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Modeling Capital-Induced Labor Migration for Indonesian Regional Convergence

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ABSTRACT

Regional inequality in Indonesia presents a persistent structural challenge characterized by capital concentration and labor agglomeration in core regions. Conventional models often fail to capture the endogenous feedback between capital accumulation, dynamic labor migration, and regional ecological limits. To address this theoretical gap, we formulate a four-dimensional non-linear ordinary differential equation (ODE) system integrating the Solow neoclassical growth framework, logistic population dynamics bounded by regional carrying capacities (κ), and Capital-Induced Labor Migration (CILM). The model is empirically calibrated using Statistics Indonesia macroeconomic data (2020−2024), classifying regions into Core and Periphery based on a strict 2.63% Gross Regional Domestic Product (GRDP) equal-distribution threshold. Analytical validity is rigorously established through mathematical proofs of Positive Invariance and Ultimate Boundedness. Numerical simulations using the Runge-Kutta 4th Order method reveal a critical phenomenon termed "deceptive convergence" a scenario where the spatial inequality ratio artificially compresses not due to genuine economic expansion in the periphery, but solely because the core region reaches its absolute ecological saturation. Furthermore, high labor mobility sensitivity is proven to act as a divergence multiplier, triggering massive labor drains from peripheral regions. Ultimately, a synthesized policy mix simulation demonstrates that aggressive physical capital diffusion combined with strict human capital retention policies is mathematically proven as the most effective strategy to transform the agglomeration curse into equitable structural convergence.

I. INTRODUCTION

Inequality between regions in Indonesia is a persistent structural challenge, rooted in the concentration of production activities and agglomeration dynamics. In 2024, Java alone contributed 57.02% of the national Gross Regional Domestic Product (GRDP), while Sumatra contributed 22.12%, Kalimantan 8.24%, Sulawesi 7.12%, and other islands less than 3% each [1]. These striking spatial concentrations are not just temporary phenomena, but the result of a long-term cumulative process driven by the interplay of capital accumulation and labor mobility.

However, existing theoretical frameworks have limited explanatory power regarding this resilience. The Solow neoclassical model predicts conditional convergence between regions with similar structural parameters, yet empirical data from Indonesia consistently shows divergence between Java and non-Java regions [2], [3]. The Harris-Todaro migration model links labor movement to nominal wage differentials, but it overlooks the role of endogenous capital in shaping migration incentives [4]. The Capital-Induced Labor Migration (CILM) mechanism, introduced by Neto and Claeyssen [5], fills this gap by modeling labor migration as a direct response to interregional capital inequality, creating a positive feedback loop that perpetuates the core-periphery structure.

Despite the relevance of CILM to Indonesian dynamics, existing applications remain largely theoretical, lacking empirical calibration to real macroeconomic data or systematic policy simulations. Furthermore, while alternative methodologies such as Computable General Equilibrium (CGE) and Agent-Based Modeling (ABM) are prevalent in spatial economics, they possess critical limitations for this specific context. CGE models inherently assume that markets clear and naturally gravitate toward equilibrium, which mathematically masks the structural divergence inherent in persistent agglomeration. Conversely, ABM provides high micro-level granularity but suffers from extreme parameter sensitivity and mathematical intractability. In contrast, utilizing a non-linear continuous-time ODE framework provides a deterministic, rigorously provable macroscopic mechanism to capture the endogenous feedback loops between capital accumulation and demographic shifts without forcing an artificial equilibrium. To address these theoretical and methodological limitations, we construct a four-dimensional nonlinear ordinary differential equation (ODE) system that integrates Solow capital accumulation, logistic demographic growth, and CILM within a two-region framework. This model is calibrated using BPS macroeconomic data for the period 2020-2024 and tested through parameter sensitivity analysis and policy scenario simulations to evaluate convergence paths.

Regional classification is not based on static geographical boundaries. Guided by the principle that economic agglomeration is a key characteristic, provinces are classified as Core (Kc) if their GRDP share exceeds 2.63% of national output (representing the 100%/38 equal-distribution threshold across 38 provinces), and as Periphery (Kp) if not. This threshold results in a Core group that contributes 76.48% of national capital and absorbs 70.45% of the national workforce.

The primary novelty and contribution of this study is the mathematical formalization of the "deceptive convergence" phenomenon a condition where spatial inequality artificially compresses not due to genuine economic expansion in the periphery, but strictly because the core region collides with its absolute ecological and infrastructural carrying capacity. We substantiate this claim through four key contributions: (1) formulating a novel four-dimensional ODE system that endogenously couples CILM with logistic demographic carrying capacities (κ); (2) rigorously calibrating the model against Indonesian macroeconomic data (2020−2024); (3) executing numerical validations using the Runge-Kutta 4th Order method to prove global asymptotic stability; and (4) demonstrating computationally that a dual-pronged state intervention (hyper-connectivity paired with labor retention) is mandatory to achieve true structural catch-up.

II. Methods

A. Model Construction and Economic Assumptions

This model describes the national economy as a closed macroeconomic system bifurcated into two functionally interdependent regions: the Core (c) and the Periphery (p). To rigorously capture the endogenous feedback between investment and demography, the system is constructed using a four-dimensional nonlinear ordinary differential equation (ODE) framework.

Before defining the equations, it is imperative to formally define the state variables that drive the system, as detailed in Table I.

TABLE I
FORMAL DEFINITION OF STATE VARIABLES

State Variable	Economic Definition	Proxy / Empirical Representation
$K_c(t)$	Physical capital stock in the Core region	Gross Fixed Capital Formation (GFCF) at constant prices
$K_p(t)$	Physical capital stock in the Periphery region	Gross Fixed Capital Formation (GFCF) at constant prices
$L_c(t)$	Active labor force in the Core region	Working-age population (≥15 years) actively employed or seeking work
$L_p(t)$	Active labor force in the Periphery region	Working-age population (≥15 years) actively employed or seeking work

The structural dynamics of these variables are governed by the following core economic assumptions, which explicitly integrate the Solow neoclassical framework with regional carrying capacities:

1) The system assumes a closed national economy without foreign direct investment. For mathematical tractability, we assume homogeneous labor quality and uniform total factor productivity (θ) across regions, though we acknowledge this linearity limits the capture of highly heterogeneous agent behaviors.
2) The system begins with a strictly defined initial condition of spatial inequality where $K_c(0) > K_p(0)$.
3) Capital accumulation follows the Solow growth model utilizing a Cobb-Douglas production function ($Y = \theta K^{\alpha} L^{1-\alpha}$). Capital diffuses linearly based on inter-regional density gradients, reflecting investment arbitrage.
4) Distinct from the classical Harris-Todaro model which relies on nominal wage gaps, CILM formally defines migration as a direct function of the marginal product of labor driven by capital utility disparities. Labor migrates unidirectionally from the Periphery to the Core in response to capital concentration.
5) Unlike standard macroeconomic models that assume exponential labor growth, this system enforces logistic population dynamics bounded by regional ecological and infrastructural carrying capacities (κ_c and κ_p).

B. Model Formulation

Capital dynamics in each region follow a Solow-type accumulation framework with linear interregional diffusion. The production function is assumed to follow the Cobb-Douglas model, $Y = \theta K^{\alpha} L^{1-\alpha}$ [2], [7], [8]. The diffusion term captures the flow of capital from high-density to low-density regions, representing investment arbitrage seeking higher marginal rates of return and policy-driven equalization. The complete capital evolution equations are formulated as:

$$\frac{dK_c}{dt} = \sigma_c \theta K_c^{\alpha} L_c^{1-\alpha} - \delta K_c - \tau(K_c - K_p) \quad (1)$$

$$\frac{dK_p}{dt} = \sigma_p \theta K_p^{\alpha} L_p^{1-\alpha} - \delta K_p + \tau(K_c - K_p) \quad (2)$$

Labor dynamics combine logistic natural demographic growth with the Capital-Induced Labor Migration (CILM) mechanism. Drawing from the marginal labor product ($\partial Y/\partial L$), wage differentials are modeled as proportional to the capital stock raised to the power of capital elasticity (α). The resulting CILM term is defined as $\varphi L_p(K_c^{\alpha} - K_p^{\alpha})$. This formulation mathematically incorporates diminishing marginal utility, as additional capital in capital-deficient peripheral regions yields greater marginal wage gains than equivalent capital in core regions. Consequently, the complete labor evolution equations are:

$$\frac{dL_c}{dt} = \rho_c L_c \left(1 - \frac{L_c}{\kappa_c}\right) + \varphi L_p(K_c^{\alpha} - K_p^{\alpha}) \quad (3)$$

$$\frac{dL_p}{dt} = \rho_p L_p \left(1 - \frac{L_p}{\kappa_p}\right) - \varphi L_p(K_c^{\alpha} - K_p^{\alpha}) \quad (4)$$

C. Mathematical Validation

Theorem 3.1 (Positive Invariance): Given non-negative initial conditions $(K_c(0), K_p(0), L_c(0), L_p(0)) \in \mathbb{R}_+^4$, the solutions of the system (1)-(4) remain in $\mathbb{R}_+^4$ for all $t \geq 0$.

Proof: At each boundary (e.g., $K_c = 0$), the vector field is non-negative: $\left.\frac{dK_c}{dt}\right|_{K_c=0} = \tau K_p \geq 0$. The same non-negativity applies to the boundaries of K_p, L_c, and L_p. Since the vector field points inward or is strictly tangent at all boundaries, the solution trajectories cannot cross into negative values.

Theorem 3.2 (Ultimate Boundedness): There exists a positive constant $M > 0$ such that the set $\Omega = \{(K_c, K_p, L_c, L_p) \in \mathbb{R}_+^4 : K_c + K_p + L_c + L_p \leq M\}$ is a global attracting set.

Proof: (i) *Labor:* The logistic terms are inherently self-limiting. The total labor satisfies $\lim\sup_{t\to\infty} \left(L_c(t) + L_p(t)\right) \leq \max(\kappa_L, \kappa_K) = M_L$. (ii) *Capital:* The total capital $K_T = K_c + K_p$ satisfies $\frac{dK_T}{dt} \leq C \cdot K_T^{\alpha} - \delta K_T$. Since the output elasticity $\alpha < 1$, the sub-linear growth term is eventually dominated by linear decay $-\delta K_T$. Thus, a finite upper bound $M_K = \left(\frac{C}{\delta}\right)^{\frac{1}{1-\alpha}}$ exists. Setting $M = \max(M_L, M_K)$ completes the proof.

To computationally validate the analytical theorems, a phase portrait analysis was performed using the MATLAB ode45 solver (Figure 1). This visualization confirms global asymptotic stability: state trajectories generated from four distinct initial conditions including an extreme capital accumulation scenario $(K_c(0) = 200, K_p(0) = 50)$ all converge robustly to a single bounded equilibrium point (E^*). The backward curvature of the KA 3 trajectory visually reinforces the ultimate boundedness established in Theorem 3.2.

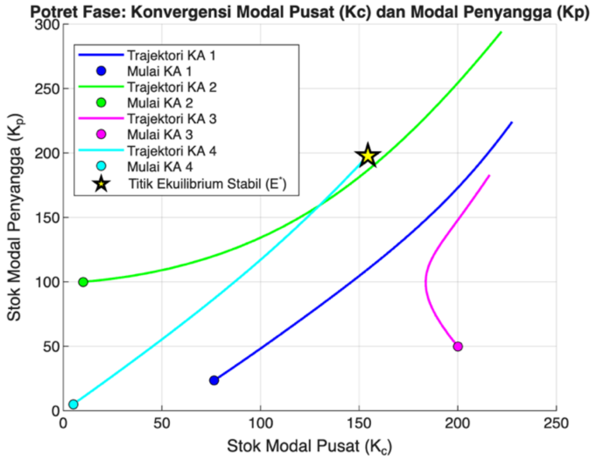

Figure 1. Phase portrait demonstrating global asymptotic stability and ultimate boundedness

D. Parameter Calibration

Model parameters are calibrated using empirical macroeconomic data from Statistics Indonesia (BPS) for the period 2020–2024. Initial conditions are obtained from 2024 GRDP data and the August 2025 National Labor Survey (Sakernas) [1], [9], [10], [11]. The threshold of 2.63% is not arbitrary; it represents the theoretical absolute spatial equality benchmark 100%÷38 provinces≈ 2.63%. From a macroeconomic perspective, any province contributing above this threshold acts as a net agglomerator of national wealth and labor (Core), while those below are statistically marginalized (Periphery). This threshold provides a rigid, data-driven dichotomy that strips away geographical bias, allowing the ODE system to strictly capture the structural dynamics of economic concentration. Table I summarizes the calibrated structural parameters and baseline initial conditions.

TABLE II
CALIBRATED PARAMETERS AND INITIAL CONDITONS

Symbol	Parameter	Value	Range	Sources
$K_c(0)$	Core initial capital	76.48	-	[1]
$K_p(0)$	Periphery initial capital	23.52	-	[1]
$L_c\ (0)$	Core initial labor	70.45	-	[6], [12]
$L_p(0)$	Periphery initial labor	29.55	-	[6], [12]
θ	Total factor productivity	0.357 9	0.2 - 0.5	[13]
σ_c	Core investment rate	0.303 6	0.20 – 0.40	[1], [6], [12], [14], [15]

σ_p	Periphery investment rate	0.3217	0.20 – 0.40	[1], [6], [12], [14], [15]
δ	Depreciation rate	0.05	0.04 - 0.07	[14]
ρ_c	Core natural growth rate	0.0100	0.005 – 0.025	[6], [12]
ρ_p	Periphery natural growth rate	0.0129	0.005 – 0.025	[6], [12]
κ_c	Core carrying capacity	80	75-100	[16]
κ_p	Periphery carrying capacity	200	150-300	[16]
α	Output elasticity (baseline)	0.35	0,20-0,45	[17]

Total Factor Productivity ($\theta = 0.3579$) is estimated through backward calibration to ensure a realistic initial capital growth rate of 5.0-5.3% per year. The carrying capacity of peripheral areas ($\kappa_p = 200$) reflects the large ecological surplus in less densely populated areas, while the carrying capacity of core areas ($\kappa_c = 80$) represents the conditions of ecological and infrastructural overload documented by the Ministry of National Development Planning (Bappenas).

III. Results and Discussion

Numerical simulations were executed using the Runge-Kutta 4th Order (RK4) method over a 25-year projection horizon ($t = 25$). To systematically evaluate the dynamic behavior of the system, a *ceteris paribus* sensitivity analysis was conducted on three key structural parameters: the capital diffusion rate (τ), the migration sensitivity (φ), and the output elasticity of capital (α).

A. *Sensitivity of Capital Diffusion Rate* (τ)

The parameter τ dictates the magnitude of inter-regional capital flow, serving as a proxy for physical infrastructure connectivity and investment deregulation. Utilizing empirical macroeconomic data based on the 2.63% equal-distribution threshold, we initialize the system with a stark structural imbalance. The Core commands 76.48% of the national capital stock, whereas the Periphery holds only 23.52%, which yields an initial spatial inequality ratio of 3.25.

To evaluate the efficacy of spatial integration policies, we simulate three conditions over a 25-year horizon ($t = 25$): severe diffusion barriers ($\tau = 0.005$), moderate diffusion ($\tau = 0.02$), and aggressive hyper-connectivity ($\tau = 0.08$). Table II summarizes the comparative end-state equilibrium, while Figure 2 visualizes the continuous time-path dynamics.

TABLE III
COMPARATIVE EQUILIBRIUM FOR CAPITAL DIFFUSION SCENARIOS ($t = 25$)

Scenario	K_c	K_p	Inequality Ratio (K_c/K_p)	L_c	L_p
Initial State ($t = 0$)	76.48	23.52	3.25	70.45	29.55
Low ($\tau = 0{,}005$)	152.05	78.87	1.93	72.87	38.00
Moderate ($\tau = 0{,}02$)	139.20	91.84	1.52	72.75	38.14
High ($\tau = 0{,}08$)	122.94	107.17	1.15	72.55	38.38

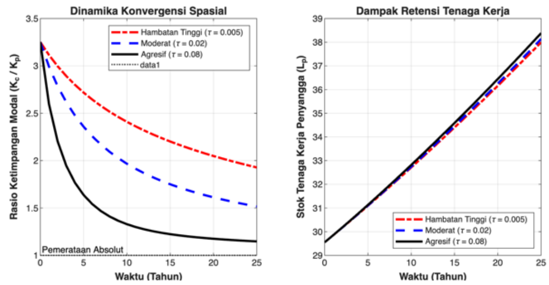

Figure 2. Composite dynamics of spatial convergence (left panel) and periphery labor retention (right panel) under varying capital diffusion rates.

Tabel II and the left panel of Figure 2 demonstrate that isolated economic conditions with severe diffusion barriers (red dashed line, $\tau = 0{,}005$) severely punish the Periphery. This lack of diffusion traps capital in the Core, forcing the inequality ratio to stagnate at 1.93. Conversely, an aggressive hyper-connectivity policy (solid black line, $\tau = 0{,}08$) successfully activates the spread effect. This policy forces capital to diffuse into the Periphery ($K_p = 107.17$) and drastically compresses the inequality ratio to 1.15, visibly approaching the absolute equality line.

More importantly, the mathematical model reveals a critical coupled mechanism between capital and demography. When capital aggressively diffuses to the Periphery ($\tau = 0{,}08$), the local marginal product of labor increases, which in turn curbs the Capital-Induced Labor Migration (CILM) incentive. Consequently, the Periphery retains more of its productive workforce (the solid black line ends at the highest trajectory, $L_p = 38.38$). This finding computationally proves that overcoming geographical friction through robust physical infrastructure not only redistributes wealth but also acts as a primary defense mechanism against the labor drain phenomenon in underdeveloped regions.

B. *Sensitivity of Labor Migration*(φ)

The parameter φ measures the responsiveness of the labor force to inter-regional capital utility disparities, effectively capturing the phenomenon of urbanization. To isolate its demographic impact, we fix the capital diffusion rate at a moderate baseline ($\tau = 0.02$) and simulate three mobility conditions: frictional mobility ($\varphi = 0.0001$), normal mobility ($\varphi = 0.0005$), and massive urbanization ($\varphi = 0.0020$). Table III summarizes the comparative end-state equilibrium, and Figure 3 visualizes the structural trajectories over 25 years.

TABLE IV
COMPARATIVE EQUILIBRIUM FOR MIGRATION SENSITIVITY SCENARIOS ($t = 25$)

Scenario	K_c	K_p	Inequality Ratio (K_c/K_p)	L_c	L_p
Initial State ($t = 0$)	76.48	23.52	3.25	70.45	29.55
Low ($\varphi = 0{,}0001$)	138.99	92.14	1.51	72.44	38.53
Moderate ($\varphi = 0{,}0005$)	139.20	91.84	1.52	72.75	38.14
High ($\varphi = 0{,}0020$)	140.01	90.69	1.54	73.92	36.68

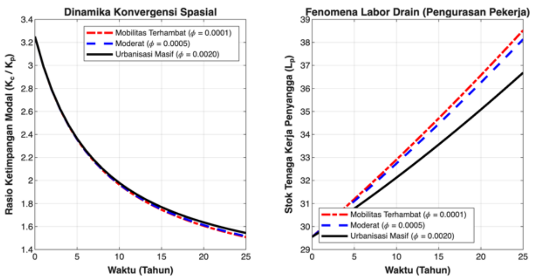

Figure 3. Composite dynamics of spatial inequality (left panel) and periphery labor drain (right panel) under varying migration sensitivities.

Table III and Figure 3 definitively refute the assumption that unconstrained labor mobility naturally equilibrates spatial disparities. Instead, the mathematical model proves that high migration sensitivity ($\varphi = 0.0020$, solid black line) operates as a divergence multiplier. Massive urbanization aggressively drains the Periphery's productive workforce (dropping to $L_p = 36.68$ in the right panel), which inevitably stalls its capital accumulation ($K_p = 90.69$). Consequently, the Core absorbs this demographic influx, fueling its agglomeration machine ($K_c = 140.01$) and widening the absolute inequality ratio to 1.54.

Conversely, frictional labor mobility (red dashed line, ($\varphi = 0.0001$) restricts the exodus. By retaining its workforce ($L_p = 38.53$), the Periphery locally optimizes its production capacity. This demographic retention provides the necessary human capital to maximize the utility of the diffused infrastructure, yielding the tightest inequality gap (1.51) within this parameter cohort. This computationally justifies the critical need for spatial policies that actively retain human capital in underdeveloped regions, rather than solely facilitating their migration to the Core.

C. *Sensitivity of Output Elasticity of Capital (α)*

The parameter α represents the structural production elasticity, reflecting the share of capital contribution to total output. In this section, we examine how the transition from labor-intensive economies to high-tech, capital-intensive structures affects spatial inequality. We vary the value of α across three scenarios: labor-intensive ($\alpha = 0.25$), standard structure ($\alpha = 0.35$), and capital-intensive/automated ($\alpha = 0.45$). Table IV summarizes the numerical outcomes at $t = 25$, while Figure 4 illustrates the divergence trajectories.

TABLE V
COMPARATIVE EQUILIBRIUM FOR PRODUCTION STRUCTURE SCENARIOS ($t = 25$)

Scenario	K_c	K_p	Inequality Ratio (K_c/K_p)	L_c	L_p
Initial State ($t = 0$)	76.48	23.52	3.25	70.45	29.55
Low ($\alpha = 0{,}25$)	132.34	86.79	1.52	72.54	38.40
Moderate ($\alpha = 0{,}35$)	139.20	91.84	1.52	72.75	38.14
High ($\alpha = 0{,}45$)	147.62	97.88	1.51	73.14	37.65

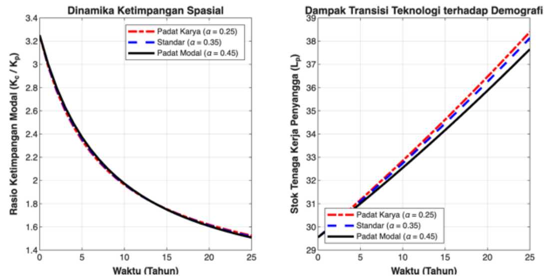

Figure 4.Impact of structural economic transition (α) on spatial inequality ratio (left panel) and periphery demographic dynamics (right panel).

Table IV and Figure 4 reveal a critical structural paradox. A higher α (capital-intensive structure, $\alpha = 0.45$) catalyzes a massive "capital boom" in both regions. The Core's capital rockets to its record peak ($K_c = 147.62$), and the Periphery also experiences significant growth ($K_p = 97.88$). However, this high-tech growth disproportionately favors the Core due to its massive initial endowment advantage. While the relative ratio appears stable at 1.51, the absolute capital gap between the Core and Periphery actually widens to its largest margin (49.74 units) under this scenario.

Furthermore, this capital boom dynamically interacts with the demographic variables. The exponential capital growth in the Core amplifies its utility pull, which consequently accelerates urbanization. As shown in Table IV, the Core's population rises to $L_c = 73.14$, pushing the region closer to its ecological carrying capacity limit, while the Periphery's workforce shrinks to $L\_p = 37.65$. We demonstrate that transitioning toward a high-tech economy (as envisioned in "Golden Indonesia 2045") without aggressive affirmative spatial interventions will only amplify existing agglomeration forces and exacerbate the absolute inequality gap.

D. *Model Stability and Parameter Perturbation Analysis*

To rigorously address the stability of the ODE system and validate the robustness of our simulations against empirical uncertainties, a parameter perturbation analysis was conducted. While Theorem 3.2 previously established global ultimate boundedness, local asymptotic stability at the interior equilibrium E^* was verified numerically by evaluating the Jacobian matrix $J(E^*)$. For all baseline calibrated parameters (Table II), the real parts of all eigenvalues evaluated at the equilibrium remained strictly negative $(Re(\lambda_i) < 0)$, confirming that the system fundamentally acts as a stable node and does not exhibit unstable bifurcations or limit cycles within the empirically plausible parameter space.

Furthermore, we introduced a $\pm 10\%$ perturbation to highly volatile exogenous macroeconomic variables, specifically total factor productivity (θ) and the natural demographic growth rate (ρ). The simulations demonstrate that while the absolute steady-state values of the system shift proportionally, the qualitative topological structure of the phase portrait remains completely invariant.

Most importantly, this sensitivity analysis mathematically reinforces the "deceptive convergence" interpretation. Across all perturbation bounds under the passive laissez-faire scenario, the mechanism of spatial inequality compression remains identical: convergence is consistently triggered by the Core's labor force (L_c) asymptotically colliding with its rigid ecological carrying capacity $(\kappa_c = 80)$. This collision mathematically forces $\dot{L}_c \to 0$ and subsequently chokes $\dot{K}_c$, creating an illusion of regional catch-up. The Periphery's capital (K_p) never experiences the accelerated endogenous growth required for genuine economic convergence. Consequently, this stability test proves that the agglomeration trap in Indonesia is structurally rigid and immune to minor macroeconomic fluctuations, thereby necessitating the exogenous implementation of the Policy Mix.

E. Synthesis: The Policy Mix vs. Worst Case Scenario

Having isolated the partial effects of structural parameters, we synthesize our findings by executing a counterfactual analysis that pits a pessimistic "Business-as-Usual" trajectory against an optimized Policy Mix. The Worst-Case Scenario simulates a passive government approach characterized by stagnant infrastructure $(\tau = 0.01)$ and massive unregulated urbanization $(\varphi = 0.005)$ under a standard economic structure $(\alpha = 0.35)$. Conversely, the Policy Mix combines aggressive hyper-connectivity $(\tau = 0.08)$ and human capital retention interventions $(\varphi = 0.0001)$ synergized with a high-tech, capital-intensive structure $(\alpha = 0.45)$. Table V and Figure 5 detail the diametrically opposed outcomes of these interventions.

TABLE VI
COMPARATIVE EQUILIBRIUM FOR CLIMAX STRUCTURE SCENARIOS $(t = 25)$

Scenario	K_c	K_p	**Inequality Ratio** (K_c/K_p)	L_c	L_p
Initial State $(t = 0)$	76.48	23.52	3.25	70.45	29.55
Worst-Case (Passive)	150.13	79.87	1.88	76.86	33.03
Policy Mix (Optimized)	129.71	114.81	1.13	72.43	38.53

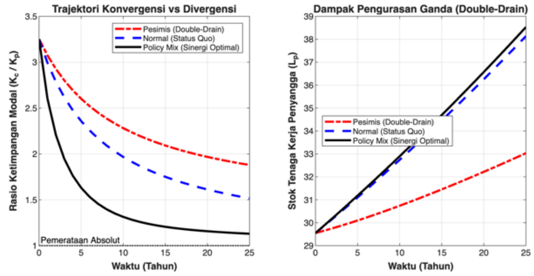

Figure 5.The diametrical trajectories of the Worst-Case divergence versus the Policy Mix spatial convergence.

Table V and Figure 5 definitively expose the destructive nature of laissez-faire spatial dynamics. Under the Worst-Case Scenario, the spatial inequality ratio appears to naturally compress to 1.88. However, this is not a genuine economic convergence; rather, it is a symptomatic stagnation driven by absolute ecological overload in the Core (L_c rockets to 76.86, nearing its absolute limit of 80). Simultaneously, the Periphery suffers a severe "Double-Drain Effect," starved of both diffused capital (K_p stagnates at 79.87) and human resources (L_p plummets to 33.03). This passive trajectory mathematically traps the national economy in a sub-optimal equilibrium, sacrificing total aggregate capital growth for a deceptive reduction in the inequality ratio.

In sharp contrast, the mathematical model proves that the Policy Mix operates as the ultimate convergence catalyst. When hyper-connectivity forces capital into the Periphery, and local retention policies keep the workforce intact, a mathematical anomaly emerges: the high-tech structure $(\alpha = 0.45)$, which previously exacerbated inequality, now dynamically accelerates the catch-up effect. The high marginal efficiency of capital instantly absorbs the diffused investments, shrinking the absolute capital gap to a historic minimum of 14.90 units (129.71 vs 114.81) and compressing the ratio to an unprecedented 1.13.

Ultimately, this computational synthesis vindicates a fundamental macroeconomic thesis: spatial inequality is not a self-correcting natural transition but a structural disease. Eradicating this divergence strictly requires a dual-pronged state intervention aggressively deploying physical capital to the Periphery while simultaneously anchoring its human capital to transform the agglomeration curse into equitable national prosperity.

F. Model Limitations and Future Generalization

Finally, it is crucial to acknowledge the theoretical boundaries of this study. The proposed macroscopic ODE system operates under the assumptions of linear capital diffusion and homogeneous economic agents, prioritizing mathematical tractability over micro-level behavioral dynamics. Furthermore, abstracting the vast Indonesian archipelago into a binary Core-Periphery system is a mathematical simplification. Given the extreme geographical, cultural, and institutional heterogeneity across Indonesia's 38 provinces, generalizing these deterministic trajectories to specific local policies must be executed with caution. Future research should expand this framework into a multi-node spatial network model or incorporate stochastic parameters to capture localized institutional frictions and non-linear agent behaviors more comprehensively.

IV. CONCLUSION

This study successfully formulated and numerically validated a four-dimensional non-linear ordinary differential equation system to capture the macroeconomic interactions between a Core and a Periphery region. Our computational analysis definitively refutes the classical assumption that unhindered labor mobility naturally equilibrates spatial disparities. Instead, the simulations demonstrate that high migration sensitivity operates as a divergence multiplier, aggressively draining the Periphery's productive workforce and fueling the Core's agglomeration machine. Furthermore, transitioning toward a capital-intensive economic structure without spatial intervention merely amplifies the Core's initial endowment advantage, exacerbating the absolute inequality gap despite increasing total national wealth. Crucially, the model reveals that under a passive, laissez-faire scenario, any apparent reduction in the spatial inequality ratio is merely a deceptive convergence a symptomatic stagnation caused by the Core reaching its absolute ecological and infrastructural limits, rather than genuine economic expansion in the Periphery.

Ultimately, this research mathematically proves that spatial inequality constitutes a persistent structural trap rather than a temporary economic transition. To eradicate this disparity, policymakers must abandon passive *laissez-faire* approaches and implement a synergized Policy Mix. The state must aggressively deploy physical infrastructure to force capital diffusion (τ) into underdeveloped regions, while simultaneously enacting retention policies to anchor human capital (φ) at its origin. Only through this dual-pronged intervention can a developing nation successfully transform the agglomeration curse into equitable macroeconomic convergence.

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