

# Institutional Dynamics in Agent-Based Models: Identifying Action-Space, Timing, and Distributional Effects Through Controlled Simulation

Roberto Garrone

`roberto.garrone@st.ouc.ac.cy`

Open University of Cyprus <https://orcid.org/0009-0005-7060-6774>

---

## Research Article

**Keywords:** agent-based modeling, institutional dynamics, action spaces, normative multi-agent systems, institutional analysis, simulation experiments

**Posted Date:** October 27th, 2026

**DOI:** <https://doi.org/10.21203/rs.3.rs-11501756/v1>

**License:** © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

**Additional Declarations:** The authors declare no competing interests.

---

# Institutional Dynamics in Agent-Based Models

Identifying Action-Space, Timing, and Distributional Effects  
Through Controlled Simulation

Roberto Garrone

Open University of Cyprus

roberto.garrone@st.ouc.ac.cy

October 2026

## Abstract

Institutions in agent-based models can be represented as parameters, agent decision rules, or explicit institutional structures. This paper focuses on a narrower experimental question: how can effects that arise specifically because an institutional state changes the actions available to otherwise unchanged agents be identified in simulation? We separate candidate-action generation, institutional admissibility, and behavioral choice, and evaluate this decomposition in a synthetic scarce-resource model. The experiment compares unrestricted action sets ( $C_0$ ), a static rights architecture ( $C_1$ ), an endogenously changing rights architecture ( $C_2$ ), and an exposure-matched front-loaded timing diagnostic ( $C_{2F}$ ). Across 100 matched stochastic runs, the baseline static regime reduces the mean action-space ratio from 1.000 to 0.770 and increases the service share of a fixed 20% priority group from 20.2% to 26.6%. The dynamic regime raises the ratio to 0.914 and reduces that share to 23.5%. Relative to the exposure-matched front-loaded condition, state-coupled timing changes waiting, exits, unresolved demand, and allocation even though each affected agent receives the same total number of priority-right steps. A robustness study over 19 parameter settings preserves the signs of the principal action-space and allocation effects, with effects becoming negligible under low-demand/high-capacity slack and larger under scarcity. The contribution is not a new institutional formalism: prior work already models rule-structured action situations, executable rights and obligations, institutional ABMs, and dynamic norms. The contribution is a computational methodological design for separating institutional action-space effects from fixed physical and behavioral specifications, together with an action-space exposure diagnostic and an exposure-matched timing ablation. The study produces mechanism-level evidence within a synthetic model; it does not estimate causal effects for a real population, validate legal institutions, or make policy prescriptions. InstiAct v0.4.6 is used as a reference implementation.

**Keywords:** agent-based modeling; institutional dynamics; action spaces; normative multi-agent systems; institutional analysis; simulation experiments; robustness.

## 1 Introduction

Institutions affect behavior not only by changing incentives but also by changing what actors may, must, or cannot do. In computational models this distinction is consequential. If an agent's candidate actions are assumed to be fixed, institutional change can be represented only indirectly through parameters, utilities, or exogenous scenario switches. A different representation is required when institutional events create, transfer, condition, prioritize, or extinguish actions themselves.

This paper considers the institutional state as part of the dynamic state of an agent-based system. The central research question is: *Under fixed physical and behavioral specifications, under*

*what conditions do institutional changes in action availability alter behavior and distributional outcomes, including cases in which aggregate throughput changes little?*

The argument is methodological rather than domain-specific. A capacity reservation, collateral claim, delegated maintenance duty, care entitlement, bidding qualification, or platform access rule differs substantively across domains, but each can alter an actor’s admissible actions without necessarily changing the physical resources of the system.

The approach has a direct antecedent in DAMMAGE, which represents economic environments through explicit rights and obligations while allowing participating agents to remain external to the institutional specification [9]. The present contribution does not reconstruct or generalize the full DAMMAGE language. Instead, it isolates an experimental consequence that is especially relevant to agent-based simulation: institutional states can be treated as determinants of action availability while the physical model and behavioral policy are held fixed. InstiAct, an independently developed Python research implementation inspired by this line of work, provides one computational instrument for testing that decomposition.

The literature creates an identification tension rather than an absence of institutional models. Existing formalisms establish that rules can structure available actions and that institutions can change, but representational expressiveness alone does not identify why two simulated institutional regimes produce different outcomes. Differences may arise from total exposure to rights, the temporal placement of that exposure, altered behavioral rules, or altered physical conditions. The methodological problem addressed here is to separate these channels inside a controlled simulation. This matters for ABM because aggregate outputs can remain nearly unchanged while institutional access and burdens are redistributed across agents; a regime comparison based only on throughput can therefore miss the mechanism of interest.

## 2 Related Work

The general idea that institutions structure action is well established. In the Institutional Analysis and Development (IAD) tradition, rules structure action situations by assigning participants to positions, specifying available actions, linking actions to outcomes, and defining information, control, and payoffs [1, 8]. The possibility of endogenous rule change is also explicit in work on adjacent action situations and polycentric governance [8]. Consequently, this paper does not claim that institution-dependent action sets are a new theoretical object.

Several computational traditions operationalize related ideas. MAIA translates institutional-analysis concepts into an agent-based modeling framework and subsequently provides procedural semantics for executable simulation models in which agents act within institutional and physical contexts [5, 6]. Work on nADICO and dynamic deontics models the emergence and evolution of normative understanding inside artificial societies [2]. More recent institutional-modeling guidance explicitly distinguishes static and dynamic treatments and discusses how agents can perceive, modify, and generate institutions during simulation [7]. In normative multi-agent systems more generally, permissions, prohibitions, obligations, regimentation, norm emergence, and norm revision have long been treated as computational objects [11].

A particularly close formal comparison is the Action Situation Language (ASL), which represents IAD rule configurations in a machine-readable logic language and includes choice rules that determine what actions are available to roles; an interpreter then grounds the resulting interaction as an extensive-form game [10]. DAMMAGE provides another close antecedent from a rights-and-obligations perspective, with executable institutional objects and an environment that is separable from participating agents [9]. These approaches establish that rules can determine available actions and that institutions can change computationally.

The novelty claim here is therefore deliberately narrower and experimental. The paper contributes: (i) an explicit mediation structure that separates a non-institutional candidate set  $A_i^*$ , an institutional filter  $\Phi_i$ , and an unchanged behavioral policy  $\pi_i$ ; (ii) the action-space

ratio  $\rho_i(t)$  as a transparent diagnostic of institutional filtering in a running ABM; (iii) a matched stochastic design with an exposure-matched temporal diagnostic that separates total right exposure from its state-coupled timing; and (iv) a robustness analysis showing when distributional institutional effects persist despite near-invariant aggregate throughput. The contribution concerns identification and measurement inside simulation, not the invention of dynamic institutions, deontic rules, or rule-conditioned action sets.

### 3 Positioning and Scope

This is a computational methodological study using a synthetic agent-based experiment. Its dominant technical anchor is agent-based computational modeling and multi-agent systems; institutional theory supplies the constructs being operationalized. Its primary knowledge claim is mechanistic: within the specified model, it identifies whether and under what tested conditions changes in institutional action availability mediate changes in realized behavior and distributional outcomes when the physical environment, stochastic inputs, and behavioral policy are held fixed. The matched-seed contrasts, exposure-matched timing diagnostic, and robustness grid are therefore simulation-based identification devices rather than estimators of an external empirical population.

The study does not provide empirical causal estimates, predictive validation, legal interpretation, welfare ranking, or policy optimization. The synthetic model is not calibrated to a substantive domain. Numerical intervals quantify stochastic variation under the encoded simulation process only. Generalization is consequently structural rather than statistical: the analysis supports the proposition that the decomposition can isolate institutional action-space effects under the modeled conditions, while substantive applications require independent evidence that the relevant rights, obligations, triggers, and behavioral rules correspond to the target system.

### 4 Institutional State and Endogenous Action Spaces

Let the non-institutional state of the modeled system at time  $t$  be  $s_t$ . Define an institutional state

$$\mathcal{I}_t = (V, R_t, O_t, P_t, G_t, T_t), \quad (1)$$

where  $V$  is the set of entities,  $R_t$  rights,  $O_t$  obligations,  $P_t$  permissions and restrictions,  $G_t$  relevant control relations, and  $T_t$  institutional transactions or state-changing events. This tuple is deliberately generic: a concrete formalism may represent these components differently or omit some of them.

Let  $A_i^*(s_t)$  denote the candidate actions that agent  $i$  could generate from the non-institutional model. Institutional evaluation induces an admissible subset

$$A_i(t) = \Phi_i(A_i^*(s_t), \mathcal{I}_t, H_t), \quad (2)$$

where  $H_t$  denotes institutional history when current admissibility depends on prior transactions or commitments. The behavioral policy then acts on the resulting set,

$$a_{i,t} = \pi_i(s_t, A_i(t), \theta_i), \quad (3)$$

with  $\theta_i$  collecting preferences or behavioral parameters.

This separates two analytically different mechanisms. Institutional rules determine the set over which choice occurs; behavioral rules determine choice conditional on that set. Consequently,

$$\mathcal{I}_t \rightarrow A_i(t) \rightarrow a_{i,t} \rightarrow s_{t+1}. \quad (4)$$

If actions or environmental events can also modify institutional arrangements, the system closes into

$$(s_{t+1}, \mathcal{I}_{t+1}) = \mathcal{F}(s_t, \mathcal{I}_t, \mathbf{a}_t, \omega_t), \quad (5)$$

where  $\omega_t$  represents exogenous conditions. Institutions are then neither fixed background nor merely a scenario label; they are part of the modeled dynamics.

#### 4.1 Physical, operational, and institutional admissibility

It is useful to distinguish institutional admissibility from other reasons why an action cannot occur. For candidate action  $a$ ,

$$\text{Executable}(a, t) = \text{PhysFeasible}(a, s_t) \wedge \text{OperAdmissible}(a, s_t) \wedge \text{InstAdmissible}(a, \mathcal{I}_t). \quad (6)$$

The institutional model need not decide whether a machine is physically capable of an operation, whether a road is traversable, or whether an agent prefers an action. It determines only the institutional component. Maintaining this boundary prevents institutional rules from becoming an undifferentiated container for every model constraint.

### 5 Mechanisms Producing Institutional Action-Space Effects

Consider two simulated systems with the same agents, resources, technologies, behavioral parameters, and exogenous shocks. If their institutional states differ, then

$$\mathcal{I}_t^A \neq \mathcal{I}_t^B \quad \Rightarrow \quad A_i^A(t) \neq A_i^B(t) \quad (7)$$

for at least some agents and times. Because the same policy  $\pi_i$  is evaluated over different action sets, behavioral trajectories can diverge without assuming a change in preferences or cognition.

This mechanism is distinct from a conventional policy intervention that directly modifies utilities, probabilities, or behavioral coefficients. It supports a cleaner counterfactual: what changes when the institutional architecture changes but the agents and environment do not?

Several recurrent mechanisms make this distinction relevant.

**Institutional discontinuity.** A continuous state variable can cross a threshold that activates or extinguishes a right or obligation,

$$x_t < x^* \Rightarrow \text{Right}(i, a). \quad (8)$$

The induced action set may therefore change discontinuously even when  $x_t$  changes smoothly.

**Asymmetric exposure.** Agents that are otherwise observationally similar may hold different priority claims, guarantees, access rights, or termination rights. Hence similarity in physical state does not imply similarity in institutional position.

**Embedded optionality.** A right can have little behavioral relevance under one state but become decisive after a shock. Its importance is therefore conditional on the future state and on whether the holder can exercise or transfer it.

**Institutional cascades.** A transaction or failure can activate secondary relationships,

$$\text{Failure}(A) \rightarrow \text{Right}(B, x) \rightarrow \text{Obligation}(C, y) \rightarrow \text{Right}(D, z). \quad (9)$$

The resulting propagation structure need not coincide with the physical interaction network.

## 6 Agreement Networks as a Second Topology

An ABM often contains an explicit interaction topology  $G_t^{\text{phys}}$  describing proximity, communication, trade, infrastructure, or social contact. Institutional relations define a second topology,

$$G_t^{\text{inst}} = (V, E_t^{\text{inst}}), \quad (10)$$

where an edge can encode a right, obligation, delegation, priority, claim, or other institutional relation.

The two graphs need not coincide. An actor may have no direct physical connection to another actor but become institutionally connected through a guarantee, delegated obligation, or contingent claim. Conversely, physically adjacent agents can have different institutional access to the same resource. Modeling both layers permits analysis of multiplex propagation in which events travel through physical and institutional relations differently.

This representation also suggests measurable quantities. For agent  $i$ , define the institutional action-space ratio

$$\rho_i(t) = \frac{|A_i(t)|}{|A_i^*(s_t)|}, \quad (11)$$

when the denominator is finite and nonzero. A regime-level measure is

$$\bar{\rho}(t) = \frac{1}{N} \sum_{i=1}^N \rho_i(t). \quad (12)$$

These quantities do not measure welfare or freedom in a normative sense; they measure how strongly the modeled institutional layer filters candidate actions. Distributional statistics of  $\rho_i(t)$  can reveal whether a regime has similar aggregate restrictiveness but highly unequal effects across agents.

## 7 Representative Cross-Domain Instantiations

The framework is intentionally abstract, but its interpretation can be illustrated with a small number of structurally different cases.

**Capacity and access.** Suppose manufacturer  $M$  holds a contractual claim to part of supplier  $S$ 's capacity. A shortage changes physical capacity for all firms, while the institutional allocation determines which firms retain access. The shock is physical; the distribution of feasible responses is partly institutional.

**Contingent financial claims.** If a default activates a collateral or guarantee right, a previously latent institutional edge becomes behaviorally relevant. The post-default exposure network therefore differs from the network inferred from ordinary payment flows alone.

**Service entitlements.** A care recipient can possess a formal service entitlement while realized access remains dependent on provider capacity, eligibility verification, and delegated responsibilities. The institutional model describes entitlement and responsibility; the physical/social model determines whether service can actually be delivered.

These examples are not intended as complete domain models. They illustrate why institutional state and non-institutional feasibility should be represented separately.

## 8 A Controlled Computational Experiment

The computational experiment isolates the institutional mechanism rather than simultaneously changing behavior and environment. All agents use the same candidate-action generator, behavioral policy, exogenous arrival process, physical resource capacity, and stochastic tie-breaking sequence under every condition. Only institutional admissibility and institutional-state transition rules differ. The unrestricted condition  $C_0$  is the null benchmark,  $C_1$  is the static institutional benchmark,  $C_2$  adds state-coupled institutional change, and  $C_{2F}$  is an alternative specification that preserves holder-specific total right exposure while removing its endogenous temporal placement.

### 8.1 Experimental conditions

Let  $A_i^*(s_t)$  denote the candidate set generated by the non-institutional model. Three substantive regimes and one paired timing ablation are compared.

Table 1: Institutional regimes and timing ablation used in the controlled experiment.

| Case     | Institutional regime                   | Operationalization                                                                                                                                                                                                                                                                                                                  |
|----------|----------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $C_0$    | No institutional filtering             | All four candidate actions are available whenever the agent has outstanding demand.                                                                                                                                                                                                                                                 |
| $C_1$    | Static institutional state             | Every agent holds rights to regular request, wait, and exit; a fixed 20% subgroup additionally holds a priority-request right.                                                                                                                                                                                                      |
| $C_2$    | Endogenous institutional state         | Starts from $C_1$ . When waiting reaches four steps, a modeled institutional event can grant a temporary priority-request right that remains active through institutional step $t + 2$ .                                                                                                                                            |
| $C_{2F}$ | Exposure-matched front-loaded ablation | For each matched seed and each non-static agent, the number of institutional steps for which a priority right is active in $C_2$ is measured. The same agent receives a priority right for exactly that many steps from $t = 0$ in $C_{2F}$ . Holder-specific total right exposure is preserved while endogenous timing is removed. |

Formally,

$$A_i^{C_0}(t) = A_i^*(s_t), \quad (13)$$

$$A_i^{C_1}(t) = \Phi_i(A_i^*(s_t), \mathcal{I}_0), \quad (14)$$

$$A_i^{C_2}(t) = \Phi_i(A_i^*(s_t), \mathcal{I}_t, H_t), \quad \mathcal{I}_{t+1} = \Psi(\mathcal{I}_t, s_t, \mathbf{a}_t, \omega_t). \quad (15)$$

For the ablation, let  $d_i^{C_2}$  denote the total number of global institutional steps during which non-static agent  $i$  holds an active temporary priority right in its matched  $C_2$  run. In  $C_{2F}$  that agent receives the same right at  $t = 0$  with duration  $d_i^{C_2}$ . Thus

$$\sum_t R_i^{C_2}(t) = \sum_t R_i^{C_{2F}}(t), \quad (16)$$

where  $R_i(t)$  indicates active priority-right exposure, but the temporal location of that exposure differs.  $C_{2F}$  is an ex post timing diagnostic rather than a proposed policy or an empirical causal estimator: it asks whether holder-specific exposure alone explains the  $C_2$  results, or whether the timing of institutional change matters.

## 8.2 Synthetic environment and fixed behavioral policy

The model contains 30 agents observed for 80 simulation steps. At each step, each agent receives a new unit of demand independently with probability 0.22. Physical service capacity is five units per step. Six agents (20%) belong to the fixed-priority subgroup in  $C_1$  and  $C_2$ . The candidate-action generator always proposes four actions for an agent with outstanding demand: `priority_request`, `regular_request`, `wait`, and `exit`.

The behavioral policy is unchanged across conditions. If the oldest unresolved demand has waited at least eight steps, the agent exits that demand when exit is admissible. Otherwise it selects the highest-ranked admissible action according to

$$\text{priority\_request} \succ \text{regular\_request} \succ \text{wait} \succ \text{exit}. \quad (17)$$

The physical allocator serves priority requests before regular requests and uses a pre-generated random tie breaker within each request class. Exogenous arrivals and tie breakers are generated once per stochastic seed and reused unchanged across  $C_0$ ,  $C_1$ ,  $C_2$ , and  $C_{2F}$ . This common-random-number design removes variation that is unrelated to the institutional treatment.

The reported analysis uses 100 matched stochastic runs with seeds 12000–12099. Mean arrivals are 527.43 demands per run. The experiment is deliberately synthetic: it is intended to identify the institutional mechanism, not to calibrate a substantive empirical system.

## 8.3 Mechanism and outcome measures

The principal mechanism measure is the action-space ratio

$$\rho_i(t) = \frac{|A_i(t)|}{|A_i^*(s_t)|}. \quad (18)$$

Additional mechanism measures include the Gini coefficient of agent-level mean  $\rho_i$ , the frequency of changes in admissible action sets, the number of endogenous institutional transitions, and the distribution of selected action types. Outcome measures include total service, exits, unresolved demand at the terminal step, waiting time among served demands, service-allocation concentration, and the share of service allocated to the fixed-priority subgroup.

For system outcome  $Y$ , paired effects are summarized as

$$\Delta_{jk} = Y(C_j) - Y(C_k), \quad (19)$$

with 95% percentile bootstrap intervals computed from the 100 paired run differences. The intervals describe simulation uncertainty under the specified stochastic process; they do not establish empirical uncertainty about a real population.

## 8.4 Robustness design

The baseline is supplemented by 18 additional parameter settings. Five parameters are varied one at a time at lower and higher levels, yielding ten one-factor-at-a-time settings, and eight compound settings combine scarcity, institutional asymmetry, and more or less responsive temporary rights. Table 2 reports the one-factor levels.

The eight compound settings are: high arrivals with low capacity; low arrivals with high capacity; high arrivals with either 10% or 40% static-priority shares; threshold 2 with expiry offset 4; threshold 6 with expiry offset 1; and the two latter dynamic designs repeated under high arrivals and low capacity. Every setting uses the same 100 matched seeds. The robustness analysis therefore contains 19 settings, four regimes or ablations per setting, and 7,600 run-level observations.

Table 2: Parameter levels used in the one-factor robustness analysis.

| Parameter                          | Low   | Baseline | High  |
|------------------------------------|-------|----------|-------|
| Arrival probability per agent-step | 0.165 | 0.220    | 0.275 |
| Service capacity per step          | 4     | 5        | 6     |
| Static-priority population share   | 0.10  | 0.20     | 0.40  |
| Dynamic waiting threshold          | 2     | 4        | 6     |
| Temporary-right expiry offset      | 1     | 2        | 4     |

## 9 Reference Implementation

DAMAGE is an important antecedent because it provides a formal precedent in which rights and obligations are first-class computational objects and external agents interact with an executable institutional environment [9]. The present framework adopts that insight as motivation but does not claim equivalence to DAMAGE’s language or runtime semantics.

InstiAct v0.4.6 is used as the reference implementation [3]. In  $C_1$ ,  $C_2$ , and  $C_{2F}$ , explicit **Right** objects determine whether request, wait, and exit actions are institutionally admissible. The  $C_2$  threshold event is represented as an institutional action whose accepted effect inserts a temporary priority-request right into the institutional state. In  $C_{2F}$  the same right type is instantiated at  $t = 0$  with a holder-specific expiry chosen to match total  $C_2$  exposure. The surrounding simulation retains responsibility for demand queues, physical capacity, stochastic scheduling, and action choice. Thus the experiment uses InstiAct only for the institutional component of the causal chain.

This separation is useful for reproducibility because the behavioral policy can be tested independently of the institutional component and alternative institutional regimes can be compared without rewriting the physical or behavioral model. The conceptual argument does not depend on InstiAct: another formalism capable of implementing the same separation could be substituted.

## 10 Mechanism Checks and Research Hypotheses

Two checks verify that the intended mechanism is actually present in the implemented experiment before substantive interpretation.

**MC1: action-space manipulation check.** The static rights treatment must change institutional action availability for at least some active agents,

$$\Pr\left(A_i^{C_1}(t) \neq A_i^{C_0}(t)\right) > 0. \quad (20)$$

This is an implementation check rather than a substantive theoretical discovery: if explicit rights do not alter the admissible set, the experiment has failed to instantiate its treatment.

**MC2: behavioral mediation check.** With the policy  $\pi_i$  held fixed, a change in admissible action sets should change the distribution of realized actions. This verifies the intended pathway  $\mathcal{I}_t \rightarrow A_i(t) \rightarrow a_{i,t}$ .

The two substantive hypotheses concern effects that are not fixed by construction.

**H1: state-coupled timing effect.** Conditional on matched holder-specific total priority-right exposure, the state-coupled timing of rights in  $C_2$  generates outcomes distinguishable from the front-loaded diagnostic  $C_{2F}$ . This tests whether equal right-time exposure is sufficient to characterize institutional influence.

**H2: distributional effect under macro similarity.** Aggregate throughput can remain similar while institutional exposure, waiting burdens, and allocation are redistributed across agents. This tests whether conventional aggregate outputs can conceal institutional effects.

## 11 Results

### 11.1 Regime-level outcomes

Table 3 reports the main baseline run-level means. Aggregate service is effectively invariant across conditions: the mean number served is 399.18 in both  $C_0$  and  $C_1$ , 399.19 in  $C_2$ , and 399.17 in  $C_{2F}$ , corresponding to a throughput rate of approximately 0.758 in every regime. Institutional differences nevertheless produce substantial changes in action-space exposure and allocation.

Table 3: Mean outcomes over 100 matched stochastic runs in the baseline setting.

| Measure                              | $C_0$  | $C_1$  | $C_2$  | $C_{2F}$ |
|--------------------------------------|--------|--------|--------|----------|
| Served demands                       | 399.18 | 399.18 | 399.19 | 399.17   |
| Exited demands                       | 100.18 | 103.29 | 94.38  | 103.31   |
| Unresolved demand at horizon         | 28.07  | 24.96  | 33.86  | 24.95    |
| Mean wait among served               | 2.744  | 2.178  | 3.685  | 2.299    |
| Service Gini                         | 0.132  | 0.161  | 0.142  | 0.172    |
| Fixed-priority service share         | 0.202  | 0.266  | 0.235  | 0.250    |
| Mean action-space ratio $\rho$       | 1.000  | 0.770  | 0.914  | 0.872    |
| Gini of agent-level mean $\rho$      | 0.000  | 0.050  | 0.026  | 0.042    |
| Action-set change rate               | 0.000  | 0.000  | 0.179  | 0.018    |
| Endogenous institutional transitions | 0.00   | 0.00   | 303.66 | 0.00     |

The static regime therefore changes distribution without changing aggregate capacity utilization. The fixed-priority subgroup comprises 20% of agents but receives 26.6% of service in  $C_1$ , compared with 20.2% in  $C_0$ . Service concentration rises from a Gini coefficient of 0.132 to 0.161. At the same time, the mean action-space ratio falls by 0.2301 relative to  $C_0$  (95% paired bootstrap interval  $[-0.2304, -0.2298]$ ), directly confirming that the encoded institutional architecture changes available actions.

In  $C_2$ , temporary contingent rights partially reverse this distributional concentration. Relative to  $C_1$ , the fixed-priority group’s service share decreases by 0.0313 (95% interval  $[-0.0340, -0.0289]$ ), service Gini decreases by 0.0184 ( $[-0.0220, -0.0149]$ ), and mean  $\rho$  increases by 0.1439 ( $[0.1427, 0.1452]$ ). The action-set change rate rises to 0.179, reflecting the repeated activation and expiry of contingent priority rights.

### 11.2 Behavioral mediation and finite-horizon tradeoffs

The institutional mechanism also changes realized action types. Priority requests account for 93.2% of selected actions in  $C_0$ , 8.0% in  $C_1$ , and 59.7% in  $C_2$ . Thus identical decision logic produces different action distributions because the policy is evaluated over different admissible sets, satisfying MC2.

The dynamic regime should not be interpreted as uniformly superior. Compared with  $C_1$ ,  $C_2$  reduces exits by 8.91 demands per run on average (95% interval  $[-9.33, -8.48]$ ) but leaves 8.90 more demands unresolved at the terminal horizon ( $[8.48, 9.32]$ ). Mean waiting time among served demands is 1.507 steps higher than in  $C_1$  ( $[1.472, 1.541]$ ). This occurs because the contingent-right rule keeps more long-waiting agents in competition for service instead of

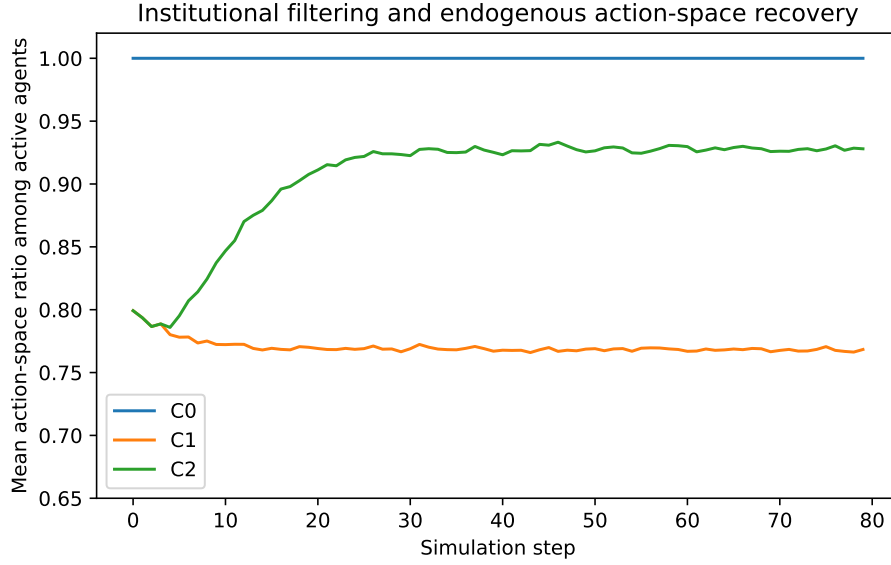


Figure 1: Mean action-space ratio among active agents by institutional regime.  $C_0$  leaves candidate sets unrestricted;  $C_1$  imposes a static rights architecture;  $C_2$  restores priority-request availability contingently through endogenous institutional transitions.

allowing them to exit at the behavioral patience threshold. The result is a redistribution of delay rather than a free efficiency gain.

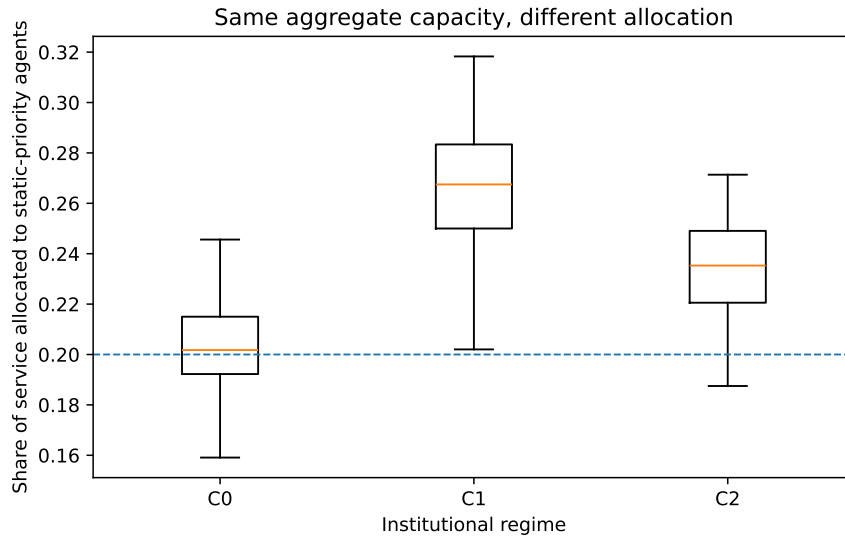


Figure 2: Share of service allocated to the fixed-priority subgroup. The dashed line marks the subgroup’s 20% population share. Static rights produce over-representation; endogenous contingent rights reduce, but do not eliminate, that advantage.

### 11.3 Exposure-matched timing ablation

The baseline  $C_2$ – $C_{2F}$  comparison isolates timing more directly than the  $C_2$ – $C_1$  comparison because each non-static agent has the same total number of institutional steps with a priority right in both conditions. Moving those rights to the start of the run nevertheless changes behavior

and outcomes. Relative to  $C_{2F}$ ,  $C_2$  increases mean active-agent  $\rho$  by 0.0418 (95% interval [0.0401, 0.0435]), increases mean wait among served demands by 1.385 steps ([1.354, 1.417]), reduces exits by 8.93 demands ([−9.37, −8.52]), and leaves 8.91 more demands unresolved at the horizon ([8.49, 9.32]). The fixed-priority group’s service share is 0.0150 lower ([−0.0173, −0.0125]) and service Gini is 0.0298 lower ([−0.0330, −0.0263]).

The action-space result is informative. Even though total holder-specific right exposure is matched,  $C_2$  produces a higher action-space ratio among active agents because rights are activated when waiting conditions make them behaviorally relevant. Equal right-time exposure is therefore not equivalent to equal effective institutional exposure. This supports H1 without requiring a claim that the endogenous design is normatively superior.

#### 11.4 Robustness across parameter settings

The main mechanism survives all 19 parameter settings. Static rights reduce the mean action-space ratio relative to  $C_0$  in every setting, with paired effects from −0.2406 to −0.2040 and bootstrap intervals excluding zero in all 19 settings. The fixed-priority service share increases in every setting, from a negligible +0.00034 under low-arrival/high-capacity slack to +0.2590 under high arrivals with a 40% priority group.

Dynamic rights also recover action-space availability relative to  $C_1$  in all 19 settings, with effects from +0.00229 to +0.20983. The fixed-priority allocation advantage falls in every setting, from −0.000066 in the slack case to −0.19709 under high arrivals with a 40% priority group. Action-set change rates are positive in every setting. By contrast, the effect of  $C_1$  on total service is small: the  $C_1 - C_0$  mean difference ranges from −0.47 to +0.01 served demands per run, and its bootstrap interval excludes zero in only three settings. Thus the distributional mechanism is substantially more stable than the aggregate-throughput response.

Table 4: Robustness of principal paired effects across 19 parameter settings. “CI nonzero” counts settings whose 95% paired bootstrap interval excludes zero.

| Contrast       | Outcome                | Expected sign | CI nonzero | Effect range         |
|----------------|------------------------|---------------|------------|----------------------|
| $C_1 - C_0$    | Mean $\rho$            | −             | 19/19      | [−0.2406, −0.2040]   |
| $C_1 - C_0$    | Fixed-priority share   | +             | 19/19      | [0.00034, 0.2590]    |
| $C_2 - C_1$    | Mean $\rho$            | +             | 19/19      | [0.00229, 0.20983]   |
| $C_2 - C_1$    | Fixed-priority share   | −             | 19/19      | [−0.19709, −0.00007] |
| $C_2 - C_1$    | Action-set change rate | +             | 19/19      | [0.00959, 0.21390]   |
| $C_2 - C_{2F}$ | Mean wait served       | +             | 19/19      | [0.00423, 1.79487]   |
| $C_2 - C_{2F}$ | Fixed-priority share   | −             | 17/19      | [−0.06179, −0.00007] |

Figure 3 reports static filtering and dynamic action-space recovery with the expected signs across all settings. The low-arrival/high-capacity case provides an informative boundary condition: the dynamic effect approaches zero because scarcity rarely makes temporary priority rights behaviorally relevant. Under high arrivals and low capacity, the same mechanism becomes much stronger.

Figure 4 illustrates H2. In high-scarcity settings, static rights can substantially redistribute service while mean total service remains essentially unchanged. Under slack, both allocation and throughput effects approach zero. The mechanism is therefore conditional on the institutional rule becoming behaviorally relevant, not mechanically large under every environment.

The timing ablation is also robust. Relative to exposure-matched front-loading, endogenous timing increases mean waiting among served demands in all 19 settings, with intervals excluding zero in all 19. The fixed-priority service share is lower in all 19, although the interval includes zero in two weak-activation settings. These results sharpen H1: the effect of a right depends not

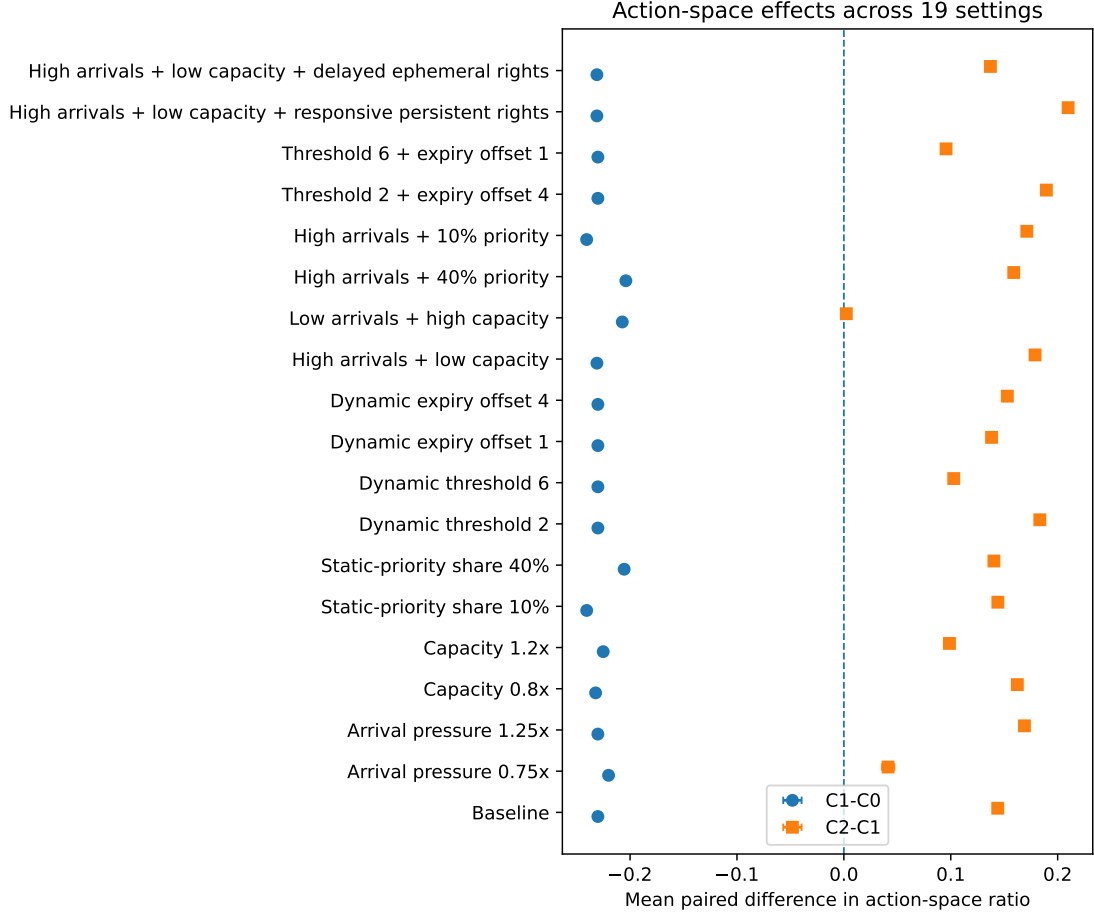


Figure 3: Paired action-space effects across 19 robustness settings.  $C_1 - C_0$  measures static institutional filtering;  $C_2 - C_1$  measures recovery of priority-action availability through endogenous temporary rights. Error bars are 95% paired bootstrap intervals.

only on who holds it and for how long, but also on when its availability is coupled to system state.

### 11.5 Assessment of mechanism checks and hypotheses

MC1 is satisfied because static institutional filtering changes admissible action sets in every tested setting. MC2 is satisfied by the large shift between priority and regular request actions under an unchanged policy. These checks confirm that the implementation realizes the intended mediation pathway; they are not presented as novel substantive findings.

H1 is supported by the exposure-matched  $C_2 - C_{2F}$  comparison: the temporal placement of rights changes waiting, active-agent action-space exposure, exits, and allocation even when holder-specific total right exposure is fixed. H2 is supported in the baseline and is strongest under scarcity: total service often changes little while institutional exposure and allocation concentration change substantially. The slack setting identifies a boundary condition, because institutional differences have little behavioral consequence when capacity is ample relative to demand.

These findings establish the computational relevance of the mechanism in the demonstrator. They do not establish that the same effects occur in a substantive empirical domain; that requires domain-specific institutional data and external validation.

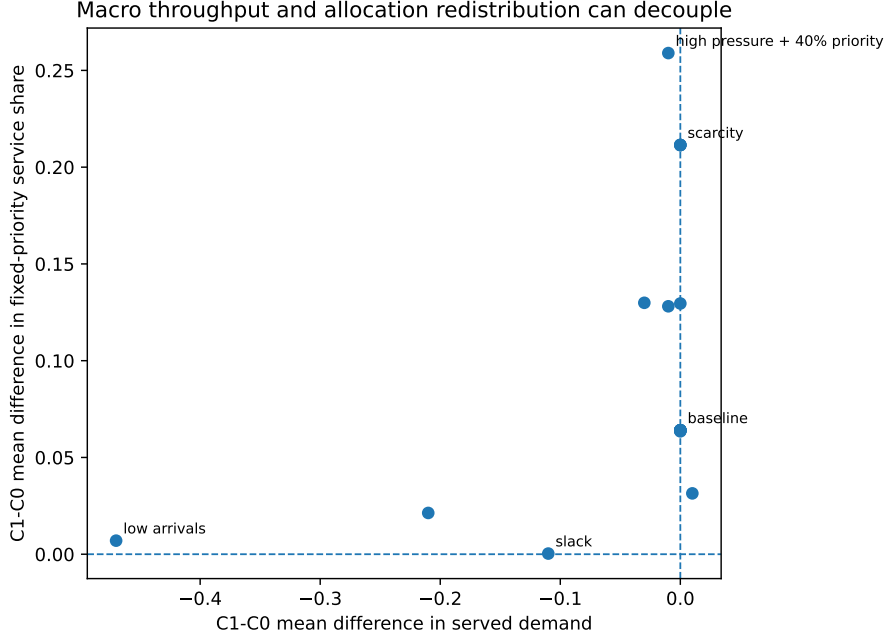


Figure 4: Mean  $C_1 - C_0$  change in total served demand versus the change in fixed-priority service share across robustness settings. Large vertical shifts with near-zero horizontal shifts illustrate distributional change under macro similarity.

## 12 Scope and Limitations

Several boundaries are necessary. First, institutional admissibility is a model construct; it does not establish legal validity or reproduce the full interpretation of real legal systems. Second, the framework does not imply that every institution operates by removing actions. Rights and obligations may also create new actions, alter priorities, or change consequences associated with actions. Third, the tuple  $\mathcal{I}_t$  is a modeling abstraction rather than a claim that institutional systems have a unique decomposition.

Fourth, institutional effects can also be represented through utilities, norms internalized by agents, learning, or social influence. The proposed approach is most useful when the research question requires a distinction between the rules governing an environment and the decision processes of agents operating within it. Finally, the demonstrator establishes computational relevance under the specified synthetic conditions, not empirical validity. The  $C_{2F}$  ablation is deliberately ex post: it uses the realized  $C_2$  exposure duration for each agent to construct a diagnostic counterfactual and should not be interpreted as an implementable institutional policy. The robustness grid is structured rather than exhaustive and is intended to test qualitative stability, not to identify globally optimal parameter values. The  $C_{2F}$  construction also conditions on exposure realized in the matched  $C_2$  run. It is therefore best interpreted as a simulation ablation of temporal placement under exposure matching, not as a general causal-identification procedure for observational institutional data. Finally, the priority-request mechanism and allocator are deliberately stylized; the experiment provides a controlled test of whether the proposed decomposition can generate and isolate effects; the particular magnitudes are not treated as generalizable to real allocation systems. Empirical applications require domain-specific institutional data, calibration or validation targets, and evidence that the encoded rules correspond to the system under study.

## 13 Relation to a Broader Agent-Based Research Program

The methodological value of the framework lies in making institutional architecture experimentally manipulable while preserving a modular ABM. It complements research in which heterogeneous agents, spatial environments, stochastic processes, and behavioral rules already generate system-level outcomes. An institutional layer adds a distinct causal channel:

$$\text{environmental event} \rightarrow \mathcal{I}_{t+1} \rightarrow A_i(t+1) \rightarrow a_{i,t+1} \rightarrow Y_{t+2}. \quad (21)$$

This formulation supports progressively richer work. A first stage can establish the mechanism in a minimal synthetic model. A second can examine network structure, heterogeneous institutional exposure, and endogenous institutional cascades. A third can introduce the institutional layer into substantive ABMs where access, entitlement, delegation, contractual relations, or governance rules are empirically relevant. Keeping these stages separate reduces the risk of attributing complex empirical outcomes to an institutional mechanism that has not first been identified in a controlled setting.

## 14 Conclusion

Institutional arrangements can be modeled as more than fixed context. When rights, obligations, permissions, restrictions, priorities, and transactions determine which actions are institutionally admissible, the institutional state becomes a dynamic component of an agent-based model. The resulting distinction between candidate actions, institutional admissibility, and behavioral choice permits controlled comparison of systems that are physically and behaviorally identical but institutionally different.

The controlled experiment provides a minimal test of this mechanism. A static rights architecture changes both action-space exposure and allocation concentration without materially changing aggregate service throughput in the baseline. Endogenous contingent rights then alter those distributions again, reducing the fixed-priority advantage and changing waiting and exit patterns while leaving physical capacity and behavioral policy unchanged. The 19-setting robustness study finds that the action-space and allocation effects retain their expected signs across changes in scarcity, priority-group size, trigger threshold, and right persistence. The exposure-matched  $C_{2F}$  ablation further indicates that temporal placement matters after holder-specific total right exposure is matched. Within the tested synthetic system, the results support the methodological decomposition

$$\mathcal{I}_t \rightarrow A_i(t) \rightarrow a_{i,t} \rightarrow s_{t+1} \rightarrow \mathcal{I}_{t+1}. \quad (22)$$

The important implication is not that dynamic institutional rules necessarily improve outcomes. In the baseline demonstrator, the endogenous regime reduces concentration and exits but increases finite-horizon waiting and unresolved demand; under slack these effects become very small, while scarcity amplifies them. Rather, within the tested synthetic system, the result is consistent with treating institutional dynamics as a distinct modeled causal layer that can redistribute access and burden even when conventional aggregate measures remain stable. Subsequent work can test the same decomposition in richer institutional networks and empirically grounded agent-based models.

## Data and Materials Availability

All model code, parameter settings, documented random seeds, run-level outputs, paired contrasts, and figure inputs used in the reported analysis are available upon reasonable request. No external empirical dataset is analyzed in this study.

## Reproducibility and Software Availability

The experiment is implemented in Python and uses InstiAct v0.4.6 [4] only for institutional admissibility and institutional-state changes. The accompanying reproducibility bundle contains the baseline and robustness runners, the exact 19-setting design, all 7,600 run-level observations, paired-contrast outputs, figure-generation inputs, automated tests, and an ODD-style model protocol documenting entities, state variables, scheduling, initialization, stochastic inputs, institutional treatments, outcome measures, and the identification logic. Six of six experiment tests pass in the archived bundle. The optimized robustness implementation was also compared with the earlier baseline implementation over 300  $C_0/C_1/C_2$  run-level records; the maximum absolute numerical difference was  $8.88 \times 10^{-16}$ , consistent with floating-point equivalence.

## Competing Interests

The author declares no competing interests.

## AI-Use Disclosure

Generative AI tools were used as research assistance during manuscript drafting and revision, code development and debugging, and document preparation. The author directed the research process, is responsible for verifying the model design, implementation, numerical outputs, citations, and interpretation, and retains full responsibility for the submitted work.

## References

- [1] Crawford, S. E. S. and Ostrom, E. (1995). A grammar of institutions. *American Political Science Review*, 89(3), 582–600. doi:10.2307/2082975.
- [2] Frantz, C. K., Purvis, M. K., Nowostawski, M., and Savarimuthu, B. T. R. (2014). Modelling institutions using dynamic deontics. In *Coordination, Organizations, Institutions, and Norms in Agent Systems IX*, Lecture Notes in Computer Science, vol. 8386, pp. 211–233. doi:10.1007/978-3-319-07314-9\_12.
- [3] Garrone, R. (2026). InstiAct: An executable institutional layer for agent-based and computational modeling: From agreement structures to dynamic action spaces. *Zenodo*. doi:10.5281/zenodo.23220549.
- [4] Garrone, R. (2026). InstiAct v0.4.6. *Zenodo*. doi:10.5281/zenodo.23220241.
- [5] Ghorbani, A., Bots, P. W. G., Dignum, V., and Dijkema, G. P. J. (2013). MAIA: A framework for developing agent-based social simulations. *Journal of Artificial Societies and Social Simulation*, 16(2), 9. doi:10.18564/jasss.2166.
- [6] Ghorbani, A., Dijkema, G. P. J., Bots, P. W. G., Alderwereld, H., and Dignum, V. (2014). Model-driven agent-based simulation: Procedural semantics of a MAIA model. *Simulation Modelling Practice and Theory*, 49, 27–40. doi:10.1016/j.simpat.2014.07.009.
- [7] Ghorbani, A. (2022). Institutional modelling: Adding social backbone to agent-based models. *MethodsX*, 9, 101801. doi:10.1016/j.mex.2022.101801.
- [8] McGinnis, M. D. (2011). Networks of adjacent action situations in polycentric governance. *Policy Studies Journal*, 39(1), 51–78. doi:10.1111/j.1541-0072.2010.00396.x.

- [9] Michael, L., Parkes, D. C., and Pfeffer, A. (2010). Specifying and monitoring economic environments using rights and obligations. *Autonomous Agents and Multi-Agent Systems*, 20(2), 158–197. doi:10.1007/s10458-009-9089-6.
- [10] Montes, N., Osman, N., and Sierra, C. (2022). A computational model of Ostrom’s Institutional Analysis and Development framework. *Artificial Intelligence*, 311, 103756. doi:10.1016/j.artint.2022.103756.
- [11] Morris-Martin, A., De Vos, M., and Padget, J. (2019). Norm emergence in multiagent systems: A viewpoint paper. *Autonomous Agents and Multi-Agent Systems*, 33, 706–749. doi:10.1007/s10458-019-09422-0.