

Supplementary Appendix

Critical Network Formation for Business Opportunity Creation

Computational settings, robustness specifications, verification procedures, and additional validation results

S1. Purpose and Reproducibility Scope

This appendix documents the computational settings and supplementary analyses used to evaluate critical network formation. It reports the baseline parameterization, experimental design, complete 81-specification robustness matrix, model verification tests, and additional compound-withdrawal results. The materials provide internal computational evidence under controlled assumptions and do not constitute empirical validation of organizational effect sizes.

S2. Baseline Model Parameters

Parameter	Baseline	Role
External actors	59	External candidate population
Required functions	5	Opportunity functions
Initial external members	3	Starting realized network
Maximum formation periods	12	Formation horizon
Baseline reinforcement periods	4	Postformation horizon
Functional heterogeneity	0.50	Baseline specialization
Opportunity interdependence	0.50	Baseline function-pair dependence
Commitment spillover	0.30	Relational spillover
Coordination penalty	0.25	Coordination-cost parameter
Actionability threshold	0.70	Formation threshold
Potential network generator	Role block	Baseline topology
Focal edge probability	0.12	Potential focal tie
Same-role edge probability	0.25	Within-role potential tie
Cross-role edge probability	0.08	Across-role potential tie
Erdos-Renyi edge probability	0.11	Alternative random topology
Preferential attachment links	3	Links per entering actor
Peer tie activation coefficient	0.55	Peer-tie activation
BD commitment increment	0.12	Increment for recruited actor
Uncertainty drag	0.035	Commitment penalty
Actionability function weight	0.65	Committed-completeness weight

Parameter	Baseline	Role
Redundancy weights	0.60 / 0.20 / 0.15 / 0.05	Function backup / dependency backup / access / influence

S3. Computational Experiment Settings

Common random numbers support paired strategy comparisons. Within a replication, compared strategies receive identical actor attributes, potential ties, functional dependencies, and stochastic streams. Functional-gap and adaptive two-stage strategies share the same formation path and diverge only after actionability triggers selective redundancy.

Analysis	Replication design	Principal variation	Base seed
Formation comparison	100 per controlled scenario	Five strategies and controlled scenarios	20260829
Reinforcement frontier	60 per 9 x 9 cell	Heterogeneity 0.10-0.90; cost 0.10-0.70	20260830
Specification sensitivity	20 paired replications	3 thresholds x 3 horizons x 3 generators x 3 weight schemes	20260831
Final horizon validation	120 per cell	Heterogeneity 0.30/0.60/0.90; cost 0.25/0.45/0.625; horizons 2/4/6	20260901
Dynamic validation	100 per cell	Interdependence 0.25/0.50/0.75; spillover 0.15/0.30/0.60	20260901

S4. Robustness Design

The factorial robustness design varies the actionability threshold (0.65, 0.70, 0.75), reinforcement horizon (2, 4, 6 periods), potential network generator (role block, Erdos-Renyi, preferential attachment), and adaptive score weights (baseline, functional emphasis, relational emphasis), producing 81 specifications. Within each specification, heterogeneity takes 0.30, 0.60, and 0.90 and coordination cost takes 0.25, 0.45, and 0.625.

Across all specifications, the heterogeneity coefficient is positive in 79%, the coordination coefficient is negative in 91%, both directions are preserved in 75%, and the interaction coefficient is negative in 53%.

S4.1 Factor-Level Directional Stability

Factor	Level	N	Het. +	Coord. -	Interaction -	Both	Fav. effect	Formation
Actionability threshold	0.65	27	0.67	0.85	0.48	0.63	0.0091	1.00
Actionability threshold	0.7	27	0.78	0.96	0.56	0.74	0.0087	0.99
Actionability threshold	0.75	27	0.93	0.93	0.56	0.89	0.0082	0.67
Reinforcement steps	2.0	27	0.48	0.74	0.00	0.37	0.0126	0.89
Reinforcement steps	4.0	27	1.00	1.00	0.67	1.00	0.0096	0.89
Reinforcement steps	6.0	27	0.89	1.00	0.93	0.89	0.0038	0.89
Network generator	Erdos-Renyi	27	0.93	0.85	0.59	0.81	0.0085	0.89
Network generator	Preferential attachment	27	0.70	1.00	0.41	0.70	0.0098	0.88
Network generator	Role block	27	0.74	0.89	0.59	0.74	0.0077	0.89
Weight scheme	Baseline	27	0.70	1.00	0.52	0.70	0.0101	0.89
Weight scheme	Functional emphasis	27	0.81	0.93	0.48	0.81	0.0102	0.89
Weight scheme	Relational emphasis	27	0.85	0.81	0.59	0.74	0.0057	0.89

S4.2 Complete 81-Specification Matrix

Table S4 reports every factorial specification. RB = role block; ER = Erdos-Renyi; PA = preferential attachment. B = baseline weights; F = functional emphasis; R = relational emphasis. Coefficients come from the specification-level response surface.

Spec.	Thr.	Hor.	Net.	Wt.	Het. coef.	Coord. coef.	Int. coef.	Both	Formation	Fav. effect
1	0.65	2	ER	B	-0.0049	-0.0033	0.0730	N	1.00	0.0107
2	0.65	2	ER	F	-0.0034	0.0064	0.0634	N	1.00	0.0096
3	0.65	2	ER	R	0.0139	0.0167	0.0631	N	1.00	0.0035
4	0.65	2	PA	B	-0.0184	-0.0298	0.0983	N	1.00	0.0214
5	0.65	2	PA	F	-0.0197	-0.0308	0.1295	N	1.00	0.0231
6	0.65	2	PA	R	-0.0115	-0.0124	0.0923	N	1.00	0.0116
7	0.65	2	RB	B	-0.0105	-0.0059	0.0419	N	1.00	0.0111
8	0.65	2	RB	F	-0.0056	0.0042	0.0466	N	1.00	0.0104
9	0.65	2	RB	R	-0.0097	0.0205	0.0271	N	1.00	0.0026
10	0.65	4	ER	B	0.0296	-0.0176	0.0039	Y	1.00	0.0119
11	0.65	4	ER	F	0.0293	-0.0205	-0.0156	Y	1.00	0.0131
12	0.65	4	ER	R	0.0277	-0.0146	0.0341	Y	1.00	0.0075
13	0.65	4	PA	B	0.0144	-0.0308	0.0243	Y	1.00	0.0134
14	0.65	4	PA	F	0.0110	-0.0254	0.0522	Y	1.00	0.0114
15	0.65	4	PA	R	0.0224	-0.0099	0.0005	Y	1.00	0.0074
16	0.65	4	RB	B	0.0247	-0.0210	-0.0265	Y	1.00	0.0122

Spec.	Thr.	Hor.	Net.	Wt.	Het. coef.	Coord. coef.	Int. coef.	Both	Formation	Fav. effect
17	0.65	4	RB	F	0.0217	-0.0294	-0.0105	Y	1.00	0.0133
18	0.65	4	RB	R	0.0266	-0.0019	-0.0574	Y	1.00	0.0081
19	0.65	6	ER	B	0.0172	-0.0173	-0.0283	Y	1.00	0.0073
20	0.65	6	ER	F	0.0164	-0.0154	-0.0378	Y	1.00	0.0071
21	0.65	6	ER	R	0.0213	-0.0098	-0.0309	Y	1.00	0.0028
22	0.65	6	PA	B	-0.0002	-0.0173	-0.0005	N	1.00	0.0051
23	0.65	6	PA	F	0.0038	-0.0133	-0.0080	Y	1.00	0.0049
24	0.65	6	PA	R	0.0091	-0.0160	-0.0154	Y	1.00	0.0026
25	0.65	6	RB	B	0.0144	-0.0181	-0.0508	Y	1.00	0.0052
26	0.65	6	RB	F	0.0102	-0.0203	-0.0393	Y	1.00	0.0055
27	0.65	6	RB	R	0.0151	-0.0099	-0.0510	Y	1.00	0.0017
28	0.70	2	ER	B	0.0062	-0.0176	0.0479	Y	0.99	0.0133
29	0.70	2	ER	F	0.0094	-0.0131	0.0381	Y	0.99	0.0145
30	0.70	2	ER	R	0.0083	0.0016	0.0192	N	0.99	0.0091
31	0.70	2	PA	B	-0.0040	-0.0414	0.0761	N	0.98	0.0196
32	0.70	2	PA	F	-0.0047	-0.0373	0.1087	N	0.98	0.0191
33	0.70	2	PA	R	0.0052	-0.0138	0.0438	Y	0.98	0.0124
34	0.70	2	RB	B	-0.0070	-0.0274	0.0477	N	1.00	0.0130
35	0.70	2	RB	F	-0.0036	-0.0195	0.0464	N	1.00	0.0133
36	0.70	2	RB	R	-0.0120	-0.0024	0.0610	N	1.00	0.0047
37	0.70	4	ER	B	0.0300	-0.0131	-0.0511	Y	0.99	0.0116
38	0.70	4	ER	F	0.0286	-0.0119	-0.0622	Y	0.99	0.0119
39	0.70	4	ER	R	0.0258	-0.0098	-0.0176	Y	0.99	0.0076
40	0.70	4	PA	B	0.0144	-0.0237	0.0031	Y	0.98	0.0107
41	0.70	4	PA	F	0.0100	-0.0137	0.0265	Y	0.98	0.0076
42	0.70	4	PA	R	0.0198	-0.0064	-0.0244	Y	0.98	0.0053
43	0.70	4	RB	B	0.0195	-0.0290	-0.0183	Y	1.00	0.0109
44	0.70	4	RB	F	0.0201	-0.0284	-0.0087	Y	1.00	0.0117
45	0.70	4	RB	R	0.0214	-0.0175	-0.0252	Y	1.00	0.0077
46	0.70	6	ER	B	0.0141	-0.0166	-0.0243	Y	0.99	0.0062
47	0.70	6	ER	F	0.0129	-0.0119	-0.0284	Y	0.99	0.0051
48	0.70	6	ER	R	0.0162	-0.0114	-0.0361	Y	0.99	0.0031
49	0.70	6	PA	B	-0.0020	-0.0163	-0.0013	N	0.98	0.0042
50	0.70	6	PA	F	0.0017	-0.0085	-0.0119	Y	0.98	0.0041
51	0.70	6	PA	R	0.0055	-0.0144	-0.0218	Y	0.98	0.0021
52	0.70	6	RB	B	0.0112	-0.0135	-0.0045	Y	1.00	0.0021
53	0.70	6	RB	F	0.0079	-0.0119	0.0035	Y	1.00	0.0034
54	0.70	6	RB	R	0.0115	-0.0101	-0.0030	Y	1.00	0.0005
55	0.75	2	ER	B	0.0116	-0.0169	0.0720	Y	0.68	0.0127
56	0.75	2	ER	F	0.0156	-0.0116	0.0946	Y	0.68	0.0129
57	0.75	2	ER	R	0.0103	0.0045	0.0371	N	0.68	0.0108
58	0.75	2	PA	B	0.0057	-0.0590	0.0846	Y	0.67	0.0177
59	0.75	2	PA	F	0.0111	-0.0583	0.0863	Y	0.67	0.0189
60	0.75	2	PA	R	0.0109	-0.0205	0.0417	Y	0.67	0.0103
61	0.75	2	RB	B	0.0051	-0.0193	0.0861	Y	0.67	0.0129
62	0.75	2	RB	F	0.0082	-0.0240	0.0830	Y	0.67	0.0143
63	0.75	2	RB	R	-0.0033	0.0060	0.0791	N	0.67	0.0080

Spec.	Thr.	Hor.	Net.	Wt.	Het. coef.	Coord. coef.	Int. coef.	Both	Formation	Fav. effect
64	0.75	4	ER	B	0.0254	-0.0160	-0.0008	Y	0.68	0.0089
65	0.75	4	ER	F	0.0211	-0.0126	-0.0024	Y	0.68	0.0087
66	0.75	4	ER	R	0.0232	-0.0084	-0.0331	Y	0.68	0.0069
67	0.75	4	PA	B	0.0146	-0.0260	0.0037	Y	0.67	0.0082
68	0.75	4	PA	F	0.0143	-0.0215	0.0157	Y	0.67	0.0078
69	0.75	4	PA	R	0.0178	-0.0030	-0.0339	Y	0.67	0.0049
70	0.75	4	RB	B	0.0222	-0.0394	-0.0261	Y	0.67	0.0104
71	0.75	4	RB	F	0.0218	-0.0417	-0.0222	Y	0.67	0.0109
72	0.75	4	RB	R	0.0217	-0.0257	-0.0351	Y	0.67	0.0079
73	0.75	6	ER	B	0.0121	-0.0176	-0.0158	Y	0.68	0.0050
74	0.75	6	ER	F	0.0080	-0.0039	-0.0289	Y	0.68	0.0040
75	0.75	6	ER	R	0.0136	-0.0103	-0.0369	Y	0.68	0.0026
76	0.75	6	PA	B	-0.0004	-0.0152	-0.0051	N	0.67	0.0037
77	0.75	6	PA	F	0.0025	-0.0116	-0.0012	Y	0.67	0.0046
78	0.75	6	PA	R	0.0099	-0.0183	-0.0044	Y	0.67	0.0014
79	0.75	6	RB	B	0.0133	-0.0156	-0.0101	Y	0.67	0.0029
80	0.75	6	RB	F	0.0130	-0.0162	0.0098	Y	0.67	0.0036
81	0.75	6	RB	R	0.0126	-0.0129	-0.0079	Y	0.67	0.0008

S5. Final Validation and Compound Withdrawal

Final validation enumerates every unordered pair of selected external actors. Random-pair resilience is mean actionability across pair removals; worst-pair resilience is the minimum. Intervals use 2,000 replication-cluster bootstrap samples.

S5.1 Reinforcement Horizon Results

Horizon	Outcome	Mean delta	95% CI low	95% CI high
2	Single actor mean resilience	0.0110	0.0088	0.0132
2	Random pair mean resilience	0.0206	0.0177	0.0235
2	Worst pair resilience	0.0228	0.0119	0.0341
2	Pair opportunity retention	0.0185	0.0103	0.0266
2	Final actionability	-0.0018	-0.0034	-0.0002
4	Single actor mean resilience	0.0066	0.0051	0.0081
4	Random pair mean resilience	0.0159	0.0136	0.0182
4	Worst pair resilience	0.0467	0.0353	0.0586
4	Pair opportunity retention	0.0185	0.0111	0.0266
4	Final actionability	-0.0020	-0.0030	-0.0010
6	Single actor mean resilience	0.0014	0.0004	0.0024
6	Random pair mean resilience	0.0062	0.0047	0.0078
6	Worst pair resilience	0.0449	0.0313	0.0591
6	Pair opportunity retention	-0.0116	-0.0191	-0.0041

Horizon	Outcome	Mean delta	95% CI low	95% CI high
6	Final actionability	-0.0023	-0.0030	-0.0015

S5.2 Opportunity Interdependence

Interdependence	Outcome	Mean delta	95% CI low	95% CI high
0.25	Single actor mean resilience	0.0151	0.0118	0.0183
0.25	Random pair mean resilience	0.0268	0.0218	0.0322
0.25	Worst pair resilience	0.0230	0.0049	0.0406
0.50	Single actor mean resilience	0.0076	0.0045	0.0102
0.50	Random pair mean resilience	0.0191	0.0151	0.0230
0.50	Worst pair resilience	0.0456	0.0283	0.0630
0.75	Single actor mean resilience	0.0138	0.0116	0.0159
0.75	Random pair mean resilience	0.0283	0.0253	0.0313
0.75	Worst pair resilience	0.0722	0.0620	0.0837

Opportunity interdependence has a positive coefficient for worst-pair resilience (0.0983; 95% cluster-bootstrap interval 0.0577 to 0.1368). Its coefficients for single-actor and random-pair mean resilience are not stable. Commitment spillover likewise lacks a stable coefficient across these outcomes.

S6. Model Verification

Verification test	Procedure	Required condition
Missing-function invariant	Remove all capability for one required function.	Potential completeness and actionability equal zero.
Seed reproducibility	Repeat environment generation and simulation with identical seeds.	Capabilities and simulation results are identical.
Candidate-score coverage	Compute scores for every strategy.	Every available candidate receives a score under every strategy.
Adaptive phase switch	Compare adaptive scores before and after formation.	Adaptive matches functional-gap recruitment during formation and changes criterion after actionability.
Graph structure	Generate all three supported potential-network types.	Adjacency matrices are symmetric with empty diagonals.
Boundedness	Evaluate model state metrics.	All state measures remain within [0,1].

Verification test	Procedure	Required condition
Experiment-level pairing	Run reduced experiment self-tests.	Paired functional-gap and adaptive runs preserve matching formation paths and expected output structures.

The supplied program modules contain executable self-tests for the core model, phase-boundary experiment, sensitivity experiment, and final-validation experiment. These checks address implementation fidelity and reproducibility rather than empirical validation.