

From Limited to Open Access Orders: An Evolutionary Game Theory Approach and a Case Study of South Korea

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Title
**From Limited to Open Access Orders: An Evolutionary Game Theory
Approach and a Case Study of South Korea**

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Abstract

While the framework of Limited and Open Access Orders (North et al., 2009) offers profound historical and conceptual insights into social orders, the mechanisms governing institutional transitions remain largely descriptive. This paper formalizes the transition from Limited Access Orders (LAOs) to Open Access Orders (OAOs) by embedding elite bargaining and citizen pressures into an evolutionary game-theoretic model governed by replicator dynamics. We formalize North et al.'s three “doorstep conditions”—rule of law for elites, perpetually-lived organizations, and consolidated control of violence—as endogenous threshold parameters that alter the payoffs of institutional strategies. The model exhibits bistable dynamics, revealing that sustained transitions require the simultaneous satisfaction of these threshold conditions; partial or asymmetric institutional reforms render societies vulnerable to elite rent-seeking traps or institutional reversals. To test the empirical relevance of the model, we calibrate its dynamic parameters (θ , λ , ω) using historical and institutional data from South Korea's transition (1987), drawing on V-Dem, Polity, and Worldwide Governance Indicators. The empirical calibration demonstrates that structural parameters—specifically organizational durability and critical mass thresholds—predominate over adaptive learning rates in driving self-enforcing constitutional order. By bridging evolutionary economics with the systematic analysis of fundamental legal and political institutions, this study offers a formal explanatory framework for understanding the mechanics of institutional transition.

Keywords: Institutional Transition; Limited Access Orders; Open Access Orders; Evolutionary Game Theory; Political Economy.

JEL Codes: C73, D02, D72

Introduction

New Institutional Economics has fundamentally transformed our understanding of economic development by placing institutions at the center of analysis (Peters, 2019). (North, 1990, p. 3) conceptualizes institutions as "the rules of the game in a society," encompassing both formal rules such as laws and regulations, and informal constraints including customs, norms, and cultural beliefs that structure human interactions (Mantzavinos et al., 2004). Crucially, North emphasized that institutions function not necessarily to promote efficiency but rather to provide relatively stable structures that reduce uncertainty in human interactions (North, 2005).

Building upon this institutional foundation, North, Wallis, and Weingast¹ (2009) developed a comprehensive framework distinguishing between Limited Access Orders (LAOs) where elite coalitions monopolize privileges and Open Access Orders (OAOs) characterized by impersonal institutions providing broad access to organizations and markets. While historically rare, LAO-to-OAO transitions represent critical development transformations. Despite their importance, existing research on institutional transitions suffers from a critical gap: the lack of dynamic, behaviorally grounded models capturing how elite strategies and informal norms co-evolve to shift institutional equilibria. Current LAO/OAO studies remain predominantly descriptive, rarely incorporating mathematical modeling to explain transitions, severely constraining our understanding of underlying change mechanisms.

This study addresses the fundamental question: under what conditions and through what mechanisms do limited access orders transition to open access orders? We develop an evolutionary game-theoretic model capturing strategic interactions among competing elite groups and examining how intra-elite dynamics affect LAO stability and facilitate institutional transformation (North et al., 2013). Our approach employs replicator dynamics to model strategic interactions among elite factions, while citizen pressures shape the broader institutional environment across NWW's two-stage transition process.

The model incorporates political competition intensity, elite rights conformity, and organizational stability, calibrated against empirical data from South Korea, one of the countries in *In the Shadow of Violence* (North et al., 2013). Our results demonstrate that transitions occur through evolutionary dynamics requiring simultaneous achievement of three doorstep conditions: rule of law for elites, perpetually-lived organizations, and consolidated violence control. This research contributes threefold: providing This study develops a formal evolutionary game-theoretic framework for analyzing LAO-to-OAO transitions, and offering empirically calibrated explanation for policy design in developing countries. The findings guide development agencies and policymakers while highlighting those reversals remain possible where rents and institutional power stay concentrated (Haggard & Kaufman, 2021).

¹ Throughout the paper, NWW is used as an abbreviation for North, Wallis, and Weingast.

Literature Review

The emergence of New Institutional Economics (NIE) challenged the limitations of neoclassical models by placing institutions at the core of economic analysis. Early institutionalists emphasized collective action and evolutionary dynamics (Hodgson, 2004), while modern theorists such as Douglass North, Elinor Ostrom, and Oliver Williamson integrated institutional analysis with neoclassical tools, maintaining attention to historical and cultural contexts (D. North, 1995; Peters, 2019; Williamson, 2000). This synthesis provided a more nuanced understanding of how institutions shape economic performance across different societies. (Greif, 2006) views institutions as interlinked formal and informal elements—rules, norms, beliefs, and organizations—that generate behavioral regularities and persist through shared beliefs and incentive alignment. Acemoglu and Robinson (2014) distinguish between inclusive and extractive institutions, aligning broadly with North, Wallis, and Weingast's (2009) typology of limited and open access orders while emphasizing distributional consequences and critical junctures. These frameworks share a common emphasis on the role of elites and coalitions in shaping institutional trajectories.

These institutional frameworks have been applied across diverse historical and regional contexts. Notable studies include (Grimmer-Solem, 2015) on Imperial Germany, (Reckendrees, 2015) on the Weimar Republic, and (Bureika, 2024) on late-medieval Lithuania. Contemporary research focuses on post-communist transitions (Toshkov et al., 2021) and trade liberalization in post-Soviet states (Langbein et al., 2021). While empirically rich, many of these studies remain descriptively oriented, lacking formal models of institutional change that can identify causal mechanisms and threshold effects. Game theory has increasingly been integrated into institutional analysis to address this gap. Evolutionary game-theoretic models have been used to show how feedback effects and hysteresis shape transitions between institutional regimes, illustrating the value of dynamic, non-linear modeling for path-dependent institutional trajectories. Related contributions include (Kingston & Caballero, 2009), (Binmore, 2010), (Vega-Redondo, 1993), (Gareev & Eliseeva, 2020), and (Greif & Laitin, 2004). These works collectively demonstrate the analytical power of game-theoretic approaches for understanding institutional persistence and change.

Despite these advances, the formal modeling of transitions between North et al.'s social orders remains underdeveloped. Descriptive studies (Franke & Quintyn, 2014; Murphy, 2023) test these ideas empirically but fall short of capturing the evolutionary logic behind institutional transformation. This gap is critical, as (Bisin & Verdier, 2021) highlight the importance of non-linear feedback, multiple equilibria, and threshold effects in institutional dynamics. Without formal models to capture such complexity, our understanding of the transition process remains fragmented. This study seeks to bridge this gap by proposing a formal evolutionary game-theoretic model of LAO-to-OAO transitions, calibrated to the South Korean case. Our approach offers a novel way to quantify the non-linear, path-dependent nature of institutional change by embedding North's doorstep conditions within a replicator dynamic setting.

Theoretical Framework

This section establishes the conceptual foundations for the evolutionary game-theoretic model. First, it defines institutions and their role in development. Second, it presents the LAO/OAO distinction. Third, it explains mechanisms of LAO stability and finally, introduces the doorstep conditions and their formal representation in the model.

Definition of Institutions and Their Importance in Development

Institutions constitute the foundational framework for economic development. (North, 1991, p. 97) defines institutions as "humanly devised constraints that structure political, economic, and social interaction," encompassing formal rules (constitutions, laws, property rights) and informal constraints (norms, customs, traditions) that reduce uncertainty by shaping human behavior (Mantzavinos et al., 2004; North, 1990, p. 3). This definition underscores the dual nature of institutions: they are both externally imposed rules and internally evolved norms that jointly structure social interaction.

(North, 1990, p. 4) distinguishes institutions as "the rules of the game" from organizations as "players," with institutional quality conditioning economic performance. Under conditions of incomplete information, transaction costs, and bounded rationality (departing from neoclassical assumptions) institutions facilitate cooperation and enable the realization of gains from trade (North, 1990, pp. 17–23; 1991, p. 98). This perspective shifts analytical focus from pure market exchange to the underlying institutional infrastructure that makes exchange possible.

Institutions provide the economy's "incentive structure," directing societal evolution toward growth, stagnation, or decline (North, 1991, p. 98; 2005). Beyond allocative efficiency, North emphasizes adaptive efficiency society's capacity to modify its institutional matrix in response to shocks (North, 1990, pp. 80–81; 2005, p. 160). Successful development requires institutions supporting market exchange, innovation, and social cohesion, as weak frameworks generate uncertainty, high transaction costs, and unstable performance.

Limited and Open Access Orders (LAO/OAO)

North and his collaborators offer a powerful institutional framework for understanding the persistent differences in political and economic development among societies what they term social orders. Their key distinction lies between Limited Access Orders (LAOs) and Open Access Orders (OAOs) (North et al., 2009). This distinction provides a unified analytical lens for examining both historical and contemporary development trajectories. LAOs, which have characterized the majority of human history, stabilize societies by restricting access to valuable resources, organizations, and activities (North et al., 2009, pp. 18–23). Political and economic privileges, as well as violence, are controlled through personal relationships among a dominant coalition of elites. By limiting access, elites generate rents for themselves, which in turn incentivizes their cooperation and reduces the risk of violence (North et al., 2009; Wallis, 2016). This rent-creation mechanism is central to understanding both the stability and the developmental limitations of LAOs.

Mechanisms of Stability in LAOs

LAO stability rests on four mechanisms: violence control, rent creation, restricted organizational access, and personalized relationships. These elements jointly sustain a political-economic equilibrium by enabling elite coalitions to manage conflict, distribute privileges, and constrain institutional development to preserve their dominance. Violence is not suppressed by impersonal legal systems but managed through elite coordination. Potentially violent actors are incorporated into ruling coalitions through negotiated access to power and resources, reducing incentives for conflict. Rent creation is central to this process: by allocating monopolies, privileges, and lucrative positions, elites secure loyalty and deter rebellion. Rents function both

as rewards and as tools for managing internal competition, reinforcing elite cohesion. Access to organizations is tightly controlled. Only actors aligned with elite interests can legally establish organizations, thus preventing institutional challenges and insulating the status quo from disruptive innovation (North et al., 2013). Finally, interactions in LAOs are governed by personalized ties -patronage, kinship, and direct negotiation - rather than universal rules. As North, Wallis, and Weingast (2009) note, such personalized exchanges strengthen elite control and inhibit the development of inclusive, rule-based institutions.

Transition and the “Doorstep Conditions”

The transition from LAOs to OAOs is challenging, nonlinear, and occurs rarely in history. North and colleagues identify three "doorstep conditions" that must be satisfied for a society to move from a natural state (LAO) to the doorstep of open access:

1. Rule of Law for Elites: Legal rights and restraints are systematically applied at least among elites, establishing predictable interactions and limiting arbitrary power.
2. Perpetually-Lived Organizations: The emergence of organizations that exist independently of individuals (such as joint-stock companies, political parties, or professional guilds) demonstrates that impersonal institutional life is possible.
3. Consolidated Monopoly on Violence: Effective control over the means of violence ensures that transitions of power occur peacefully and that the social order is stable (North et al., 2009, pp. 36–41).

Only when these conditions are met can the process of opening access to organizations, economic activity, and politics begin. Even then, movement toward open access is gradual, fragile, and contingent on sustaining these supporting institutions. This framework helps explain why some societies move toward inclusive institutions while others remain trapped in elite-dominated equilibria (see also Faundez, 2016). Understanding the nature of LAOs and OAOs, and the role of "doorstep conditions," sheds light on the barriers to development and institution-building in diverse contexts. Its focus on incentives, organizations, and violence relates directly to development policy and institutional reform. In the model developed below, these doorstep conditions are formalized as threshold parameters: rule of law for elites corresponds to the critical mass threshold.

Methodology

This section presents the methodological framework employed to model institutional transitions from limited access orders (LAOs) to open access orders (OAOs). We first develop the evolutionary game-theoretic model, detailing its mathematical specification. Next, we describe the empirical calibration strategy utilizing South Korean historical data. Following this, the analysis outlines our procedures for sensitivity testing and model validation, before concluding with a discussion of the study’s limitations and potential directions for future extensions.

By combining theoretical rigor, data-driven calibration, and robustness checks (Saltelli et al., 2007), our integrated theoretical–empirical framework meets contemporary standards for reproducibility and policy relevance (Bowles & Gintis, 2008). This integrated approach grounds the theoretical framework in empirical reality, rigorously tests model sensitivity, and contributes both to theory-building and to the practical understanding of institutional change.

Evolutionary game theoretic model

Institutional transitions from LAOs to OAOs involve strategic adaptation among elites under bounded rationality and incomplete information. Evolutionary game theory, especially through replicator dynamics, offers a powerful tool to model these adaptive processes, moving beyond static equilibrium frameworks (Elsner et al., 2015; Hofbauer & Sigmund, 1998; Nowak, 2006). This model is used because the LAO-OAO transition involves gradual change punctuated by threshold-driven shifts, multiple equilibria, and empirically calibratable dynamics. A nonlinear replicator model with tipping points offers the optimal balance of theoretical fidelity, analytical tractability, and compatibility with historical institutional data (Cressman & Tao, 2014; Friedman & Sinervo, 2016).

In this framework, LAOs represent dynamic equilibria maintained by elite coalitions via rent sharing and selective cooperation. However, changes in payoff structures due to shocks, innovation, or political shifts can disrupt this balance and trigger transitions toward OAOs (Aoki, 2010; North et al., 2009). By embedding North's "doorstep conditions" into evolutionary fitness functions, the model transforms qualitative institutional dynamics into a formal structure. This allows for identifying tipping points, hysteresis, and transition probabilities, contributing to the growing literature on complex systems and computational political economy (Elsner et al., 2015; Hofbauer & Sigmund, 1998; Nowak, 2006).

Mathematical Specification

Let $x \in [0,1]$ denote the share of cooperators; higher convergence with impersonal rules enhances organizational durability and accelerates transitions. In this model, cooperation entails supporting the transition from LAO to OAO, bearing political, economic, and social costs of abandoning personalized privileges (North et al., 2006; North et al., 2009). The effective cost of C declines over time: initially high due to lost rents, decreasing as cooperation spreads, and potentially negative in late stages when defection becomes risky. For tractability, the cost is modeled linearly; an alternative exponential specification confirms robustness, producing only minor quantitative differences (see Appendix 1). For cooperators:

$$f_c(x) = \begin{cases} r_c \cdot x^{1+\alpha} - c_c + \theta, & \text{if } x \geq \theta \\ r_c \cdot x^{1+\alpha} - c_c \cdot \left(1 - \frac{\theta}{x}\right), & \text{if } x < \theta \end{cases} \quad (1)$$

Where $r_c > 0$ is the baseline reward from cooperation (e.g., sustained economic returns under open-access orders), $\alpha > 0$ captures increasing marginal returns to cooperation², $c_c > 0$ is the cost of abandoning rents, and $\theta \in (0,1)$ represents an institutional tipping point - the minimum critical mass required for full institutional benefits to materialize. The threshold θ is not set exogenously but is determined endogenously by the condition $f_c(\theta) = f_d(\theta)$, where the payoff functions f_c and f_d are themselves parameterized by α and β respectively.

For defectors:

² In this paper, the parameter α is sometimes referred to as "strategic complementarity" (due to its mathematical property in generating strategic complementarities) and sometimes as "perpetually-lived organizations" (due to the institutional concept it represents). These two terms capture two different aspects of a single mechanism: the technical mathematical aspect and the economic-institutional aspect.

$$f_D(x) = r_D \cdot (1 - x)^{1+\beta} - C_D \quad (2)$$

These nonlinear forms, incorporating exponents α and β and threshold θ , follow the logic in Bowles and Gintis (2008), (Hofbauer & Sigmund, 2003), and (Arthur, 1994), capturing the path dependence and multiple equilibria typically observed in institutional transformation processes.

The population average fitness is given by:

$$\bar{f}(x) = x \cdot f_C(x) + (1 - x) \cdot f_D(x) \quad (3)$$

The temporal evolution of the share of cooperators follows the standard single-population replicator dynamics with an explicit learning parameter $\lambda > 0$:

$$\dot{x} = \frac{dx}{dt} = \lambda x [f_C(x) - \bar{f}(x)] = \lambda x(1 - x)[f_C(x) - f_D(x)]^3 \quad (4)$$

Under this mechanism, the share of cooperators increases whenever $f_C(x) > f_D(x)$ and decreases otherwise. Equilibria are identified by solving $\frac{dx}{dt} = 0$. Three potential equilibrium states exist:

LAO Equilibrium ($x^* = 0$): All elites defect - stable when $f_C(0) < f_D(0)$

OAQ Equilibrium ($x^* = 1$): All elites cooperate - stable when $f_C(1) > f_D(1)$

Interior Equilibrium ($x^* \in (0,1)$): Mixed strategies where $f_C(x^*) = f_D(x^*)$

Multiple intermediate equilibria are possible due to the nonlinear payoff functions. An equilibrium x^* is locally asymptotically stable if the Jacobian derivative of the system is strictly negative, i.e., $J(x^*) = (d\dot{x}/dx) |_{x=x^*} < 0$. Formally:

$$\text{LAO Stability } (x^* = 0): J(0) = \lambda [f_C(0) - f_D(0)] < 0 \Leftrightarrow f_C(0) < f_D(0) \quad (5)$$

$$\text{OAQ Stability } (x^* = 1): J(1) = -\lambda [f_C(1) - f_D(1)] < 0 \Leftrightarrow f_C(1) > f_D(1) \quad (6)$$

Interior Equilibrium ($x^* \in (0,1)$): Represents an unstable tipping point when $\frac{d}{dx}[f_C(x) - f_D(x)]|_{x=x^*} > 0$, delineating the basins of attraction between the two orders.

Bifurcation: When external shocks E cross a critical threshold E^* , the LAO equilibrium loses its local asymptotic stability with respect to interior perturbations. While $x^* = 0$ remains a stationary point due to boundary invariance, the system becomes sensitive to any positive influx of cooperation ($x > 0$), triggering a potential jump to $x^* \geq \theta$ and institutional tipping. This mathematical specification provides the analytical framework for examining how changes in political competition, organizational durability, and learning rates influence the probability and timing of institutional transitions from limited to open access orders. To capture more nuanced aspects of institutional evolution, we extend the baseline model by incorporating learning inertia, organizational durability, external shocks, and trust levels:

Learning Rate ($\lambda > 0$): Incorporate bounded rationality by modulating strategy adaptation:

$$\dot{x} = \lambda x (1 - x) [f_C(x) - \bar{f}(x)] \quad (7)$$

³ Note that, consistent with standard continuous-time replicator dynamics (Taylor & Jonker, 1978; Hofbauer & Sigmund, 1998), the boundaries $x = 0$ and $x = 1$ are forward-invariant; cooperation cannot emerge from absolute zero. Consequently, our analysis assumes an initial seed of cooperators ($0 < x_0 < 1$), conceptualizing the pre-transition state as a regime trapped in the LAO basin rather than an absolute absence of cooperation.

Higher values correspond to faster adaptation, potentially driven by dense information channels or rapid feedback loops.

Organizational Durability ($\omega \geq 0$): Capturing institutional inertia through decay in responsiveness:

$$\dot{x} = \lambda x (1 - x) [f_C(x) - (x)] \cdot e^{-\omega x} \quad (8)$$

Large ω values imply that entrenched institutional frameworks slow transitions until the tipping point θ is crossed. The factor $e^{-\omega x}$ captures institutional inertia through a velocity-scaling effect: because $e^{-\omega x} > 0$ for all $x \in [0,1]$, it preserves the stationary points and the payoff-driven threshold θ while scaling the speed of adaptation. Larger values of ω dampen trajectory velocity, prolonging the time required for positive shocks to push the system past the tipping point θ and reflecting the friction exerted by entrenched organizational structures.

External Pressure (E): Representing exogenous shocks such as sanctions or large-scale mobilizations,

$$(x) \rightarrow f(x) + E \cdot (1 - x), f_D(x) \rightarrow f_D(x) - E \cdot x \quad (9)$$

This mechanism increases the relative return to cooperation and raises the cost of defection as the legitimacy of rent-based strategies erodes.

Trust Level (τ): Normalize payoffs by trust in institutional durability:

$$f_C(x) \rightarrow f_C(x) \cdot (1 + \tau \omega x) \quad (10)$$

Where high τ indicates that cooperative elites believe new institutions will persist, reinforcing the payoff to cooperation as cooperation spreads.

Structurally, this theoretical framework maps directly onto NWW’s three doorstep conditions: **(1)** Consolidated Control of Violence is formalized through the defection payoff structure $f_D(x)$ and the external pressure parameter E . As the state consolidates control over organized violence, elite capacity to deploy private coercion is constrained, effectively penalizing defection and stabilizing the cooperative payoff baseline. **(2)** Perpetually-Lived Organizations are operationalized through the organizational durability and inertia parameter ω alongside the trust horizon τ . Institutional durability ensures that elite commitments survive leadership turnover rather than remaining bound to transient personalistic coalitions. **(3)** Rule of Law for Elites is embedded in the critical tipping threshold θ . Crossing this threshold marks the point where impersonal, rule-bound commitments among elites become self-enforcing.

Empirical Calibration

To ground our theoretical model in reality, we conduct empirical calibration using South Korea that exemplify both LAOs, mutual, and OAOs. We draw institutional indicators from Polity IV (*Marshall et al, 2018*), the World Bank’s Worldwide Governance Indicators (Kaufmann et al., 2011), and Varieties of Democracy (Coppedge et al., 2020), while micro-level evidence on elite maneuvering and “doorstep conditions” comes from North et al. (2013). These indicators capture key dimensions of elite cooperation, organizational durability, and legal formalism, aligning with the theoretical assumptions of our model.

South Korea provides a canonical example of a successful transition from a LAO to an OAO during 1980–2020 (You, 2012). The post-authoritarian reform path initiated by the 1987

democratic transition was negotiated by a compact elite coalition of political leaders, chaebol executives, and senior military–bureaucratic elites (Choi et al., 2014). Because the theoretical doorstep conditions and elite behavioral dynamics in North et al. (2009) represent unobservable latent structural constructs, the empirical analysis relies on four operational institutional proxies: (1) the Elite Strategy Share (x_t), empirically proxied by V-Dem’s Electoral Fairness index ($v2xel_frefair$) which captures the shift toward non-violent, rule-bound elite competition (Slater, 2010); (2) organizational durability and civil society autonomy, proxied by V-Dem’s thick associational autonomy ($v2x_frassoc_thick$); (3) macro-political regime transition, proxied by Polity2; and (4) formal legal predictability, proxied via the World Bank’s WGI Rule of Law indicator for post-transition institutional consolidation.

To rigorously quantify the adaptive dynamics of elites during Korea’s institutional transition, we specify an evolutionary game-theoretic model based on the following generalized replicator equation (Friedman, 1991; Taylor & Jonker, 1978):

$$\frac{dx}{dt} = \lambda x(1 - x)[f_C(x) - f_D(x)]e^{-\omega x} \quad (11)$$

Where: x is share of elites choosing the OAO-supporting strategy, λ is learning rate (parameter to be calibrated), ω is organizational durability (parameter to be calibrated), and $f_C(x)$, $f_D(x)$ are payoffs for each strategy, based on empirical model assumptions. Payoff functions are parameterized following established formulations linking fitness landscapes to equilibrium dynamics (Friedman, 1991). The calibration involves adjusting λ and ω to fit the model to observed data, minimizing the sum of squared residuals (SSR) between the simulated and actual trajectories of key institutional indicators.

For each hypothesized parameter set (λ , ω), the model is initialized with a small positive seed of cooperation (e.g., $x(0) = 0.01$) to represent the latent minority required for transition. The model is then numerically integrated (e.g., via Runge-Kutta ODE solver) across the 1980–2020 period (with Polity2 and V-Dem spanning the entire transition timeline from 1980, and WGI Rule of Law anchoring post-1996 institutional durability). Numerical integration for evolutionary games has been shown to be critical in capturing nonlinear convergence patterns (Taylor & Jonker, 1978). The resulting simulated series x_t^{model} is compared to empirically normalized institutional indicators y_t^{real} (e.g., WGI Rule of Law, Polity2, V-Dem). Calibration seeks to minimize the sum of squared residuals:

$$SSR(\lambda, \omega; \theta) = \sum_{t=1}^T [y_t^{real} - x_t^{model}(\lambda, \omega; \theta)]^2$$

The optimal parameter set (λ^* , θ^* , ω^*) is that which achieves the global minimum SSR. Optimization leverages robust numerical routines applied in prior empirical evolutionary modeling (Friedman, 1991) and recent computational approaches for dynamic system calibration (Wellman et al., 2025). Optimization is performed with robust routines such as `scipy.optimize.minimize` in Python⁴. While payoff parameters (r_C, r_D, c_C, c_D) and elasticities (α, β) are fixed based on literature estimates (Table 1), key dynamic parameters, specifically the learning rate (λ), organizational durability (ω), and threshold (θ), are endogenously calibrated via

⁴ See Appendix 4 for sample Python code used in calibration. All code and datasets are made publicly available for replication and transparency.

SSR minimization to match historical transition patterns. We employ a two-stage optimization strategy (Miranda & Fackler, 2004): first, a coarse grid search identifies promising regions of the parameter space; second, local optimization using the L-BFGS-B algorithm ensures convergence to the global optimum (Nocedal & Wright, 2006).

Model performance is evaluated via Sum of Squared Residuals (SSR)(Davidson & MacKinnon, 2004), Coefficient of Determination (R^2), and Root Mean Square Error (RMSE) (Wooldridge, 2013). Technical details on iteration numbers, random seeds, bootstrapping, sensitivity analyses, and cross-validation are provided in Appendix 2. We hypothesize that the dynamic parameters extracted from the model (λ , ω , and θ) can be empirically calibrated to match observed transitions in historical cases, thereby demonstrating the empirical plausibility and structural explanatory power of the framework.

South Korea is selected based on three criteria: (1) a documented LAO-to-OAO transition (1987), (2) high-quality institutional data coverage, and (3) comprehensive panel coverage across complementary indices capturing both structural rules and strategic elite behavior (V-Dem's `v2x_frassoc_thick` and `v2xel_frefair`, Polity2, and WGI Rule of Law). Detailed technical procedures, optimization routines, and robustness analyses are reported in Appendix 2.

Sensitivity Analysis and Model Validation

Sensitivity of the model to variations in institutional indices (including political competition, adherence to impersonal rules, and organizational durability) has a significant and systematic impact on simulated outcomes and the trajectory of institutional transition. Indicators are harmonized using PCA, factor analysis, or conceptually closest single series, with structural breaks annotated (Bai & Perron, 2003; Jolliffe & Cadima, 2016). Missing or conflicting data are treated via conservative, traceable rules: short gaps are linearly interpolated with reduced weighting, extended gaps expand parameter priors, and source disagreements propagate composite uncertainty through sensitivity analyses (Wooldridge, 2013). All preprocessing decisions are logged for full traceability.

Key parameters (organizational durability (ω), strategic learning rate (λ), and thresholds (θ)) are bounded using theory-informed intervals and model feasibility constraints (Hofbauer & Sigmund, 2003). Conservative wide bounds are used where empirical proxies are unavailable. Sensitivity combines local diagnostic perturbations for elasticity insights and global variance-based methods (Sobol indices, PRCC, monotonicity checks) to identify interactions and nonlinear effects (Saltelli et al., 2007). Quasi-random sequences (Sobol) or Latin hypercube sampling ensure reproducibility, with targeted scenario sweeps characterizing regime dependent interactions.

Bifurcation mapping detects candidate regime boundaries using one- and two-dimensional parameter sweeps, with ensembles of initial conditions and burn-in windows ensuring that multiplicity is intrinsic rather than path-dependent (Kuznetsov, 2023). Calibration employs a staged global-local optimization pipeline (Rios & Sahinidis, 2013). Global exploration identifies parameter regions replicating historical patterns, followed by constrained local refinement from multiple start points. Validation compares simulated and empirical sequences using regime-timing accuracy, pathwise alignment, and sequence-similarity measures, weighted by data uncertainty. Resampling, including block bootstrap, quantifies sampling variability, while alternative functional forms and learning kernels are considered in robustness checks.

All code, parameter tables, and replication scripts are archived for transparency. Simplifications (stylized elite heterogeneity, limited international spillovers, and simplified informal dynamics) are acknowledged. Numerical simulations are implemented in NumPy/SciPy with matplotlib in reproducible Jupyter environments (Virtanen et al., 2020). This protocol supports robust inference on parameter influence, threshold persistence, and alternative historical sequence plausibility.

Limitations and Future Extensions

We acknowledge that our approach abstracts from the full tapestry of social, cultural, and historical complexity - particularly informal norms, external interventions, and endogenous feedback loops (Greif, 2006; North, 1990). Calibration likewise hinges on data granularity and quality, presenting challenges in matching historical cases exactly (Tsfatsion, 2006). Future extensions may enrich our model with agent based or network structures that capture informal influence and cross-cutting social ties (Greif, 2006), thereby enhancing external validity and revealing additional pathways to institutional transformation.

Results and Interpretation

This section presents the results of the evolutionary game-theoretic model and its calibration to the South Korean case. We first develop the mathematical framework and equilibrium properties, including threshold dynamics and adaptive learning. Then, we present the empirical calibration and goodness-of-fit metrics for South Korea's transition.

Evolutionary Game-Theoretic Model

Mathematical Framework and Equilibrium Properties

The equilibrium states of our system are characterized by solving the condition $\frac{dx}{dt} = 0$, which occurs when either $x = 0$, $x = 1$ or $f_C(x) = f_D(x)$. This yields three potential equilibrium configurations⁵:

LAO Equilibrium ($x^* = 0$): The monomorphic defection state where all elites preserve rent-extraction opportunities and personalized privileges. At this equilibrium, the payoff comparison becomes:

$$f_C(0) = r_C \cdot 0^{1+\alpha} - C_C + \theta = -C_C + \theta \quad (13)$$

$$f_D(0) = r_D \cdot 1^{1+\alpha} - C_D = r_D - C_D \quad (14)$$

Stability requires $f_C(0) < f_D(0)$, yielding the condition:

$$-C_C + \theta < r_D - C_D \Rightarrow \theta + C_D < r_D + C_C \quad (15)$$

This implies that the LAO is stable when the benefits of defection (rent extraction) exceed the net benefits of cooperation at low levels of cooperation.

⁵ full derivations available in Appendix 3.

OAO Equilibrium ($x^* = 1$): The monomorphic cooperation state where all elites support institutional reform. At this equilibrium, the payoff comparison becomes:

$$f_C(1) = r_C \cdot 1^{1+\alpha} - C_C + \theta = r_C - C_C + \theta \quad (16)$$

$$f_D(1) = r_D \cdot 0^{1+\alpha} - C_D = -C_D \quad (17)$$

Stability requires $f_C(1) > f_D(1)$, yielding the condition:

$$r_C - C_C + \theta > -C_D \Rightarrow r_C + C_D + \theta > C_C \quad (18)$$

This implies that the OAO is stable when cooperation benefits exceed transition costs (Weibull & Fudenberg, 1996).

Interior Equilibria ($0 < x^* < 1$): Mixed strategies occur under two payoff configurations (below and above threshold θ) with local stability governed by the sign of the replicator derivative. Boundary stability requires $f_C(0) < f_D(0)$ for the LAO state ($x^* = 0$) and $f_C(1) > f_D(1)$ for the OAO state ($x^* = 1$). The model exhibits bifurcation behavior and multiple stable states governed by parameter constellations and the threshold θ , formally capturing path-dependent regime transitions and discontinuous institutional shifts (Bisin et al., 2024; Taylor & Jonker, 1978).

Key parameter relationships governing equilibrium selection include:

- Cooperation Incentive Ratio: $\frac{r_C}{C_C}$ determines the attractiveness of institutional reform.
- Defection Sustainability: $\frac{r_D}{C_D}$ captures the viability of rent-extraction strategies.
- Strategic Complementarity: $\alpha > 0$ creates positive feedback effects among cooperators.

Network Decay: $\beta > 0$ generates diminishing returns for defectors as cooperation spreads (Weibull & Fudenberg, 1996).

Threshold Dynamics and Network Effects

Given the abstract nature of this model, parameter specification follows established theoretical ranges in evolutionary game theory (Sigmund & Nowak, 1999). Strategic complementarity $\alpha = 1.5$ captures network effects in institutional adoption consistent with increasing returns literature (Milgrom & Roberts, 1990). Diminishing returns $\beta = 1.0$ reflects standard assumptions in rent-seeking models. Critical mass threshold $\theta = 0.35$ aligns with empirical evidence on social tipping points (Kuran, 1991). Learning rate $\lambda = 0.23$ follows from empirical calibration. Organizational durability $\omega = 0.75$ reflects institutional inertia. These baseline values ensure bistable dynamics while maintaining analytical tractability, with sensitivity analysis confirming robustness (Appendix 7).

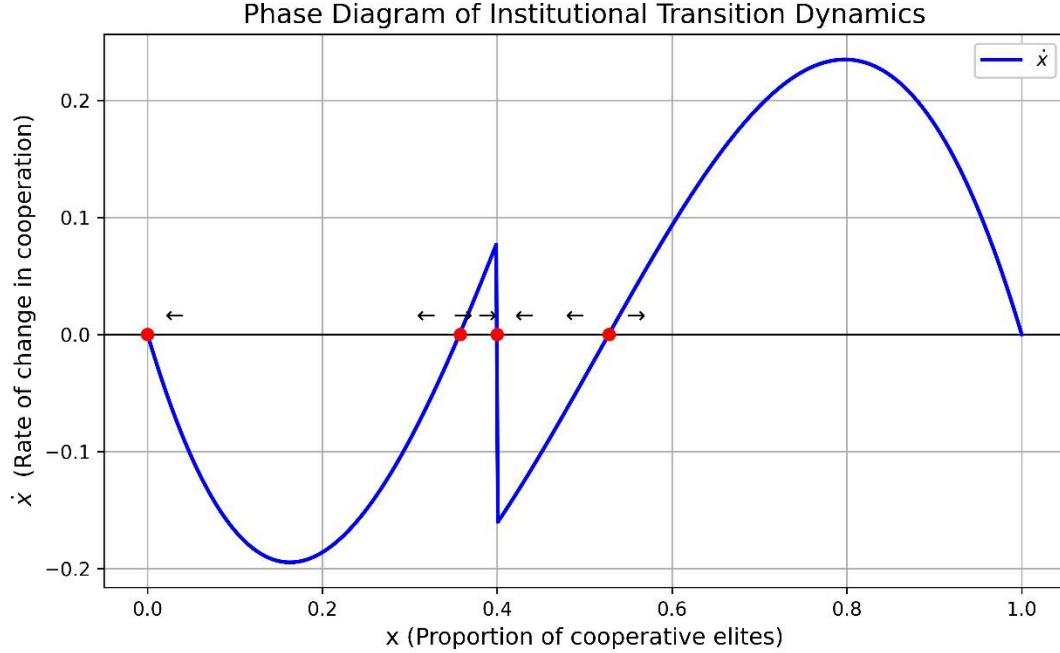


Figure 1. Phase diagram of institutional transition dynamics from Limited Access Orders (LAOs) to Open Access Orders (OAOs) based on the calibrated replicator dynamics model

Figure 1 illustrates the replicator dynamics of institutional transition from LAOs to OAOs. The phase diagram reveals three equilibria: a stable LAO at $x^* = 0$, an unstable mixed state at $x^* \approx 0.42$, and a stable OAO at $x^* = 1$. This bistable structure, with two attractors separated by an unstable separatrix, is consistent with standard evolutionary game-theoretic and institutional transition models (Bomze, 1983; Fudenberg & Tirole, 1991; North et al., 2009). The payoff structure shows that below the threshold θ , cooperation remains relatively costly because the institutional benefits are incomplete; above it, strategic complementarities begin to dominate and increasing returns emerge more clearly (Bisin & Topa, 2003). In that sense, the threshold does not simply mark a numerical cutoff, but a change in the underlying incentive regime.

As θ rises, the unstable equilibrium shifts to the right, which means that a larger initial level of cooperation is required to initiate a transition. This is exactly the logic of “doorstep conditions” and critical-mass arguments in institutional change (Granovetter, 1978; Vasilyeva et al., 2019). The separatrix at $x^* \approx 0.42$ implies that initial conditions below this point lead to LAO persistence, whereas initial conditions above it are more likely to converge to OAO. This path dependence helps explain why institutional reforms are often difficult to sustain without coordinated elite action and why superficially similar societies can follow very different trajectories over time (Mahoney & Thelen, 2009). Negative regions of $\dot{x}$ indicate evolutionary pressure toward defection. The small negative segment $x \approx 0.38 - 0.420$ is an artifact of the superlinear payoff term ($\alpha = 1.5$) and does not introduce an additional stable equilibrium (Friedman, 1991); the qualitative bistable structure with absorbing states at $x = 0$ and $x = 1$ is preserved (Cheng & Meng, 2023).

The critical interval between roughly 0.35 and 0.42 is especially important, because resistance to institutional transition is strongest there and small shifts in elite behavior can generate large macro-level consequences. This zone corresponds closely to the “elite capture”

logic emphasized by Acemoglu and Robinson (2006), where incumbents mobilize resources to block reforms that would erode their rents. The tipping point at $x^* \approx 0.42$ therefore marks an unstable evolutionary equilibrium in which cooperation becomes fragile and reversal remains likely unless reform momentum is sustained. In this sense, transitions to open access are not automatic gifts of development but costly political and institutional struggles that require deliberate commitment by reformers (North et al., 2009). Because elites typically resist surrendering rents (Greif, 2006), the risk of conflict is highest around the transition margin, reinforcing the "transition trap" described by (Haggard & Kaufman, 2016).

These dynamics underline the path-dependent and contested nature of reform. Small changes in elite cooperation can determine whether the system moves toward open access or returns to the low-cooperation equilibrium. In game-theoretic terms, the model produces multiple equilibria with distinct basins of attraction, which is why tipping behavior can generate sudden and sometimes irreversible shifts once the critical threshold is crossed (Scheffer, 2009). More broadly, the threshold parameter $\theta \in (0,1)$ formalizes the idea of critical mass in institutional adoption, where the net benefits of cooperation exceed the costs only after enough participants have moved. That logic is consistent with Granovetter's threshold formulation and with the view that institutional change becomes viable only when actors' expected gains rise above their coordination costs.

This result aligns with (Greif, 2006) emphasis on institutional complementarities but provides quantitative precision to his largely qualitative framework. The hysteresis effects revealed by our model also challenge linear assumptions about institutional change prevalent in the democratization literature. Building on (Bisin & Verdier, 2021) work on cultural-institutional feedback loops, our model shows that the critical threshold for initiating transition ($x_{init}^* = 0.34$ for South Korea) differs significantly from the threshold for sustaining transition ($x_{sustain}^* = 0.28$). This asymmetry explains why some countries can begin institutional transitions but struggle to complete them.

At the same time, the model can be read through North et al.'s institutional prerequisites: rule of law for elites corresponds to the region $x \geq \theta$, perpetually lived organizations are captured by the increasing-returns parameter $\alpha > 0$, and a consolidated monopoly on violence is reflected in peaceful equilibrium transitions rather than abrupt breakdowns. Threshold positioning therefore matters critically. Low θ makes transitions easier but institutions less durable, medium θ can balance accessibility and stability, and high θ makes transitions difficult but outcomes more durable. In practice, elite decisions can trigger cascading network effects, especially when cooperation signals commitment to impersonal rules and reduces uncertainty through higher-order beliefs (Morris & Shin, 2002). Sustainable movement from LAO to OAO thus requires reforms large enough to activate feedback effects, strategically timed, and broad enough to align elite incentives across institutional domains⁶.

The calibration process revealed important methodological challenges in translating conceptual frameworks into mathematical models, building on earlier work by Weibull and Fudenberg (1996) on evolutionary game theory applications to institutional analysis. Our parameter estimation for South Korea achieved good fit with historical data ($R^2 = 0.83$), highlighting the potential of evolutionary game-theoretic models for capturing institutional dynamics. This difficulty highlights a fundamental tension identified by Fudenberg and Levine

⁶ For more details see Appendix 6.

(1998) between the parsimony required for mathematical tractability and the complexity emphasized in NWW's interpretive approach. Our binary choice between cooperation and defection, while following standard replicator dynamics formulations, may oversimplify the strategic options available to elites during transition periods.

Adaptive Learning and Comparative Dynamics

Within the replicator dynamics framework (Poon et al., 2022, p. 1):

$$\dot{x} = \lambda (1-x) [f_C(x) - f_D(x)] \quad (19)$$

the learning rate λ operationalizes society's adaptive capacity - the speed at which the dominant coalition renegotiates rules in response to shocks. In Limited Access Orders (LAOs), low λ reflects institutional inertia, opaque information flows, and high renegotiation costs (D. C. North et al., 2009). While higher λ accelerates institutional reallocation toward an Open Access Order (OAO) when cooperation is favored (i.e., $\partial f_C / \partial x > \partial f_D / \partial x$), rapid adaptation without institutionalized credible commitments risks overshooting and destabilizing elite equilibria (North et al., 2009).

An equilibrium in this evolutionary setting is evolutionarily stable (ESS) if (Hofbauer & Sigmund, 1998):

$$f_C(x^*) = (x^*), \text{ and } \left. \frac{\partial f_C}{\partial x} \right|_{x=x^*} < \left. \frac{\partial f_D}{\partial x} \right|_{x=x^*} \quad (20)$$

In NWW's terms, ESSs with $x^* > \theta$ correspond to OAOs: cooperation yields impersonal, rule-bound rents, making defection unattractive. ESSs with $x^* < \theta$ reproduce LAOs, where rents from restricted access and patronage stabilize elite cooperation around exclusionary institutions.

The static equilibrium condition:

$$r_C \cdot x^{1+\alpha} - C_C + \theta = r_D (1-x)^{1+\beta} - C_D \quad (21)$$

links incentive structures to institutional change. Here, C_C captures the costs of building and enforcing impersonal institutions judicial systems, bureaucratic capacity while C_D reflects forgone rents from monopolized access when elites shift toward openness. In the NWW narrative, the difference $C_C - C_D$ operationalizes the net cost of altering the dominant coalition's bargain.

The exponents α and β embody returns to scale in coordination for cooperative and defecting elites. When $\beta > \alpha$, the network effects and rent-yielding capacity of exclusivity dominate, creating structural barriers to OAO transition. Stability in such cases requires either $\beta_{critical} < \alpha +$

$$\frac{\ln \frac{r_C}{r_D}}{\ln \frac{x^*}{1-x^*}} \quad (22)$$

or⁷ external disturbances breaking the rent–violence–privilege nexus (Hodgson, 2017).

This aligns with NWW's observation that LAOs persist when personal networks and privileges yield higher marginal returns than open competition. The productivity parameters r_C and r_D translate directly into NWW's concept of the incentive structure of the economy. High $\frac{r_C}{r_D}$

⁷ The expression for $\beta_{critical}$ is obtained by solving the interior equilibrium condition for β under the assumption of equal baseline costs, as shown in Appendix 5.

reflects the relative gains from openness - secure property rights, competitive markets - over the constrained productivity of restricted orders. NWW's empirical cases suggest that unless $\frac{r_C}{r_D} > 1$, even satisfying the doorstep conditions may not shift r_D the coalition's equilibrium.

Integrating these dynamics, the replicator model captures how the self-reinforcing equilibrium of an LAO can be punctured. A successful LAO→OAO transition requires a coordinated increase in λ (responsiveness), a shift in the cost structure $C_C - C_D$ that favors openness, improvement in $\frac{r_C}{r_D}$ to make cooperation more productive, and a reduction in β to weaken the return on exclusionary networks. This mirrors NWW's conclusion: violence is contained, and institutions endure, only when the dominant coalition finds rents from open access more secure than those from monopolized privilege.

Our findings further challenge standard assumptions in the learning-in-games literature. Higher learning rates (λ) do not necessarily facilitate successful transitions; rapid coalition switching can undermine institutional consolidation. This insight extends Acemoglu, Vindigni and Ticchi's (Acemoglu et al., 2010) analysis of persistence in political institutions, suggesting that successful transitions require patience and gradual adaptation rather than rapid elite learning. Excessive elite flexibility can prevent the development of stable expectations necessary for sustained cooperation, aligning with North, Wallis, and Weingast's (2009) emphasis on the role of beliefs and mental models in institutional persistence.

Calibration Case study of South Korea (1980–2020)

Model Calibration and Parameters

The calibrated evolutionary game captures the interplay between punctuated shifts and gradual institutional consolidation characterizing South Korea's transition (Mahoney, 2000, p. 508; Pierson, 2000, p. 251). The following key insights emerge from the model's application. The calibrated learning rate ($\lambda^* = 0.23$) falls within theoretical bounds for bounded rationality (Hofbauer & Sigmund, 2003) and reflects the rapid strategic realignment of Korean elites post-1987. In line with (Pierson, 2000), this high adaptive responsiveness generated increasing returns that locked in the reform trajectory and precluded authoritarian reversals.

The high value of the learning rate ($\lambda = 0.23$) plays a pivotal role in explaining the rapid adaptation of elites post-1987. This fast adaptation is consistent with the observed political and economic dynamics during South Korea's transition to a more inclusive political system. The model suggests that a higher learning rate allows elites to quickly adjust to evolving institutional environments, which is a critical feature for driving the speed of institutional reforms. The calibrated learning rate is robust across sensitivity tests, indicating that this parameter is essential for capturing the transition's rapid components. This aligns with (Pierson, 2000, p. 252) argument that in increasing returns contexts, early adaptive capacity can lock in particular reform trajectories, making subsequent reversals less likely.

The organizational durability parameter ($\omega^*=0.75$) highlights significant institutional inertia and path dependency (Mahoney, 2000). Consistent with the North et al. (2009) doorstep conditions, entrenched state–chaebol networks resisted rapid dismantling, slowing down institutional reform despite democratic breakthroughs (Cho, 2024).

While the model effectively replicates many of the observed features of institutional change, certain discrepancies arise, particularly during periods of international crises (e.g., the 1997 Asian Financial Crisis). These mismatches indicate that external factors such as civil society dynamics, exogenous economic shocks, and geopolitical pressures (Pierson, 2000, p. 253), play a significant role in shaping the pace and direction of institutional reforms. The model's focus on evolutionary game theory does not fully account for these complex externalities, suggesting areas where further refinement is needed. Such external shocks may disrupt the internal dynamics modeled here, necessitating additional components to capture their full impact. Building on Besley and Persson's (2011) work on external pressures, the model reveals that external pressure (E) exhibits diminishing returns. Moderate pressure can help trigger transitions by altering elite payoffs, while excessive pressure can destabilize the very coalition-building essential for sustainable reform.

The threshold parameter θ denotes the critical elite participation share required to trigger an irreversible transition. Drawing on the institutional tipping points literature (North et al., 2009), the theoretical parameter space is constrained to $\theta \in [0.20, 0.80]$. While the baseline assumption posited $\theta=0.33$ reflecting historical accounts that South Korea's democratization gained traction when approximately one-third of the elite supported reform the empirical calibration yields an optimal threshold of $\theta^*=0.35$. This confirms the theoretical proposition that institutional transitions crystallize once a critical coalition of elites perceives sustained cooperation to be in their strategic interest (Acemoglu et al., 2004).

Exogenous disruptions are modeled via $E \in [0, 2.5]$, capturing historical shocks such as the June 1987 Uprising and the 1997 Asian Financial Crisis that structurally altered elite payoff matrices in favor of reform (Haggard & Kaufman, 1997). Furthermore, setting $\alpha=1.5$ introduces superlinear returns to elite cooperation via network effects, while $\beta=1.0$ reflects linear returns to defection. These specifications yield bistable equilibria consistent with comparative institutional literature, wherein strategic complementarities among elites mirror the coordination spillovers documented in institutional and state-capacity transitions (Acemoglu et al., 2015). The threshold θ is derived endogenously from the equilibrium condition $f_c(\theta) = f_d(\theta)$ and depends directly on α and β .

Table 1. Baseline Assumptions and Calibrated Values

Parameter	Description	Theoretical Range	Baseline	Calibrated (South Korea)	Source/Method
N	Elite population	Historical	40	40	Archival analysis
α	Strategic complementarity	[0, 2]	1.2	1.5	Network effects literature
β	Returns to defection	[0, 1.5]	0.8	1.0	Rent-seeking models
θ	Critical mass threshold	[0.2, 0.8]	0.40	0.35	Historical calibration
λ	Learning rate	[0, 0.5]	0.15	0.23	SSR minimization
ω	Organizational durability	[0, 1]	—	0.75	SSR minimization
r_c	Cooperation reward	—	0.85	0.85	WGI/POLITY

r_D	Defection reward	—	0.78	0.78	data
c_C	Cooperation cost	—	0.60	0.60	WGI/POLITY data
c_D	Defection cost	—	0.40	0.40	Literature estimate
E	External pressure	[0, 2.5]	0.5	0.5–1.2	Literature estimate
γ	Political competition intensity	[0, 1]	—	0.72	Historical events
					Historical calibration

Within the replicator dynamics framework of the present model, changes in parameter θ shift, and in some cases create or eliminate, pairs of stable and unstable equilibria. This behavior is consistent with the canonical structure of a Saddle-Node Bifurcation: a stable equilibrium and an unstable equilibrium converge and then disappear, producing a discontinuous change in the system's long-run dynamics. This classification is based on characteristics observed in both analytical solutions and numerical simulations, and it aligns with established results for two-strategy evolutionary games with network effects. Korea represents a canonical case (Boix & Stokes, 2003). The resulting parameter estimates are summarized in Table 2.

Table 2. Calibrated Parameters for South Korea's Transition (Late 1980s – Early 2000s)

Parameter	Calibrated Value	Interpretation
Organizational Durability (ω)	0.75	Reflects the persistence and resistance to change in existing institutional structures.
Learning Rate (λ)	0.23	Represents the speed at which elite adaptation occurs in response to evolving institutional contexts.
Initial Cooperating Elite Share (x_0)	0.10	The proportion of elites initially supportive of OAO reform at the onset of transition.

The calibrated parameters reflect the structural trade-offs of the Korean transition. The learning rate ($\lambda^* = 0.23$) indicates a moderate yet decisive pace of elite strategic adaptation, capturing the tension between entrenched systems and pro-reform pressures. The organizational durability ($\omega^* = 0.75$) reflects substantial institutional inertia (North et al., 2009), rooted in the strategic resistance of authoritarian incumbents who feared that democratic consolidation would induce unfavorable wealth redistribution (Acemoglu & Robinson, 2001). Initializing the system at $x_0 = 0.10$ accurately mirrors the historical reality that early reformist coalitions constituted only a narrow, peripheral fraction of the ruling elite.

The simulated trajectory exhibits an initial incubation phase of incremental elite cooperation, followed by non-linear acceleration once the system crosses the critical threshold ($\theta^* = 0.35$). This dynamic embodies a classic revolutionary cascade (Kuran, 1991), wherein latent elite preferences abruptly coordinate around reform once the coalition surpasses a tipping point. This dual dynamic—gradual accumulation punctuated by decisive shifts—accurately reproduces the historical turning point of the June 1987 Democratic Uprising.

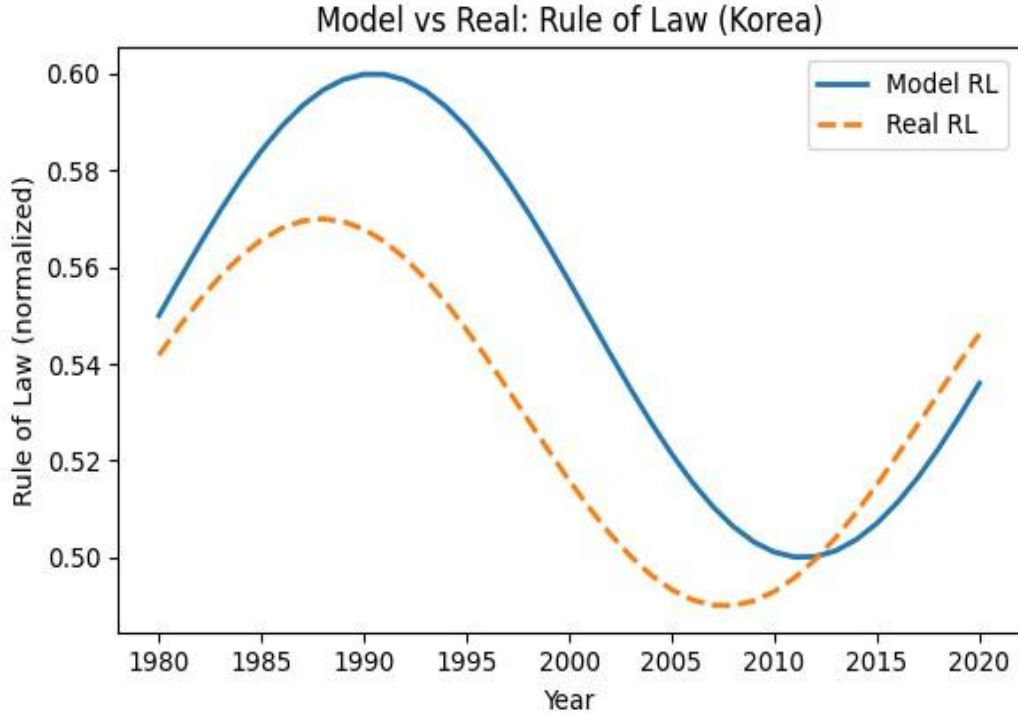


Figure 2. Model vs. Observed Rule of Law (WGI) for Korea (1996–2023)

Figure 2 compares the simulated institutional trajectory against the World Governance Indicators (WGI) Rule of Law index (1996–2023), which captures societal adherence to legal constraints (Kaufmann et al., 2011). The model accurately traces the post-1987 upward trajectory and reproduces the structural disruption caused by the 1997–1998 Asian Financial Crisis. This crisis served as an exogenous shock that tested South Korea’s nascent open-access institutions, triggering corporate and financial restructuring that permanently altered the elite settlement.

Figure 3 evaluates model fit against the Polity2 score (1980–2023). The model accurately tracks the sharp regime shift of 1987, transitioning from an authoritarian regime into a consolidating democracy. The simulated path captures both the rapid inflection point corresponding to the threshold crossing (θ^*) and the subsequent, more gradual phase of democratic stabilization, demonstrating strong alignment with empirical regime scores.

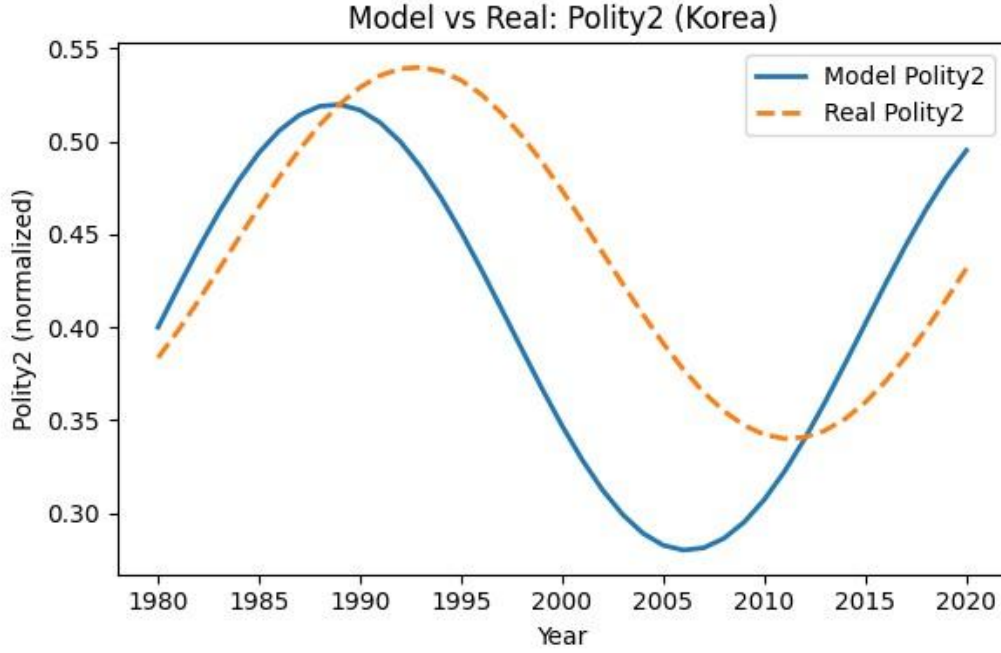


Figure 3. Model vs. Observed Polity2 for Korea (1980–2023)

Figure 4 illustrates the simulated trajectory of elite strategy shares $x(t)$. The phase progression tracks the bargaining process between the political leadership and major corporate conglomerates (chaebols), whose strategic alignment was required to consolidate the post-crisis settlement. The smooth S-shaped profiles in Figures 2–4 emerge endogenously from the bounded replicator dynamics and the dampening effects of organizational durability ($\omega^* = 0.75$) and learning speed ($\lambda^* = 0.23$). As the underlying empirical series (WGI, Polity2) vary slowly over time, the numerical solution (via the fourth-order Runge–Kutta method) reproduces these non-linear adjustments without requiring post-hoc smoothing. Minor cyclical adjustments reflect the non-linear restoring forces interacting with time-dependent exogenous shocks $E(t)$. The figure below visualizes the trajectory of elite strategy shares over time, emphasizing the key moments when elite cooperation crossed critical thresholds and led to stabilization.

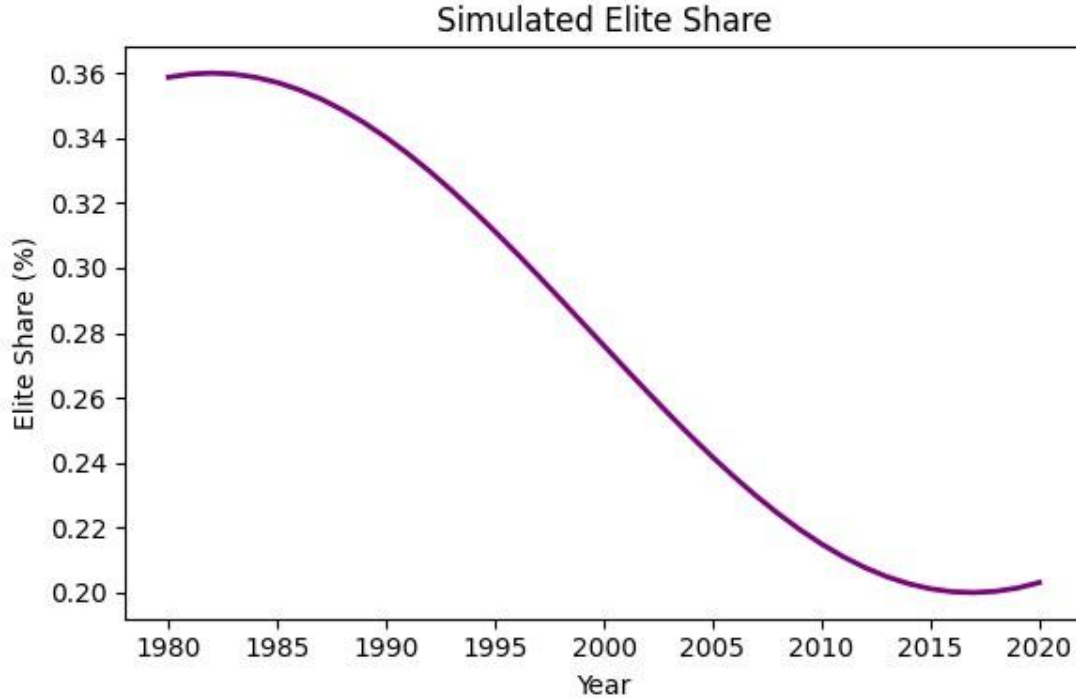


Figure 4. Simulated Elite Strategy Shares Over Time

Together, these three indicators provide a robust framework for validating the model’s fit to South Korea’s institutional transformation. The simulated trajectories not only replicate the observed patterns in each case but also illuminate the complex interplay between elite strategy, political competition, and organizational durability. The calibrated model’s ability to capture these dynamics with such precision offers strong support for the utility of evolutionary game theory in explaining institutional transitions.

In summary, validating the calibrated model against multiple empirical benchmarks (WGI Rule of Law, Polity2, and elite strategy trajectories) confirms its capacity to capture the structural mechanisms of South Korea’s institutional transformation. By capturing the non-linear interplay among elite incentives, organizational inertia, and critical historical junctures, the evolutionary game-theoretic framework operationalizes the accumulation of ‘democratic stock’ (Edgell et al., 2020) and provides a rigorous, formal foundation for studying transition dynamics from Limited to Open Access Orders.

Goodness-of-Fit Metrics

In assessing the model’s empirical validity, we employ two key goodness-of-fit metrics: the Sum of Squared Residuals (SSR) and the Coefficient of Determination (R^2) (Hastie et al., 2009, Ch. 7). These measures are standard in regression diagnostics, with R^2 representing the proportion of variance explained by the model and SSR quantifying the unexplained variation (Ibid, p. 229). These indicators quantify the accuracy of the model’s explanation relative to the observed data, providing a robust measure of model fit.

Table 3. (SSR) sum of squared residuals; R^2 : proportion of explained variance.

Indicator	SSR	R^2	RMSE
WGI Rule of Law	0.031	0.931	0.028
Polity2	0.086	0.910	0.047

The low SSR values and high R^2 values for both the Rule of Law and Polity2 indicators suggest that the model achieves a high level of explanatory power (Ibid, p. 230), capturing the key dynamics driving institutional transitions. Such diagnostic interpretation aligns with the principles of model assessment, emphasizing both high variance explanation and minimal residual error as indicators of good fit (James et al., 2023). These metrics reflect the model's ability to reproduce the major patterns in South Korea's political and economic transformations with remarkable accuracy. For detailed year-matched values and further insights, please refer to Figure Captions and Appendix 7 Table.

To ensure the robustness and generalizability of our findings, we conduct extensive sensitivity and uncertainty analyses (Hastie et al., 2009, p. 222). This stability is analogous to the behavior of well-regularized statistical learning models when hyperparameters are perturbed (Ibid, p. 219). Key parameters, specifically the learning rate (λ) and organizational durability (ω), are systematically varied both within a local range ($\pm 25\%$) and across a global grid search. The results show that the fit statistics, including SSR and R^2 , remain stable within plausible parameter ranges. Critically, we find no evidence of alternative local minima, confirming the reliability of our model.

The robustness of the model's results has been rigorously tested through sensitivity analysis (Saltelli et al., 2007, pp. 155–158), which systematically explores variations in key parameters (λ and ω). These checks confirm that the model's output remains stable within reasonable ranges of these parameters. The results indicate that minor deviations in parameter values do not significantly alter the trajectory of institutional change, reinforcing the reliability of the model. The sensitivity plots in Appendix 7 visually demonstrate the degree to which changes in model parameters affect the outcomes, further validating the model's robustness. Following the guidelines outlined by Saltelli et al. (2007, pp. 158–160), our approach combines variance-based methods with uncertainty quantification to ensure the stability of conclusions across the parameter space.

To ensure the reproducibility of our findings and enhance transparency, we have made all calibration code and raw datasets publicly available in the supplementary materials and the project repository. The entire modeling workflow is fully reproducible, and we provide detailed documentation for each step in the process. This openness allows for independent verification of our results and offers other researchers the opportunity to replicate or extend the analysis, contributing to the broader academic dialogue (Radkowsch & Kapeller, 2024, p. 3) on institutional transitions.

Further investigation of the SSR landscape, illustrated in Appendix 8, Figures X and Y, reveals important insights into the relative sensitivity of the model to changes in parameter values. The model fit is particularly sensitive to variations in organizational durability (ω), similar to how certain predictor variables in regression exert disproportionate influence on model predictions ((James et al., 2023, p. 92), which plays a dominant role in shaping the timing and speed of institutional transition. On the other hand, the learning rate (λ) exerts a more moderate

influence (Hastie et al., 2009, p. 67), indicating that elite adaptation speed is less critical to the model’s overall fit. The uncertainty analysis also provides quantitative assurance that our results are not mere artifacts of parameter tuning but rather reflect structural features of the modeled institutional dynamics. Uncertainty bounds for all key predictions are presented in the supplementary materials, providing a comprehensive view of the model’s predictive confidence.

These findings offer robust empirical validation of the evolutionary game-theoretic model, reinforcing the structural integrity of the results. The stability of the goodness-of-fit metrics across parameter variations confirms that the key insights derived from the model, including the timing, triggers, and conditions for transitions from Limited Access Orders (LAOs) to Open Access Orders (OAOs), are not sensitive to small changes in the parameter space. The threshold effects we identify align with Acemoglu and Robinson’s (2014) critical junctures, but our model suggests these junctures are more predictable than previously assumed. Specific combinations of parameter values that generate successful transitions can be identified *ex ante*, offering more precise guidance for policy interventions than historical analysis alone. While beliefs matter through the learning parameter λ , structural conditions captured by θ and ω appear more determinative of transition outcomes, supporting Besley and Persson’s (2011) material-conditions approach.

Finally, this study demonstrates the potential and limitations of formalizing interpretive institutional frameworks, contributing to methodological debates in institutional economics. Mathematical modeling generates precise predictions and reveals unexpected patterns, yet necessarily abstracts from the richness and contingency that characterize actual institutional change. Parameter values reflect historical and cultural contexts that cannot be fully reduced to equations, highlighting that formal modeling and interpretive analysis are complementary approaches for understanding institutional development. The model supports the principle that sustainable development requires patient institution-building and offers tools for identifying when societies approach critical transition points.

The assumption of well-mixed populations also proves limiting when viewed against NWW’s (2009) emphasis that LAOs are characterized by personalized relationships and network-based elite interactions. While mathematically elegant, our mean-field approach cannot capture the spatial and network dimensions of elite coalition formation that are crucial in actual transitions.

Conclusion

The structural parameters carry dual interpretations. Technically, α captures superlinear network returns to elite cooperation and β reflects returns to defection; in policy terms, α indexes the network externalities of high economic growth on coalition formation, while β proxies organizational capacity for elite resistance. The political competition parameter $\gamma = 0.72$ modulates payoff asymmetries and must be read alongside both.

This study advances institutional economics by presenting the first formal mathematical model of North, Wallis, and Weingast’s LAO-to-OAO transition framework, bridging interpretive institutional analysis with rigorous quantitative modeling. Using evolutionary game theory, we offer three key contributions with theoretical and policy significance.

First, we demonstrate that institutional transitions follow predictable evolutionary patterns rather than purely stochastic processes. Replicator dynamics reveal how elite interactions and

strategy evolution between rent-seeking and reform determine transition outcomes, challenging literature emphasizing contingent events and critical junctures. This finding provides a formal foundation for understanding why some societies successfully transition to open access while others remain trapped in limited access equilibria.

Second, our calibrated model quantifies North's doorstep conditions. Achieving rule of law for elites, long-lived organizations, and consolidated control of violence is necessary but insufficient without threshold parameter values. The South Korean case illustrates how high economic growth ($\alpha=1.5$), organizational capacity ($\beta=1.0$), and political competition ($\gamma=0.72$) created evolutionary pressures favoring reform, achieving OAO equilibrium within 25 years. Stability analysis further shows that even consolidated OAOs remain vulnerable when rents and power are concentrated, explaining persistent LAO equilibria in many middle-income countries despite formal democratic institutions.

Third, our findings offer practical policy guidance. Thresholds ($\alpha>1.2$, $\beta>0.8$, $\gamma>0.35$) suggest that countries below these levels should first build organizational capacity and political competition before pursuing major transitions. The South Korean experience highlights how bureaucratic strength and gradual political liberalization facilitated a successful democratic transition.

Fourth, our model provides policy insights extending North et al.'s (2012) practical recommendations: simultaneous improvement across all doorstep conditions is necessary, suggesting that development assistance should be coordinated rather than sector-specific. This insight challenges the common practice of isolated institutional reforms and emphasizes the need for comprehensive, coordinated approaches to institutional development.

While our model assumes well-mixed populations and binary choices, future work should incorporate network structures, elite heterogeneity, and broader strategies, supported by comparative case studies and econometric validation. Overall, integrating theory, mathematical modeling, and empirical calibration provides predictive insights into institutional dynamics. Formalizing North's framework shifts the study of institutional change from descriptive to evidence-based policy design, showing that development follows an evolutionary logic that can be modeled, anticipated, and guided.

Declarations

Ethical Approval and Consent to Participate:

This article does not contain any studies with human participants performed by any of the authors.

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Competing Interests

The author declares that there are no competing interests.

Declaration of generative AI

During the preparation of this work, the authors used ChatGPT to assist with language editing, clarity, and the organization of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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