Network Motifs and the Rise of Entrepreneurial Ecosystems

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Motivation. Entrepreneurial ecosystem research has primarily focused on macro-level attributes such as aggregate venture capital (VC) availability, university strength, and regulatory conditions [1], [2]. While this perspective has clarified why some regions outperform others, it often treats ecosystems as "black boxes," overlooking the micro-level relational structures through which actors create and mobilize resources [2], [3]. Because ecosystems are fundamentally networked systems, understanding how local interaction patterns aggregate into regional outcomes is essential [2], [4]. Without examining these micro-foundations, ecosystem theory remains incomplete and policy interventions risk being misdirected.

This study addresses this gap by examining how network motifs (small recurring subgraphs representing fundamental interaction patterns) within venture capital co-investment networks predict ecosystem rise. When venture capitalists syndicate deals, they form structured ties reflecting trust, information exchange, and complementarity [5], [6], [7]. Rather than focusing on dyadic ties or global network metrics, I analyze motif structures that capture intermediate coordination logics. Three research questions guide the analysis:

1. Do entrepreneurial ecosystems exhibit distinct motif signatures?
2. How do specific motif patterns correlate with ecosystem growth trajectories?
3. Does motif heterogeneity (diversity in investor type, success rate, or organizational age within motifs) predict more sustained growth than homogeneous structures?

Approach and Methodology. Network motifs are small recurring subgraphs that appear more frequently than expected by chance and function as building blocks of complex systems [8], [9]. I introduce motif analysis to entrepreneurial finance by studying VC co-investment networks across 29 U.S. state ecosystems from 2015–2024.

For each state-year, I construct an undirected network in which nodes represent VC investors and ties represent repeated co-investment (≥2 shared deals). I detect four canonical induced motifs:

- Triangles (3-node cliques): dense, trust-based coordination
- Squares (4-node cycles): indirect trust chains
- Pentagons (5-node cycles): extended recombinatory coordination
- Hexagons (6-node cycles): scalable orchestration and bridging

To assess structural diversity, I compute three entropy-based heterogeneity indices measuring diversity within motifs by: Investor type (corporate vs. independent VC, angel, etc.); Prior success rate; Organizational age.

Ecosystem vitality is measured using three outcomes: Share of U.S. VC capital; Share of U.S. deal count; Rank increase in annual capital rankings. Panel OLS regressions with year fixed effects estimate the relationship between motif composition and performance, controlling for network size, density, and prior performance. Robustness tests include one-year lags and alternative rolling windows (2- and 3-year).

Results. Entrepreneurial ecosystems exhibit systematic structural differences in their underlying venture capital co-investment networks. Established ecosystems such as California, New York, and Massachusetts are characterized by high shares of triangles and hexagons, reflecting dense trust clusters and orchestrated large-scale coordination. In contrast, booming ecosystems display elevated shares of

squares and pentagons, indicating extended trust chains that facilitate new investor entry and rapid expansion. These distinct motif signatures map clearly onto developmental stages and directly answer Research Question 1: ecosystem evolution is associated with identifiable structural configurations. Importantly, motif composition is not merely descriptive but predictive. A one-standard-deviation increase in pentagon share is associated with a 12.1% increase in growth ($p < 0.01$), while hexagon share predicts a 20.3% increase ($p < 0.01$). Squares are positively linked to rank mobility. These effects remain robust after controlling for network density, investor count, and prior performance, and persist in lagged specifications. Triangles correlate strongly with capital share in mature ecosystems, suggesting that dense trust-based coordination supports capital mobilization, whereas squares and pentagons are particularly relevant for upward mobility, consistent with the idea that extended trust chains enable ecosystem ascent.

The most critical finding concerns structural heterogeneity within motifs. Heterogeneous configurations outperform homogeneous ones: type heterogeneity predicts a 13.6% increase in growth ($p < 0.05$), success heterogeneity an 11.8% increase ($p < 0.05$), and age heterogeneity a 9.1% increase ($p < 0.10$). Mixing investor types, experience levels, and track records within small-scale coordination structures enhances both resilience and expansion, indicating that ecosystem vitality depends not only on motif presence but on the diversity embedded within those motifs. Overall, the study demonstrates that micro-level network motifs are powerful predictors of entrepreneurial ecosystem rise and bridges relational coordination with regional performance. The evidence suggests that ecosystem policy should move beyond aggregate capital accumulation toward fostering diverse collaborative structures that enable extended trust chains and heterogeneous coordination.

Table 1: Venture capital invested by U.S. ecosystem (selected states, USD millions)

State	2015	2019	2021	2024
California	28,450	52,380	98,240	92,100
New York	8,920	16,780	32,450	30,540
Massachusetts	6,780	11,230	19,870	18,920
Texas	2,340	5,680	12,340	16,780
Florida	1,450	3,240	7,120	10,890

Triangles represent dense trust-based coordination; squares and pentagons capture extended trust chains; hexagons reflect scalable orchestrated collaboration among multiple investors.

Table 2: Motif structure, heterogeneity, and ecosystem performance

Variable	Coefficient	Significance
Triangles	0.182	***
Squares	0.094	**
Pentagons	0.121	***
Hexagons	0.203	***
Het. (type)	0.136	**
Het. (success)	0.118	**
Het.(age)	0.091	*

Dep. variable: share of U.S. VC capital. Year fixed effects included. N = 290.
$p < 0.01$, $p < 0.05$, $p < 0.10$.

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