above or below the system's long-term needs. Therefore, live bird price stabilization should be understood as a coordination problem among market mechanisms, operational hatchery control, and breeding-capacity control.
At the downstream level, frozen broiler meat inventory is positioned as a residual buffer. When the supply of fresh broiler meat exceeds demand, part of the surplus can be redirected to frozen stock. However, frozen stock does not address the root cause of production imbalance; rather, it absorbs part of the surplus pressure after broiler meat has already been produced. Thus, frozen broiler meat inventory serves as a residual buffer that mitigates downstream pressure, while the primary control mechanisms remain B6 and B7, namely hatchery setting adjustments and GPS DOC import corrections. Table 3 summarizes the main feedback loops identified in the causal loop diagram, including their loop type, principal mechanism, and the dominant delays through which their effects are transmitted across the broiler supply chain.

Table 3. Summary of the Main Feedback Loops in the Causal Loop Diagram

Feedback loop (type)	Main mechanism	Dominant delay
B1-FS DOC Open Market (Balancing)	Higher open-market FS DOC inventory lowers FS DOC price, improves independent farmer margins, increases FS DOC placement and shipments, and eventually reduces open-market FS DOC inventory.	Mainly market/information adjustment delay;
B2-Independent Farmer Margin-Driven DOC Placement (Balancing)	Higher farmer margins increase FS DOC placement, which later raises live broiler supply and market inventory, thereby reducing live bird prices and margins.	FS grow-out/rearing delay between chick-in and market-ready live broilers
B3-Live Broiler Price Adjustment (Balancing)	Higher live broiler inventory depresses live bird prices, alters procurement margins, and changes procurement and shipments, which then help relieve stock pressure.	Price perception/ adjustment delay and short procurement/ slaughter response delay

B4-Broiler Meat Supply Adjustment (Balancing)	Higher procurement and slaughtering increase broiler meat inventory, which reduces shortage pressure in the broiler meat market.	Short operational delay in procurement, transport, and slaughtering
B5-Broiler Meat Price Adjustment (Balancing)	Higher broiler meat inventory lowers broiler meat prices, changes demand, and transmits adjustment signals upstream to live bird, FS DOC, PS, and GPS requirements.	Price adjustment/ perception delay and demand response delay
B6-Hatchery Setting Adjustment (Balancing)	A wider FS DOC requirement gap triggers hatchery setting adjustment, which increases FS DOC realization and raises hatchery inventory, thereby narrowing the gap.	Hatchery setting adjustment delay and FS egg incubation/hatching delay
B7-GPS Capacity Adjustment (Balancing)	A wider GPS capacity gap triggers GPS import correction, which later increases GPS laying capacity and reduces the gap.	Long administrative/ import delay plus GPS maturation delay, followed by downstream biological propagation through PS and FS stages

4.4 Operational Model Development

The operational model is structured as an SFD comprising ten interconnected submodels that represent the supply chain sequence and price formation mechanisms, as presented in Figure 4. The SFD comprises 222 variables and parameters, including 21 stock/level variables, 146 auxiliary variables, and 55 constant parameters. The stock and flow diagram of the operational model is presented in Figure 4. Then a summary of the ten interconnected submodels and the main system components represented in each submodel is provided in Table 4.

Table 4. Submodels of the System Dynamics Model of the Broiler Supply Chain

No.	Submodel	Main representation
1.	End Consumer Submodel	Generates household and non-household demand for broiler meat.
2.	Retail Broiler Meat Market Submodel	Captures fresh broiler meat inventory, sales, demand fulfillment, and broiler meat price formation.
3.	Cold Storage Submodel	Represents surplus freezing and the release of frozen broiler meat stock as a downstream buffer
4.	Slaughterhouse Submodel	Represents integrator and non-integrator slaughterhouse operations, where live birds are converted into carcasses based on slaughter capacity and dressing yield.
5.	Live Bird Market Submodel	Covers live bird stock, supply from integrator and non-integrator farmers, delivery to slaughterhouses and the live market, and live bird price formation.

No.	Submodel	Main representation
6.	Open-Market FS DOC and Non-Integrator Farming Submodel	Includes open-market FS DOC stock, DOC sales, non-integrator chick-in decisions, mortality, rearing, and harvest supply.
7.	Integrator Farming and Partnership Submodel	Covers DOC placement, rearing, harvesting, allocation to internal slaughterhouses, and release to the live bird market.
8.	GPS–PS Breeding Submodel	Captures GPS maturation, PS DOC production, PS maturation, hatching egg production, and FS DOC production.
9.	GPS DOC Import Determination Submodel	Determines GPS DOC imports by linking upstream capacity requirements to import decisions.
10.	Price and Cost Structure Submodel	Links FS DOC prices, live bird prices, broiler meat prices, feed costs, rearing costs, farmer margins, and slaughterhouse margins.

The distinction between integrator and non-integrator actors is operationalized explicitly in the model through separate farming, allocation, and slaughtering structures. Non-integrator production is represented in the Open-Market FS DOC and Non-Integrator Farming submodel, where FS DOC placement depends on open-market DOC availability and farmer decision rules, and where live bird supply is released to the market after rearing and mortality adjustment. By contrast, integrator and partnership production is represented in the Integrator Farming and Partnership submodel, where FS DOC placement is linked to the system-indicated requirement through the integrator market share. In the current model, the production split is anchored by an integrator market share of 0.8, while the remaining 0.2 is assigned to non-integrators. This split is used consistently in the allocation of FS DOC requirements, fresh broiler meat demand, and live bird demand. Spillover from integrators to the live bird market is represented explicitly through the variable Integrator LB to live market, which captures the portion of integrator-grown live birds that is not absorbed by internal slaughterhouse capacity and is therefore released into the open live bird market. As a result, the model captures not only differences in actor position within the supply chain but also asymmetry in market access and downstream absorption capacity between integrators and non-integrators.

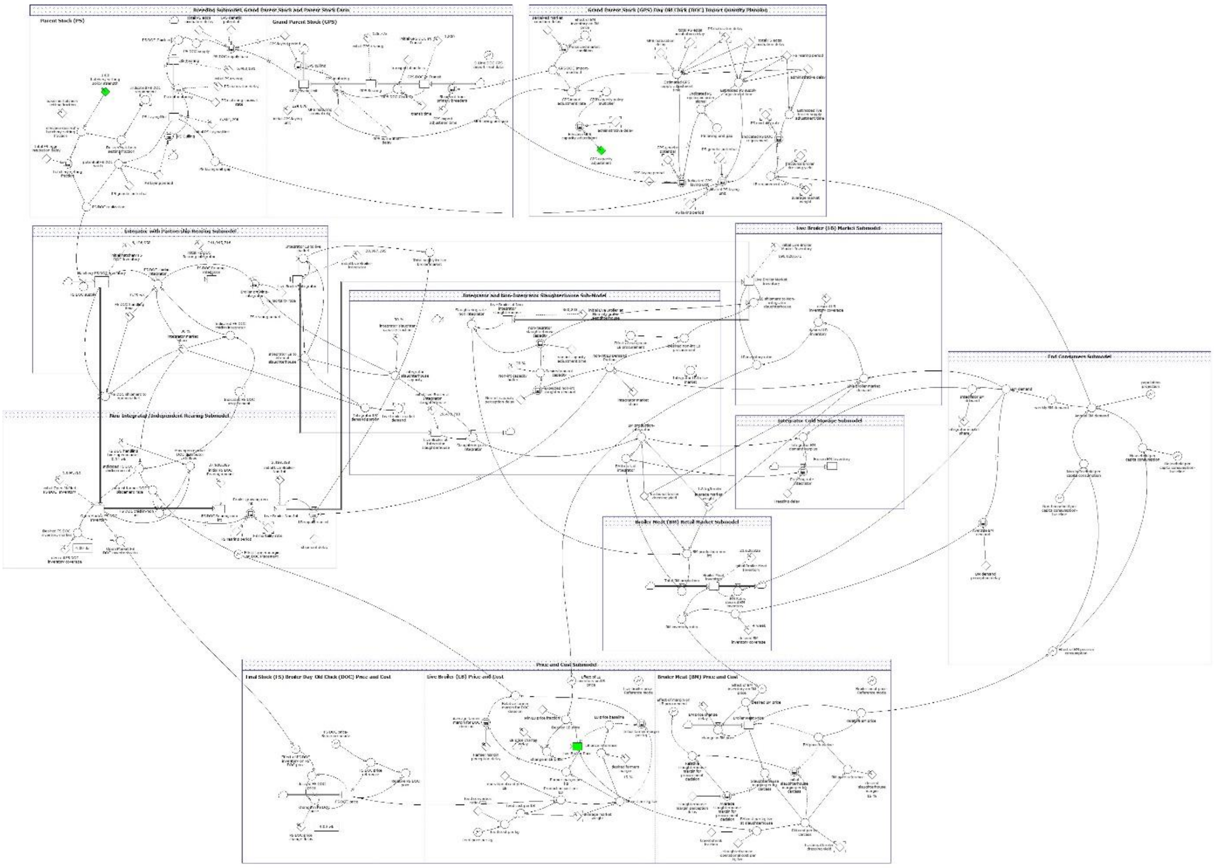

Figure 4. Stock and flow diagram of the operational model.

In the operational model, the main novelty lies in the dual-control structure of the breeding subsystem. The first control mechanism is long-term capacity control through GPS DOC imports. This mechanism adjusts the system's biological capacity based on the required number of GPS-laying units, which is derived from downstream demand. In the final model configuration, GPS capacity adjustment occurs over a long time horizon. Therefore, GPS import decisions cannot be used to respond to weekly fluctuations. Instead, they must be designed as capacity policies based on projected system requirements. The control lever for GPS DOC imports in the SFD, incorporated into the GPS DOC Import Quantity Determination submodel, is shown in Figure 5.

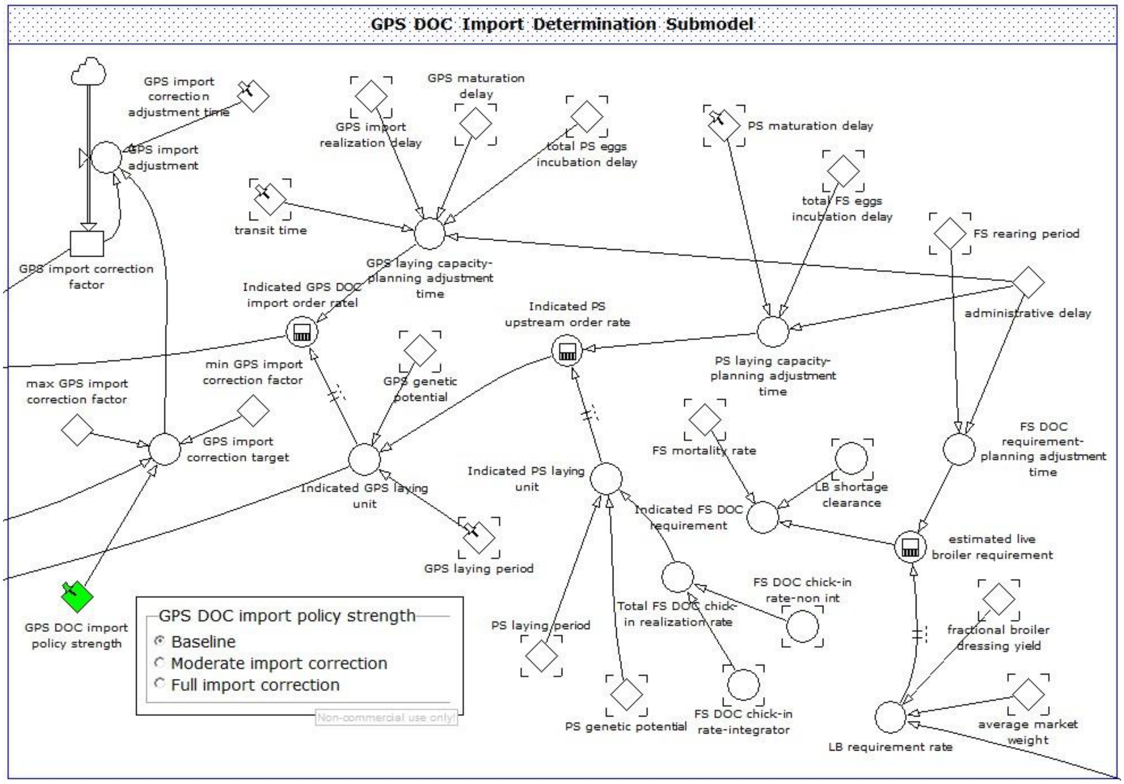

Figure 5. The GPS DOC Import Policy Strength lever.

GPS DOC import adjustment works through the policy lever GPS DOC Import Policy Strength, which regulates how strongly the system translates the GPS capacity gap into import correction. In this submodel, downstream demand is first converted into the indicated FS DOC requirement, then propagated upstream into the indicated PS laying unit and finally the indicated GPS laying unit. The difference between indicated and actual GPS laying capacity forms the basis for the GPS import correction target. The constant GPS DOC import policy strength acts as a scaling parameter on this correction process: when the value is set at the baseline or low level, the system responds only weakly to the GPS capacity gap, so GPS DOC imports remain closer to their existing path; when it is set at a moderate level, only part of the capacity gap is translated into import correction; and when it is set at full correction, the model allows the import decision to respond more completely to the normalized GPS laying unit gap, subject to the specified minimum and maximum correction bounds. The resulting adjustment does not affect supply immediately, because the corrected GPS DOC imports must still pass through import realization, transit, GPS maturation, PS maturation, hatching, and broiler grow-out delays before influencing downstream live bird availability. Therefore, this policy lever functions as a long-term capacity-design instrument rather than a short-term price-stabilization instrument.

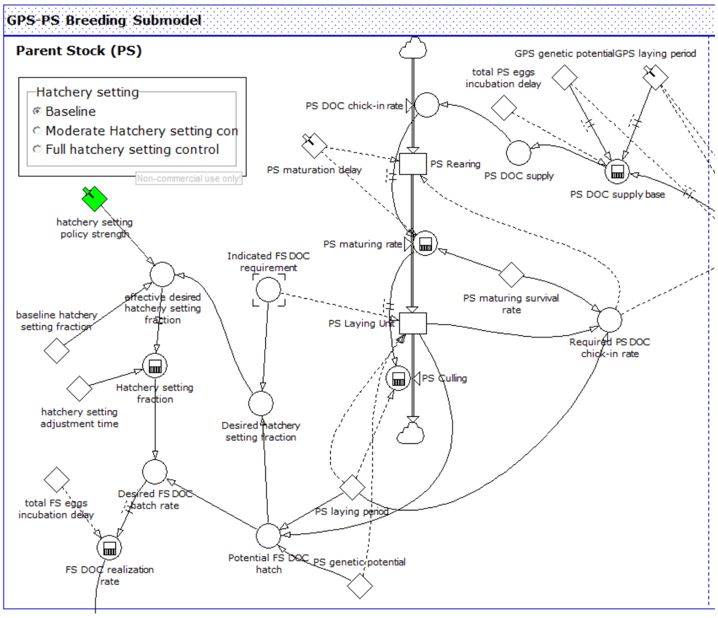

Figure 6. The Hatchery Setting Policy Strength lever.

The second control mechanism is short-term operational control through hatchery setting adjustment. This mechanism affects the realized hatching of FS DOC and operates on a shorter horizon than GPS imports do. Its objective is to reduce excess FS DOC before it turns into excess live birds. In the model, the live bird supply adjustment time is approximately seven weeks, while the PS adjustment time is approximately 34.43 weeks. This difference in adjustment horizons indicates that stabilization policies need to operate in layers, covering operational control, medium-term capacity control, and long-term capacity control. The control lever for hatchery setting adjustment in the SFD incorporated into the Breeding submodel is shown in Figure 6.

Strength lever, which regulates how strongly the system translates downstream FS DOC requirements into realized hatchery-setting decisions. In this submodel, the indicated FS DOC requirement is compared with potential FS DOC hatch capacity to generate the desired hatchery setting fraction. The constant hatchery setting policy strength then acts as a blending parameter that determines the extent to which the system follows this desired setting rather than the baseline hatchery setting fraction. When the value is set at the baseline or low level, hatchery operations remain close to their existing setting practice, so the response to downstream requirement signals is weak; when it is set at a moderate level, only part of the gap between baseline and desired setting is translated into operational adjustment; and when it is set at full adjustment, the hatchery setting fraction responds more completely to the indicated FS DOC requirement, subject to the adjustment process embedded in the model. The resulting adjustment does not affect supply immediately, because changes in hatchery setting must still pass through the FS egg incubation delay before altering FS DOC realization and hatchery inventory. Therefore, this policy lever functions as a short-term operational control instrument for aligning FS DOC realization with downstream needs before excess FS DOC propagates into excess live bird supply.

4.5 Model Testing and Validation

Model testing and validation were conducted as complementary confidence-building activities after the operational simulation model had been formulated. In line with system dynamics methodology, validation in this study was not treated as an attempt to prove that the model is true in an absolute sense but as a process of establishing sufficient confidence that the model is structurally sound, behaviorally credible, and useful for its intended purpose. Model testing was therefore treated as an integral part of the broader validation process rather than as a separate post-hoc exercise. At this stage, validation was conducted primarily as a structural and plausibility assessment rather than as a full statistical validation exercise. Structural validity was assessed by examining whether the model boundary, causal relationships, stock-and-flow structure, parameter assumptions, and decision rules were consistent with the literature, relevant regulations, empirical evidence, and expert knowledge. This approach is consistent with the system dynamics view that confidence in a model should be built through multiple tests of structure and behavior, selected according to the purpose of the model (Bala et al., 2017; Sterman, 2000).

4.5.1 Dimensional Consistency Check

Dimensional consistency was checked within Powersim using the software's unit-checking function and the 'enforce time unit consistency' option. This step was intended to ensure that all equations use compatible units, such as birds per week, kilograms per week, rupiah per kilogram, and weeks, and that the model formulation remained internally consistent in terms of both quantity and time dimensions.

4.5.2 Behavioral Validity Assessment

Behavioral validity was assessed by comparing simulated outputs with the reference modes of price fluctuation and supply pressure, with emphasis on the model's ability to reproduce the principal dynamic patterns of instability rather than exact point-by-point historical values. This orientation is consistent with the purpose of the model as an explanatory and policy-oriented simulation model rather than a short-term forecasting model.

4.5.3 *Expert-based Validation*

To strengthen the structural assessment, the validation process also incorporated expert judgment through an interview with one poultry sector expert drawn from the group of experts previously consulted during model development. The purpose of this review was to assess whether the operational model adequately represented the main mechanisms of the Indonesian broiler supply chain, particularly those related to production control, upstream breeding capacity, FS DOC allocation, hatchery setting adjustment, and live bird price stabilization.

The expert review focused on three aspects. First, it examined the structural plausibility of the model, including whether the main causal relationships, control points, and actor interactions were consistent with actual industry practice. Second, it assessed the logic of the policy scenarios, especially the use of hatchery setting adjustment as a short-term operational control and GPS DOC import adjustment as a long-term capacity-control mechanism. Third, it reviewed whether the interpretation of the simulation outputs was consistent with observed conditions in Indonesia's poultry system. The expert feedback indicated that the policy scenarios were reasonably plausible and that the simulated behavior could be interpreted coherently from a system dynamics perspective. At the same time, the review emphasized that the practical implementation of these policies would depend on business actor compliance, stakeholder integrity, institutional coordination, and data transparency. Taken together, the dimensional consistency check, behavior reproduction assessment, and expert-based review were intended to establish the model as a credible basis for policy analysis and for understanding the structural drivers of system behavior.

4.6 Sensitivity Analysis Design

Sensitivity analysis was conducted to examine whether the two main policy levers embedded in the model generated coherent responses along their intended control pathways. To isolate the response of each mechanism and avoid redundancy with the policy scenario analysis presented later, one-way sensitivity tests were performed separately for hatchery setting policy strength and GPS DOC import policy strength while the other policy lever was held inactive. For the hatchery-control mechanism, GPS DOC import policy strength was set to zero and the simulation horizon was set at 52 weeks. The observed variables were effective desired hatchery setting fraction, hatchery setting fraction, FS DOC realization rate, and hatchery FS DOC inventory ratio. For the GPS import-control mechanism, hatchery setting policy strength was set to zero, and the simulation horizon was extended to 104 weeks to capture the longer administrative and biological delays in the upstream capacity pathway. The observed variables were GPS import correction target, GPS import correction factor, modified GPS DOC import order rate, and GPS laying unit.

4.7 Policy Scenario Design

Based on the model structure, this study formulates one baseline condition and three policy scenarios. The baseline represents the existing system condition in which market-based adjustment mechanisms operate without hatchery setting adjustment and GPS import correction. In this setting, chick-in decisions, FS DOC allocation, culling, cold storage operation, and price formation follow the existing behavioral rules based on prices, margins, inventory levels, and demand conditions. Cold storage is treated as an existing downstream buffering mechanism and is therefore kept active across all scenarios. Accordingly, the scenario comparison focuses on two upstream breeding-control levers: hatchery setting adjustment and demand-driven GPS DOC import correction.

Scenario 1 focuses on short-term operational control through hatchery setting adjustment. This policy modifies the effective hatchery setting fraction so that FS DOC realization can be aligned more closely with live bird requirements. The policy is expected to reduce excessive FS DOC realization when downstream demand is insufficient. However, if the adjustment is too restrictive, it may create future supply shortages because DOC FS availability affects live broiler supply only after the FS rearing delay.

Scenario 2 represents a long-term breeding-capacity control policy through demand-driven GPS DOC import correction. This policy adjusts GPS DOC import decisions based on downstream-derived FS DOC requirements and the adequacy of existing breeding capacity. Because GPS import decisions are transmitted through long biological, administrative, and import realization delays, their effects do not appear immediately in live broiler prices or broiler meat supply. Therefore, GPS import correction should be interpreted as a national breeding-capacity design policy rather than a short-term price stabilization instrument.

Scenario 3 combines hatchery setting adjustment and GPS import correction. This combined policy integrates short-term DOC FS realization control with long-term upstream breeding-capacity adjustment. The purpose is to examine whether operational hatchery control and structural GPS import correction can jointly reduce recurrent oversupply and improve alignment between upstream breeding decisions and downstream demand. However, this policy requires stronger coordination of information among downstream demand signals, hatchery decisions, PS capacity, and GPS import planning. A summary of the scenarios is presented in Table 5.

Table 5. Policy Scenarios and Expected System Effects

Scenario	Policy setting	Horizon	Expected system effect	Main limitation
Baseline	Market-based adjustment with active cold storage buffer	Existing condition	Benchmark for system behavior without hatchery setting adjustment and GPS import correction	Recurrent oversupply risk and delayed correction in upstream breeding capacity
Scenario 1	Hatchery setting adjustment	Short-term operational control	Align FS DOC realization with live bird requirements by adjusting the effective hatchery setting fraction	Risk of future supply shortage if hatchery setting control is too restrictive
Scenario 2	Demand-driven GPS DOC import correction	Long-term breeding-capacity control	Align upstream GPS import decisions and breeding capacity with downstream-derived DOC FS requirements	Slow effect due to long biological, administrative, and import realization delays

Scenario	Policy setting	Horizon	Expected system effect	Main limitation
Scenario 3	Combined hatchery setting adjustment and GPS import correction	Multi-horizon breeding-control policy	Integrate short-term DOC FS realization control with long-term upstream breeding-capacity adjustment	Requires stronger information coordination between downstream demand signals, hatchery decisions, and GPS import planning

4.8 Model Simulation

4.8.1 Simulation Setting

The operational model was simulated in Powersim Studio 10 Academic Version using calendar-dependent simulation settings with week as the base time unit and the Gregorian calendar. The simulation horizon ran from 1 January 2020 to 1 September 2024 so that the simulated behavior could be compared with the reference mode over the same period. A fixed time step of 0.143 week, equivalent to one day, was used to capture short-run price and inventory adjustments while maintaining consistency with weekly production, breeding, and slaughtering processes. To avoid generating dynamics from arbitrary starting imbalances, the model was initialized in a near-equilibrium condition, so that subsequent deviations in prices, inventories, and capacities are produced mainly by endogenous feedback structure. Most auxiliary variables in the model are endogenously determined; however, several exogenous variables, specified as time-series inputs, were used to provide external inputs to the operational model. The FS DOC price was treated differently as a semi-exogenous variable because its time-series reference input was adjusted endogenously by the inventory ratio in the FS DOC market. The exogenous time-series variables used in the operational model are presented in Table 6.

Table 6. Exogenous Time-Series Variables used in the Operational Model

Variable name	Unit	Meaning	Source
Population projection	People	Projected Indonesian population for 2020-2050	BPS-Statistics Indonesia
Household per capita consumption	Kg/people/year	Per capita consumption of broiler meat by household consumers for 2016-2029	Ministry of Agriculture
Non-household per capita consumption	Kg/people/year	Per capita consumption of broiler meat by non-household consumers for 2016-2029	Ministry of Agriculture
feed price per kg	Rp/kg/month	Monthly broiler feed price	Ministry of Agriculture

Policy experiments were then conducted by changing the relevant policy-strength parameters under three alternative scenarios and comparing the results with the baseline condition. This configuration was selected because the broiler supply chain combines daily market adjustments with weekly biological processes. Live bird prices, fresh broiler meat prices, and inventory conditions may change within a few days, whereas hatching, breeding, and rearing processes unfold over several weeks. Therefore, a daily computational step nested within a weekly time unit provides sufficient temporal resolution to represent short-term operational responses without losing consistency with the biological structure of the system. The chosen simulation horizon also allows the model to cover several production cycles and to reveal whether the policy effects are immediate, delayed, or cumulative.

4.8.2 Initial Values, Constant Parameters, and Nonlinear Graph Functions

To enable the simulation to run properly, all stock variables were assigned initial values representing an approximate equilibrium condition at the beginning of the simulation horizon. In system dynamics, each stock variable is mathematically represented as an accumulation of the difference between its inflow and outflow:

$$X(t) = X(t_0) + \int_{t_0}^{t} [In_X(s) - Out_X(s)]\, ds \tag{1}$$

or equivalently,

$$\frac{dX(t)}{dt} = In_X(t) - Out_X(t) \tag{2}$$

where $X(t)$ denotes the stock value at time t, $In_X(t)$ denotes the inflow rate, and $Out_X(t)$ denotes the outflow rate. Based on this formulation, an equilibrium condition is obtained when the net rate of change of the stock is zero:

$$\frac{dX(t)}{dt} = 0 \Rightarrow In_X(t) = Out_X(t) \tag{3}$$

For inventory and pipeline-type stocks, the equilibrium initialization followed a Little's Law-type stock-flow consistency principle, in which the desired stock is equal to the average throughput rate multiplied by the relevant residence, handling, or coverage time:

$$X^* = R^* \tau_X \tag{4}$$

where X^* is the desired or equilibrium stock, R^* is the relevant throughput rate, and τ_X is the corresponding residence time, handling time, or inventory coverage parameter. This principle was applied to physical inventory and pipeline stocks so that the initial inflows and outflows were broadly balanced at the beginning of the simulation.

For breeding-capacity stocks, the initial GPS Laying Unit and PS Laying Unit were derived from the required downstream chick-in rates and the biological productivity of each breeding layer. For inventory stocks, the initial values were set at their desired inventory levels based on demand and the relevant inventory coverage parameters. For price stocks, the initial values were set at their respective cost-plus reference prices so that subsequent price changes could emerge endogenously from stock pressure, margin conditions, and adjustment processes. The key stock variables and their initial value equations are summarized in Table 7.

Table 7. Key Stock Variables, Units, System Meaning, and Initial Value Equations

No.	Stock variable (unit)	System meaning	Initial value equation
11.	GPS Laying Unit (GP breeder bird unit)	Represents the number of productive GPS units actively generating PS DOC within the upstream breeding subsystem.	*Required PS DOC chick-in rate*/ (*GPS genetic potential*/ *GPS laying period*)
12.	PS Laying Unit (parent breeder bird unit)	Represents the number of productive PS units actively generating FS DOC to meet downstream requirements.	*Indicated FS DOC requirement*/(*PS genetic potential*/*PS laying period*)
13.	Hatchery FS DOC Inventory (broiler)	Represents the inventory of FS DOC available at the hatchery before being allocated to integrators or shipped to the open market.	*Desired hatchery FS DOC inventory = Indicated FS DOC requirement * FS DOC handling time*
14.	Open Market FS DOC Inventory (broiler)	Represents the stock of live broilers available in the live bird market before being absorbed by non-integrator slaughterhouses or live market slaughtering.	*Desired FS DOC inventory-market = Desired FS DOC inventory coverage * Indicated FS DOC requirement non-int*
15.	Live Broiler Market Inventory (broiler)	Represents the stock of live broilers available in the live bird market before being absorbed by non-integrator slaughterhouses or live market slaughtering.	*Desired LB inventory = Live broiler market demand * Desired LB inventory coverage*
16.	Simulated Live Broiler Price (rupiah/kg)	Represents the dynamically simulated live bird price as it responds to stock pressure, production cost, and market price adjustment mechanisms.	*LB cost-plus reference price*
17.	Fresh Broiler Meat Inventory (kg)	Represents the inventory of fresh broiler meat available to meet market demand before surplus accumulation or shortage occurs.	*Desired BM inventory = Average weekly fresh BM demand * desired BM inventory coverage*
18.	Simulated Fresh Broiler Meat Price (rupiah/kg)	Represents the dynamically simulated fresh broiler meat price as it evolves in response to inventory pressure, demand conditions, and downstream price references.	*BM cost-plus reference price*

The key constant parameters used in the operational model are summarized in Table 8. These parameters were obtained from the preliminary study, stakeholder surveys, and interviews with actors in the poultry industry. They represent biological, technical, and structural characteristics of the national broiler system, including genetic potential, maturation delay, laying period, hatching delay, FS rearing period, dressing yield, average market weight, feed conversion ratio, and the market share of the integrator channel. Because these parameters strongly influence the timing and magnitude of supply responses, they were specified explicitly in the operational model to preserve dimensional consistency and policy transparency.

Table 8. Key Constant Parameters, Units, System Meaning, and Parameter Values

No.	**Constant parameter**	**System meaning**	**Value**	**Unit**
1.	GPS genetic potential	Determines the potential number of PS units that can be generated by each productive GPS laying unit over its productive horizon.	60	parent breeder bird unit/GP breeder bird unit
2.	PS genetic potential	Determines the potential number of FS DOC that can be generated by each productive PS laying unit over its productive horizon.	150	broiler/parent breeder bird unit
3.	GPS/PS maturation delay	Determines the biological time required for GPS DOC and PS DOC to mature into productive laying units at their respective levels.	24	week
4.	GPS/PS laying period	Determines the duration of the productive phase during which GPS and PS units generate their respective biological outputs.	40	week
5.	Total PS/FS eggs incubation delay	Determines the incubation period required for hatching eggs to become DOC at the PS and FS levels.	3.43 (24 days)	week
6.	FS rearing period	Determines the grow-out period required for FS DOC to become market-ready live broilers.	5	week
7.	Integrator market share	Determines the proportion of the broiler system operating within the integrator channel, thereby affecting FS DOC allocation, rearing stocks, slaughtering, and internal absorption capacity.	0.8	Dimensionless
8.	Fractional broiler dressing yield	Determines the proportion of live broiler weight converted into carcass or broiler meat after slaughtering.	0.71	Dimensionless
9.	Average market weight	Determines the average harvest weight of live broilers used to convert bird numbers into live weight output and related cost calculations.	1.8	Kg/broiler
10.	Feed conversion ratio (FCR)	Determines the amount of feed required to produce 1 kg of live broiler weight and directly affects feed cost per unit of output.	1.45	Dimensionless

Several auxiliary variables were formulated as nonlinear graph functions, as shown in Table 9. These functions were used because behavioral responses in the broiler supply chain are not expected to be proportional across all operating conditions. For example, the effect of inventory pressure on price may become stronger when the stock ratio exceeds a critical level and the effect of farmer margins on DOC placement may weaken when physical, financial, or managerial constraints become binding. The shapes of these nonlinear functions were developed through consultation with experts and were subsequently confirmed through interviews. In the operational model, they represent boundedly rational responses linking prices, margins, inventories, procurement, and consumption. Together, the initial values, constant parameters, and nonlinear auxiliary functions allow the model to reproduce realistic adjustment patterns while remaining consistent with the explanatory purpose of the study.

Table 9. Auxiliary Variables with Nonlinear Graph Functions: Causal Tendencies and Powersim Studio 10 Graph Function Equations

No.	Auxiliary variable	Causal tendency	Powersim graph function equation
1.	Effect of BM Price on Consumption	Represents the nonlinear relationship between broiler meat price and consumption; as BM price increases, consumption tends to decline, and vice versa.	GRAPH('Relative BM price', 0.5,0.25, {1.50,1.20,1.00,0.85,0.70,0.55,0.40 //Min:0;Max:1.8//})
2.	Desired Frozen BM Substitution Share–Non-HH	Represents the nonlinear adjustment of frozen broiler meat substitution in the non-household market; as the relative attractiveness of fresh broiler meat declines, the desired frozen substitution share tends to increase.	GRAPH('Relative frozen to-fresh BM price', 0.7, 0.05,{ 0.98, 0.85, 0.70, 0.55, 0.40, 0.25, 0.15, 0.08, 0.03, 0.00//Min:0;Max:1//})
3.	Effect of BM Inventory on BM Price	Represents the nonlinear effect of broiler meat inventory on price formation; as BM inventory increases, BM price tends to decline, and vice versa.	GRAPH('BM inventory ratio',0.5,0.25, {1.23, 1.144, 1, 0.943, 0.92, 0.86, 0.84//Min:0.4;Max:1.8//})
4.	Effect of Margin on LB Procurement	Represents the nonlinear response of live broiler procurement to margin conditions; as margin increases, LB procurement tends to increase, and vice versa	GRAPH('Relative slaughterhouse margin for procurement decision', 0.5, 0.25,{ 0.60, 0.80, 1.00, 1.20, 1.40, 1.55, 1.70//Min:0;Max:2// })
5.	Effect of LB Inventory on LB Price	Represents the nonlinear effect of live broiler inventory on price dynamics; as LB inventory increases, LB price tends to decline, and vice versa.	GRAPH('LB inventory ratio', 0.5, 0.25, { 1.4, 1.2, 1.0, 0.9, 0.85, 0.83, 0.82//Min:0.5;Max:2// })
6.	Effect of Farmer Margin on DOC Placement	Represents the nonlinear response of DOC placement to farmer profitability; as farmer margin increases, DOC placement tends to increase, and vice versa.	GRAPH('Relative farmer margin for DOC decision', -3, 0.7,{ 0.75, 0.88, 1.00, 1.08, 1.16, 1.24, 1.30//Min:0.5;Max:1.5// })
7.	Effect of FS DOC Inventory on FS DOC Price	Represents the nonlinear effect of FS DOC inventory on price adjustment; as FS DOC inventory increases, FS DOC price tends to decline, and vice versa.	GRAPH('Bounded open market FS DOC inventory ratio', 0.5, 0.25,{1.08, 1.04, 1.00, 0.97, 0.94, 0.91, 0.88//Min:0.8;Max:1.2//})
8.	Effect of Hatchery FS DOC Inventory on FS DOC Allocation	Represents the nonlinear response of FS DOC allocation to hatchery inventory conditions; as hatchery FS DOC inventory increases, FS	GRAPH('Bounded hatchery FS DOC inventory ratio', 0.5, 0.25, {0.95, 0.98, 1.00, 1.04, 1.08, 1.11, 1.12//Min:0.9;Max:1.2//})

No.	Auxiliary variable	Causal tendency	Powersim graph function equation
		DOC allocation tends to increase, and vice versa.	

4.9 Baseline Simulation Results

The baseline simulation results are presented to assess whether the operational model is able to reproduce the main dynamic patterns observed in the reference modes before policy intervention is introduced. In this study, the baseline condition represents the behavior of the system under the existing control structure, without additional policy adjustment beyond the model's default configuration. The baseline run is therefore used as the behavioral reference for evaluating whether the model captures the general pattern of price instability, inventory pressure, and margin deterioration in the Indonesian broiler supply chain. The figures presented in this section focus on the main market variables, namely live broiler price, FS DOC price, fresh broiler meat price, and farmer margin. For the three price variables, the simulated results are compared directly with their respective reference modes to assess the extent to which the model reproduces the observed historical pattern.

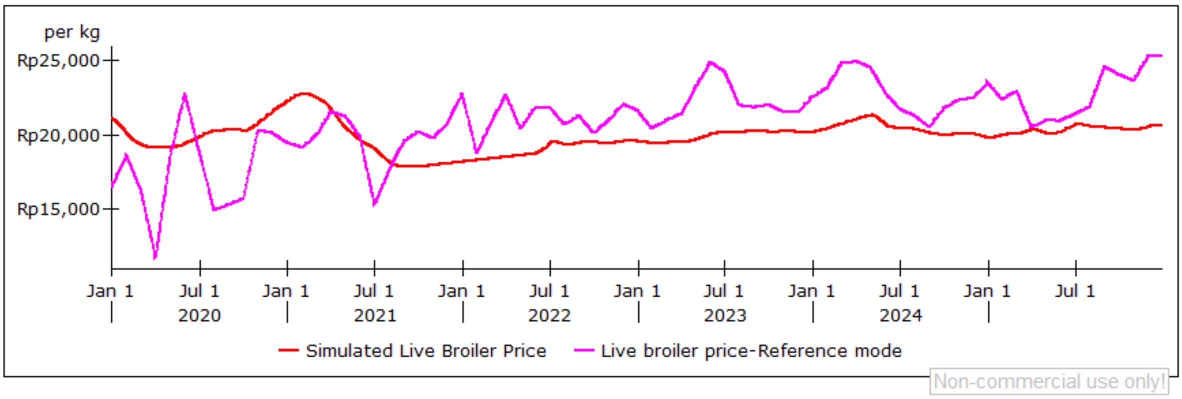

Figure 7. Baseline simulation of live broiler price compared with the live broiler price reference mode, January 2020–December 2025.

Figure 7 shows the baseline simulation of live broiler price compared with the historical reference mode over the period from January 2020 to December 2025. The simulated live broiler price reproduces the broad direction of movement and several major turning points observed in the reference mode. However, the simulated pattern is smoother and less volatile than the historical series, indicating that the model captures the general structure of live bird price instability but underrepresents some short-term fluctuations. Even so, the baseline result is sufficient to show that the model can reproduce the main behavioral pattern of live broiler price dynamics for subsequent policy analysis.

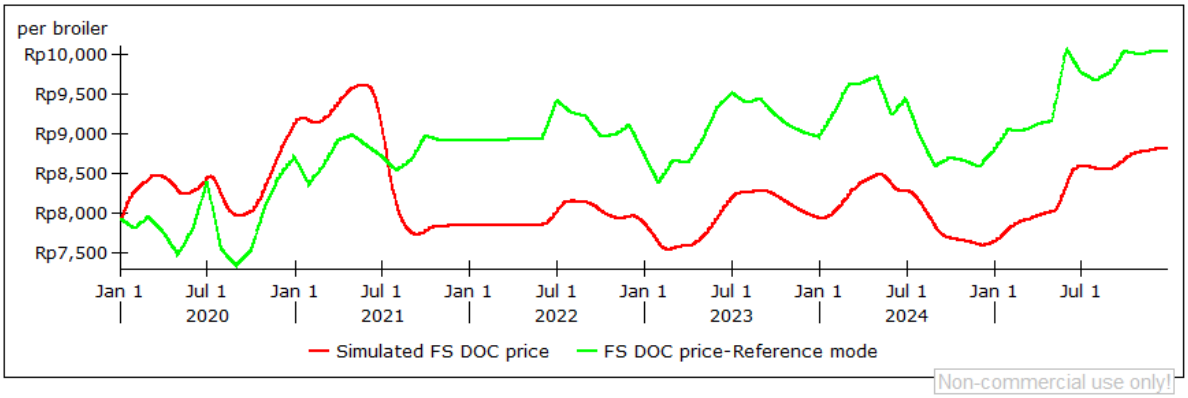

Figure 8. Baseline simulation of FS DOC price compared with the FS DOC price reference mode, January 2020–December 2025.

Figure 8 presents the baseline simulation of FS DOC price compared with the historical reference mode over the period from January 2020 to December 2025. The simulated FS DOC price follows the general direction of the reference series, including the main upward and downward movements. However, the simulated trajectory remains smoother and generally lower than the reference mode over much of the simulation horizon. This indicates that the model is able to reproduce the qualitative pattern of upstream DOC price dynamics, although the empirical fluctuations remain sharper than those generated by the baseline simulation.

Figure 9 shows the baseline simulation of fresh broiler meat price compared with the historical reference mode over the period from January 2020 to December 2025. The simulated fresh broiler meat price reproduces the broad movement of the reference series, particularly in terms of medium-term direction and the main turning points. Nevertheless, the simulated behavior remains smoother than the historical pattern and does not fully capture the sharper short-term fluctuations observed in the reference mode. This result suggests that the model is able to represent the general downstream price dynamics sufficiently for structural explanation and policy.

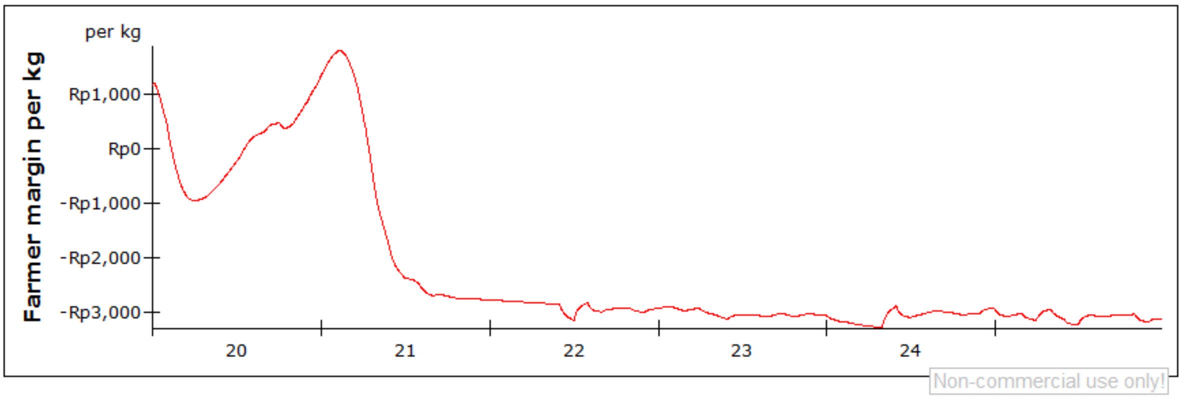

Figure 10. Baseline simulation of farmer margin per kg, January 2020–December 2025.

Figure 10 presents the farmer margin per kg under the baseline simulation. The result shows that the margin becomes negative after the early phase of the simulation and remains below zero for most of the observed period. This indicates that the baseline problem represented by the model is not limited to price fluctuation alone but also includes persistent economic pressure on farmers. In this sense, the baseline simulation supports the argument that instability in the broiler supply chain should be understood not only as volatile market prices but also as prolonged deterioration in producer margin.

Table 10. Baseline Performance Indicators Across the Broiler Supply Chain, January 2020–December 2022

Indicator	Value
Mean simulated live broiler price (Rp/kg)	19,619
Coefficient of variation of simulated live broiler price (%)	6.64%
Mean simulated FS DOC price (Rp/chicks)	8,324
Coefficient of variation of simulated FS DOC price (%)	6.50%
Mean simulated fresh broiler meat price	34,841
Coefficient of variation of simulated fresh broiler meat price (%)	11%
Average farmer margin per kg (Rp/kg)	-1365
Minimum farmer margin per kg (Rp/kg)	-3146

Table 10 presents the baseline performance indicators across different levels of the broiler supply chain over the period from January 2020 to December 2022. The results show that the simulated live broiler price averages Rp 19,619/kg, with a coefficient of variation of 6.64%, indicating moderate price variability under baseline conditions. A similar level of variability can be seen in the upstream FS DOC market, where the average price reaches Rp 8,324 per chick with a coefficient of variation of 6.50%. This suggests that price dynamics at the upstream level are closely aligned with live bird market fluctuations, reflecting a relatively strong transmission of supply–demand imbalances along the production chain.

At the downstream level, the simulated fresh broiler meat price averages Rp 34,841/kg, with a higher coefficient of variation of 11%. This indicates that price fluctuations become more pronounced at the retail level, potentially reflecting the combined effects of demand variability, price transmission delays, and market adjustment mechanisms. The higher variability in broiler meat price suggests that downstream markets do not necessarily dampen upstream instability but may instead amplify it under certain conditions.

From an economic perspective, the baseline results indicate persistent pressure on producers. The average farmer margin per kg is negative at Rp -1,365, with a minimum value of Rp -3,146, indicating that farmers experience sustained losses over a substantial portion of the simulation horizon. This finding suggests that the baseline problem represented in the model extends beyond price fluctuation alone, encompassing structural imbalances that adversely affect producer profitability.

Overall, the baseline performance indicators indicate that instability in the broiler supply system is manifested not only in price variability across the supply chain but also in persistent negative economic outcomes at the farm level. These results provide a quantitative basis for evaluating the effectiveness of alternative policy scenarios in improving both price stability and farmer economic conditions. Based on these baseline conditions, the following section evaluates how alternative policy interventions influence system behavior. The policy scenario analysis examines whether the proposed control mechanisms can improve price stability and farmer economic outcomes relative to the baseline.

4.10 Sensitivity Analysis Resuts

Based on the sensitivity analysis design described in Section 4.6, the results of the sensitivity analysis are presented in Tables 11 and 12.

Table 11. Sensitivity of Hatchery Setting Policy Strength to Short-Term Hatchery Adjustment and FS DOC Supply Variables

Policy strength	Avg effective desired hatchery setting fraction	Avg Hatchery setting fraction	Avg FS DOC realization rate (chicks/week)	Avg Hatchery FS DOC inventory ratio
0	1	1	8,589,079	1.077
0.25	0.997	0.997	8,561,798	1.063
0.5	0.993	0.993	8,532,407	1.045
0.75	0.990	0.990	8,504,321	1.026
1	0.987	0.987	8,479,476	1.008

As shown in Table 11, increasing hatchery setting policy strength produces a consistent monotonic response in the short-term hatchery adjustment pathway. The average effective desired hatchery setting fraction and Hatchery setting fraction both declined from 1.000 at policy strength 0 to 0.987 at policy strength 1. The average FS DOC realization rate also decreased, from 8,589,079 to 8,479,476, while the average Hatchery FS DOC inventory ratio fell from 1.077 to 1.008. These results indicate that stronger hatchery control reduced realized hatching intensity and moved hatchery inventory conditions closer to the desired level.

Table 12. Sensitivity of GPS DOC Import Policy Strength to Upstream Import-Correction and GPS Laying Capacity Variables

Policy strength	Avg GPS import correction target	Avg GPS import correction factor	Avg Modified GPS DOC import order rate (GP breeder bird unit)	Avg GPS Laying Unit (GP breeder bird unit)
0.00	0.000	0.000	1,588,899	220,409,448
0.25	0.064	0.082	1,693,971	294,458,059
0.50	-0.109	-0.073	1,440,345	280,207,471
0.75	-0.282	-0.229	1,186,417	265,601,249
1.00	-0.416	-0.348	991,335	253,203,874

As shown in Table 12, GPS DOC import policy strength generated systematic but nonlinear responses in the upstream capacity pathway. At low policy intensity, the average GPS import correction target, GPS import correction factor, and modified GPS DOC import order rate increased, followed by an increase in the average GPS Laying Unit from 220,409,448 to 294,458,059. At higher policy strengths, however, the correction target and correction factor became increasingly negative, the modified import order rate declined, and the average GPS Laying Unit fell to 253,203,874 at policy strength 1. This pattern indicates that the GPS import lever operates as a bounded capacity-correction mechanism rather than a simple linear expansion rule.

Overall, the sensitivity analysis confirmed that both policy levers are structurally functional within their respective subsystems. Hatchery setting policy strength produced a clear and monotonic response along the short-term operational pathway, while GPS DOC import policy strength produced a coherent but nonlinear response along the long-term upstream capacity pathway. These findings strengthen confidence that the model responds logically to variation in the intensity of both short-term operational control and long-term capacity control.

4.11 Policy Scenario Results

The policy scenario results are presented to examine how the model behavior changes when the main policy levers are activated relative to the baseline condition. In this study, the baseline simulation serves as the reference case against which the effects of alternative policy interventions are evaluated. The scenario analysis focuses on three policy configurations: hatchery setting adjustment as a short-term operational control, demand-driven GPS DOC import correction as a long-term capacity-control mechanism, and the combination of both interventions within a single control structure. The main outputs observed include simulated live broiler price, farmer margin per kg, and the internal variables directly associated with each policy pathway. In addition, the scenario results are assessed using selected performance indicators to evaluate changes in price behavior and farmer economic conditions. Beyond their role in price stabilization, these scenarios are also relevant for understanding how multi-horizon control can inform food supply planning, including the coordination of upstream capacity, DOC allocation, and downstream absorption in the broader broiler supply system. The results are interpreted not only in terms of directional change, but also in relation to the response horizon, consistency with the model structure, and implications for policy design.

4.11.1 Scenario 1: Hatchery Setting Adjustment

Scenario 1 evaluates the effect of hatchery setting adjustment as a short-term operational control mechanism. In this scenario, hatchery setting policy strength is activated, while GPS DOC import policy strength remains inactive. The purpose of this scenario is to examine whether tighter control over hatchery setting can moderate excess FS DOC realization before it propagates into excess live bird supply and price pressure in the downstream market.

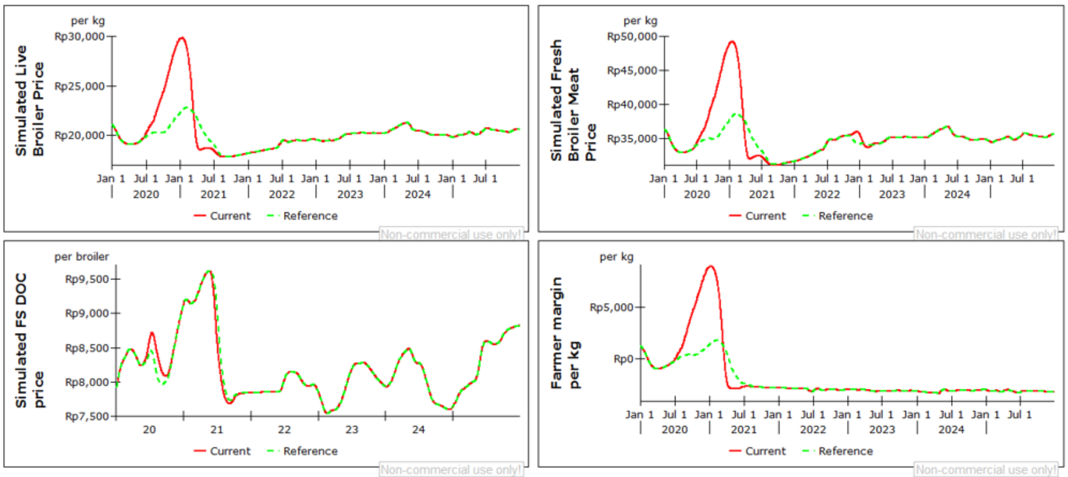

Figure 11. Scenario 1 results

Scenario 1 results under hatchery setting adjustment, January 2020–December 2025: simulated live broiler price, simulated fresh broiler meat price, simulated FS DOC price, and farmer margin per kg. In each panel, ‘Current’ denotes Scenario 1, while ‘Reference’ denotes the baseline simulation.

Figure 11 presents the results of Scenario 1 for simulated live broiler price, simulated fresh broiler meat price, simulated FS DOC price, and farmer margin per kg over the period from January 2020 to December 2025. In each panel, ‘Current’ denotes Scenario 1, while ‘Reference’ denotes the baseline simulation. As shown in the upper-left panel, Scenario 1 produced a noticeable increase in simulated live broiler price during the early phase of the simulation, especially around the period of strongest supply correction. This indicates that hatchery setting adjustment is able to reduce downstream oversupply pressure and temporarily improve live bird price conditions relative to the baseline. A similar pattern appears in the upper-right panel, where simulated fresh broiler meat price also rises above the baseline during the same period, although the effect is somewhat less pronounced than in the live broiler market. This suggests that the short-term reduction in live bird supply is transmitted downstream to broiler meat prices.

By contrast, the lower-left panel shows that the effect of Scenario 1 on simulated FS DOC price is relatively limited. The scenario and baseline trajectories remain very close for most of the simulation horizon, with only minor deviations. This implies that the hatchery setting intervention works more directly through quantity adjustment and downstream supply moderation than through a strong price correction in the FS DOC market itself.

The lower-right panel shows the behavior of farmer margin per kg. Under Scenario 1, margin improves substantially during the initial period when live broiler prices rise above the baseline, indicating that short-term hatchery control can temporarily relieve producer pressure. However, after the initial adjustment phase, the farmer margin trajectory converges closely toward the baseline pattern and remains negative over much of the simulation horizon. This suggests that hatchery setting adjustment alone is not sufficient to generate sustained recovery in farmer profitability, even though it can provide short-term stabilization benefits.

Overall, Scenario 1 shows that hatchery setting adjustment functions as an effective short-term operational lever, particularly in moderating downstream oversupply and improving live broiler price conditions in the near term. However, its effect appears stronger on downstream price behavior than on upstream FS DOC price and its contribution to farmer margin improvement is only partial and temporary. These results indicate that hatchery setting adjustment is useful for short-term correction but may need to be complemented by longer-horizon capacity control if more durable stabilization is to be achieved.

4.11.2 Scenario 2: Demand-Driven GPS DOC Import Correction

Scenario 2 evaluates the effect of demand-driven GPS DOC import correction as a long-term capacity-control mechanism. In this scenario, GPS DOC import policy strength is activated, while hatchery setting policy strength remains inactive. The purpose of this scenario was to examine whether upstream breeding-capacity adjustment, driven by downstream demand signals, can moderate supply imbalance and improve price behavior over time.

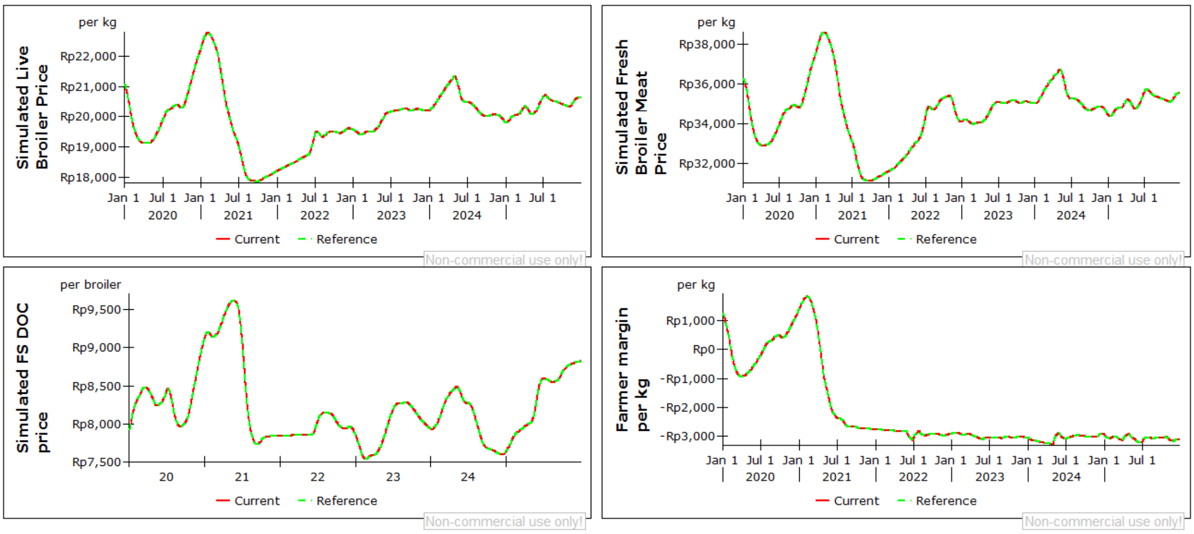

Figure 12. Scenario 2 results
Scenario 2 results under demand-driven GPS DOC import correction, January 2020–December 2025: simulated live broiler price, simulated fresh broiler meat price, simulated FS DOC price, and farmer margin per kg. In each panel, ‘Current’ denotes Scenario 2, while ‘Reference’ denotes the baseline simulation.

As shown in Figure 12, the Scenario 2 trajectories remain very close to the baseline across all four variables. The simulated live broiler price shows almost no visible deviation from the baseline, and a similar pattern is observed for simulated fresh broiler meat price and simulated FS DOC price. Farmer margin per kg also remains nearly identical to the baseline trajectory throughout most of the simulation horizon. These results indicate that the demand-driven GPS DOC import correction does not generate a strong short-term effect on downstream market behavior within the observed period.

This limited visible impact is consistent with the structure of the model. Unlike hatchery setting adjustment, which operates through a short-term operational pathway, GPS DOC import correction affects the system through a much longer chain involving import realization, transit, maturation, and subsequent breeding-capacity transmission. As a result, its contribution lies primarily in long-term upstream capacity adjustment rather than immediate price stabilization. In this sense, Scenario 2 confirms that GPS DOC import correction is structurally relevant, but its effect on live bird price and farmer margin is delayed and less pronounced within the simulation horizon considered in this study.

4.11.3 Scenario 3: Combined Hatchery Setting Adjustment and GPS DOC Import Correction

Scenario 3 evaluates the combined effect of hatchery setting adjustment and demand-driven GPS Scenario 3 evaluates the combined effect of hatchery setting adjustment and demand-driven GPS DOC import correction. In this scenario, both hatchery setting policy strength and GPS DOC import policy strength are activated simultaneously. The objective is to examine whether the integration of short-term operational control and long-term capacity adjustment can produce a more balanced and sustained stabilization effect compared to each policy applied individually.

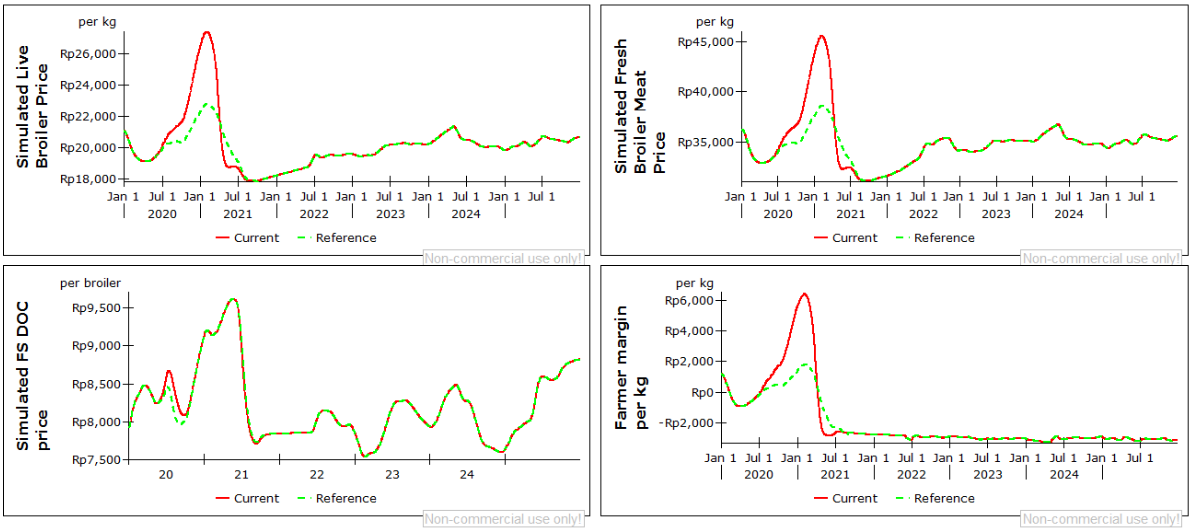

Figure 13. Scenario 3 results
Scenario 3 results under combined hatchery setting adjustment and demand-driven GPS DOC import correction, January 2020–December 2025: simulated live broiler price, simulated fresh broiler meat price, simulated FS DOC price, and farmer margin per kg. In each panel, ‘Current’ denotes Scenario 3, while ‘Reference’ denotes the baseline simulation.

As shown in the upper-left panel in Figure 13, the combined policy produced a significant increase in simulated live broiler price during the early phase of the simulation, similar to the pattern observed in Scenario 1. The price peak is substantially higher than the baseline, indicating that the short-term reduction in FS DOC realization effectively reduces downstream oversupply. A comparable response is observed in the upper-right panel for simulated fresh broiler meat price, where the combined scenario also generates a strong upward deviation from the baseline during the same period. These results confirm that the short-term dynamics of the combined policy are primarily driven by hatchery setting adjustment.

The lower-left panel shows that the simulated FS DOC price remains largely similar to the baseline, with only minor deviations. This suggests that, even under the combined policy, the primary transmission mechanism operates through quantity control rather than a strong price correction in the DOC market. The contribution of GPS DOC import correction to FS DOC price dynamics remains limited within the simulation horizon.

The most notable difference from Scenario 1 appears in the farmer margin behavior shown in the lower-right panel. Under the combined policy, farmer margin increases sharply during the initial phase, reaching a higher peak than in the baseline and remaining above the baseline level for a longer period. This indicates that the integration of upstream capacity control, although not immediately visible in price variables, helps to sustain the improvement in producer conditions following the initial correction. Nevertheless, after the adjustment phase, the margin gradually converges toward the baseline pattern and remains negative for a substantial portion of the simulation horizon.

Overall, Scenario 3 demonstrates that combining short- and long-term policy instruments produces a more coherent control structure than applying either policy in isolation. The results suggest that hatchery setting adjustment provides immediate stabilization by controlling FS DOC realization, while GPS DOC import correction contributes to moderating upstream capacity over time. However, within the simulation horizon considered in this study, the short-term dynamics remain dominant and the long-term effects of GPS adjustment are only partially realized. These findings highlight the importance of coordinated, multi-horizon policy design in addressing structural instability in the broiler supply chain.

4.11.4 Summary of Policy Scenario Results

The policy scenario results can be compared more clearly by using a common set of performance indicators that summarize how each scenario affects price behavior across the broiler supply chain and the economic condition of farmers relative to the baseline. Table 13 presents the comparison of these indicators for the baseline, Scenario 1, Scenario 2, and Scenario 3 over the period from January 2020 to December 2022.

Table 11. Comparison of Performance Indicators across the Baseline and Policy Scenarios, January 2020–December 2022

Indicator	Baseline	Scenario 1	Scenario 2	Scenario 3
Mean simulated live broiler price (Rp/kg)	19,619	20,467	19,619	20,130
Coefficient of variation of simulated live broiler price (%)	6.64%	16.01%	6.64%	12.35%
Mean simulated FS DOC price (Rp/chick)	8,324	8,310	8,309	8,324
Coefficient of variation of simulated FS DOC price (%)	6.50%	6.41%	6.53%	6.50%
Mean simulated fresh broiler meat price (Rp/kg)	34,841	35,403	34,072	34,841
Coefficient of variation of simulated fresh broiler meat price (%)	11%	14%	6%	11%
Average farmer margin per kg (Rp/kg)	-1365	-516	-1363	-862
Minimum farmer margin per kg (Rp/kg)	-3146	-3146	-3146	-3146

As shown in Table 13, Scenario 1 produced the strongest improvement in the mean simulated live broiler price, increasing it from Rp 19,619/kg to Rp 20,467/kg, and also yielded the largest improvement in average farmer margin, from Rp -1,365/kg to Rp -516/kg. However, this scenario also raised the coefficient of variation of simulated live broiler price from 6.64% to 16.01%, indicating that the price improvement was accompanied by greater volatility.
Scenario 2 shows only a limited effect on live broiler price and farmer margin, with the mean simulated live broiler price remaining at Rp 19,619/kg and the average farmer margin changing only slightly to Rp -1,363/kg. Its most visible effect appears in the downstream market, where the coefficient of variation of simulated fresh broiler meat price declined from 11% to 6%. This suggests that demand-driven GPS DOC import correction contributes more to longer-term downstream moderation than to short-term live bird price stabilization.

Scenario 3 produced more balanced results. The mean simulated live broiler price rises to Rp 20,130/kg, while the average farmer margin improves to Rp -862/kg. At the same time, the coefficient of variation of simulated live broiler price increased to 12.35%, which is lower than in Scenario 1 but still above the baseline. This indicates that the combined policy provides a more moderate trade-off between price improvement and volatility.

Across all scenarios, the mean and variability of simulated FS DOC price change only slightly, indicating that the policy interventions have limited direct influence on FS DOC price behavior within the observed period. Importantly, the minimum farmer margin per kg remains Rp -3,146 across all scenarios, suggesting that none of the scenarios fully eliminated the most severe episode of producer loss. Overall, Scenario 1 provides the strongest short-term improvement, Scenario 2 has the weakest direct effect on live bird market outcomes and Scenario 3 offers the most balanced, though still partial, improvement.

Beyond their immediate effect on price stabilization, the scenario results also carry important implications for regional food supply planning. The findings indicate that short-term operational control and long-term capacity control perform different but complementary functions in the broiler system. Hatchery setting adjustment generates a relatively rapid response by directly influencing FS DOC realization, whereas GPS DOC import correction operates through a much longer chain of biological and administrative delays. From a regional planning perspective, this implies that short-term supply management should be based on timely operational monitoring, while longer-term planning should be linked to projected production requirements and demand conditions rather than short-run price signals alone.

The results further suggest that regional food supply planning should not be oriented solely toward final market prices but toward coordination across multiple stages of the supply chain. Hatchery setting, FS DOC realization, live bird supply, slaughterhouse absorption, and downstream product distribution are structurally interconnected. Consequently, regional planning institutions need to monitor not only market outcomes but also upstream production signals and midstream capacity constraints. Early identification of excess chick-in, excessive hatchery setting, or weak slaughterhouse absorption may help prevent localized oversupply from developing into broader regional price pressure.

The comparison between Scenario 1 and Scenario 3 also indicates that regional stabilization is likely to be more effective when short-term operational control is supported by longer-horizon capacity adjustment. In practical terms, this points to the need for multi-horizon coordination between tactical supply management and strategic breeding-capacity planning. Production-intensive regions may require more responsive short-term intervention to manage local surplus conditions, while interregional or national coordination remains necessary to align upstream breeding decisions with expected downstream demand over time.

Finally, these findings underscore the importance of integrated data systems for regional planning. A regional food supply planning framework for broiler products would require connected information on hatchery setting, FS DOC realization, live bird inventory, slaughterhouse capacity, cold-chain utilization, and market demand. Although the present model is formulated at an aggregate national level, the scenario results provide a useful analytical basis for designing regional planning mechanisms that combine short-term monitoring with longer-term supply-capacity coordination. In this sense, the policy scenarios are relevant not only for price stabilization but also for strengthening the planning logic of regional food supply systems.

5. Discussion

The results show that instability in Indonesia's broiler system is not simply a matter of prices moving up and down in the market. It reflects a deeper mismatch between how supply is formed and how demand is absorbed across the supply chain. The baseline simulation indicates that unstable live bird prices are accompanied by prolonged pressure on farmer margins, which means that the problem is not only short-term volatility but also a repeated imbalance that weakens producer viability. The policy scenarios further show that the system responds differently to short-term operational control and long-term capacity control.

This finding is consistent with the broader literature on agricultural and livestock systems, which shows that instability often emerges when supply responds more slowly than market signals change. In broiler production, this tendency is stronger because decisions made in breeding and hatching continue to influence supply long after the original market signal has changed. The present study adds to that literature by showing that, in the Indonesian broiler system, instability is reinforced by the interaction between two adjustment horizons: a short operational horizon at the hatchery level and a much longer capacity horizon at the breeding level. This means that the problem is not only delayed response but also poor alignment between different levels of control. From a policy perspective, the strongest short-term effect comes from hatchery setting adjustment. This policy can reduce excess chick output before it leads to excess live birds in the market. In practical terms, this makes it a useful instrument when early signs of oversupply are already visible. However, the results also show that stronger hatchery control can increase volatility if applied too aggressively. This means that hatchery setting should not be treated as a blunt reduction tool but as a calibrated operational instrument. At the national level, this policy falls under the authority of the Ministry of Agriculture and the National Food Agency (NFA), while at the regional level it must be carried out technically by the regional agricultural offices (Dinas Pertanian). Their role is therefore crucial, because effective adjustment depends on timely information about hatchery plans, chick placement, broiler population, and local market pressure. The results also clarify the role of demand-driven GPS DOC import correction. This policy does not produce a strong short-term effect on live bird prices, but that does not mean it is unimportant. Its function is different: it works as a long-term capacity-planning instrument. Because imported breeding stock affects future production only after a long biological and administrative process, this policy should not be used to react to weekly price changes. Instead, it should be based on projected production needs and expected market demand. Institutionally, this places the main authority at the Ministry of Trade, while technical implementation and coordination at the regional level involve the regional trade offices (Dinas Perdagangan). The implication is clear: short-term market stabilization and long-term capacity planning must be treated as related but different policy tasks.

The scenario results also show that government action alone is not enough. Broiler supply chain actors at the regional level must also play an active role. Hatcheries need to align their setting decisions with realistic downstream needs. Integrators need stronger coordination between breeding, grow-out farms, slaughterhouses, and market release. Slaughterhouses and cold-chain operators need to strengthen their capacity to absorb supply shocks, especially in production regions where local surplus can quickly depress prices. Traders and distributors need to improve linkages between surplus and deficit regions. Independent farmers also need better access to planning signals and market information so that production decisions are not made in isolation. In this sense, stabilization is a coordination problem involving both public institutions and private actors across the regional supply system.

These findings are highly relevant for regional food supply planning. Even though the model is constructed at the national level, the policy logic applies directly to regional planning practice. Short-term planning should focus on early monitoring of excess chick placement, excess hatchery output, and weak slaughterhouse absorption before these conditions turn into local price collapse. Medium- and long-term planning should focus on aligning future breeding capacity with expected regional and national demand. This also means that regions cannot rely only on observing live bird prices after the problem appears. They need integrated monitoring of upstream, midstream, and downstream conditions. A regional food supply planning system for broiler products therefore needs connected data on hatchery setting, chick realization, broiler stock, slaughter capacity, cold-chain use, and local demand.

From a system dynamics perspective, this study contributes by showing that price stabilization in a biological food system depends on the design of control structure, not only on the choice of policy instrument. The model demonstrates that short-term and long-term interventions are not interchangeable: hatchery control affects the system quickly, while breeding-capacity control works slowly but addresses deeper structural imbalance. This helps explain why some interventions may improve conditions temporarily without solving the underlying problem. More broadly, the study links price stabilization to food supply planning and shows that instability should be understood as a system-wide coordination issue. In that sense, the model provides a practical framework for understanding how policy design, institutional roles, and supply-chain behavior interact in the regional broiler food system.

6. Limitations and Future Development

Several limitations should be acknowledged before the model is used as a basis for more operational policy design. First, the model is formulated at the aggregate national level and therefore does not yet represent regional heterogeneity in production concentration, consumption patterns, logistics costs, slaughtering capacity, and local market structure. In practice, live bird price pressure often emerges unevenly across regions, with some production areas experiencing severe oversupply, while other areas face tighter market conditions. Future development should therefore extend the model toward a regional or interregional framework so that local supply pressure, capacity constraints, and distribution imbalances can be represented more explicitly.

Second, actor behavior is still simplified through aggregate decision rules based on margins, inventory conditions, and adjustment delays. This representation is appropriate for explaining the feedback structure of the system, but it does not yet capture the full diversity of behavior among integrators, independent farmers, hatcheries, traders, slaughterhouses, and regional distributors. Further work could refine the behavioral structure of the model by differentiating decision rules across actor groups, especially in relation to access to information, working capital, contractual arrangements, and market access.

Third, the model does not yet explicitly represent the institutional and political complexity of policy implementation. In practice, hatchery setting adjustment, GPS DOC import decisions, and regional supply coordination depend not only on technical logic but also on compliance, data quality, inter-agency coordination, and the incentives of private actors. Future research may therefore combine system dynamics modeling with participatory policy design, broader expert validation, and stronger integration of institutional processes, so that the model can function not only as an analytical tool but also as a practical platform for coordination across national and regional food supply systems.

7. Conclusion

This study developed a system dynamics model of the Indonesian broiler supply chain to explain recurring live bird price instability and identify policy leverage points for stabilization. The model integrates the FS DOC market, live bird market, broiler meat market, integrator and non-integrator production, cold storage, slaughterhouses, the GPS–PS breeding subsystem, and the GPS DOC import determination subsystem within a unified feedback structure. Its main conceptual contribution is the introduction of a dual-control structure that separates short-term operational control through hatchery setting adjustment from long-term biological capacity control through GPS DOC import policy.

The simulation results indicate that instability emerges because supply correction is delayed across multiple biological and operational stages. Baseline behavior reproduces the broad pattern of recurring live bird price fluctuation and prolonged periods of pressure relative to production cost. Scenario analysis shows that hatchery setting adjustment is the most relevant short-run stabilization lever because it can moderate FS DOC realization before surplus propagates into the live bird market. Demand-driven GPS DOC import correction may have limited short-run effect, because it operates through long maturation and production delays, but it remains necessary for aligning upstream capacity with downstream demand over a longer horizon. Cold storage contributes as a residual downstream buffer rather than as the main source of stabilization.

Overall, the study suggests that live bird price stabilization should be approached as a multi-horizon supply chain control problem rather than solely as a reference-price issue. Effective policy requires coordination between downstream demand estimation, hatchery operations, breeding-capacity planning, and GPS import decisions. Future work should strengthen empirical calibration, expand model validation and sensitivity testing, and incorporate regional heterogeneity so that the model can support more operationally specific policy design.

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