Temporal Motif Structures in Japanese Corporate Shareholding Networks

Ownership network, Temporal network, Network motif, Corporate governance, Cross-shareholding

Extended Abstract

Corporate shareholding relationships have attracted attention from both asset management and corporate governance perspectives. Network analysis provides a systematic framework to examine such relationships, revealing structural invariance through centrality metrics [1]. The use of network motifs, small subgraphs that appear significantly more or less frequently than in randomized networks, has clarified the mechanisms of economic networks [2]. Motif-based analyses of Chinese corporate shareholding networks have shown that reciprocal ties are relatively rare and V-shaped motifs are dominant [3]. In this study, we analyze corporate shareholding relationships among all listed companies in Japan from January 2001 to March 2023, using Nikkei NEEDS data. Networks are represented as unweighted directed graphs: nodes represent companies, and edges point from shareholders to invested firms. Annual fiscal-year snapshots yielded 23 networks, averaging 3,530 nodes. Directed edges averaged 32,495 in 2001–2010 and rose to 44,169 in 2011–2023, reflecting regulatory reforms that expanded disclosure of major shareholdings. Directed three-node subgraphs yield 13 distinct motifs, depending on edge configuration. Motif significance was evaluated using Z-scores, $z_i = (N_i - \langle N_i^{rand} \rangle)/\sigma_i$, where N_i denotes the number of occurrences of motif i, $\langle N_i^{rand} \rangle$ the average number in randomized networks, and σ_i denotes the standard deviation in randomized ensemble, which preserves in-degree, out-degree, and reciprocity distributions. Notably, two-node motif analysis shows reciprocal ties as persistently overrepresented relative to one-way ties.

Figure 1 shows the temporal variation of motif Z-scores, computed against 1,000 randomized networks. Motifs 1-6 consistently exhibit large positive Z-scores in stark contrast to V-shaped motifs (8–13), which remain significantly underrepresented (negative Z-scores). A loop motif (7) shows no significant deviation from random expectation, indicating neither overrepresentation nor underrepresentation. The temporal trajectory of motifs 1-3 highlights three distinct phases: (i) a decline in 2008 or 2009, reflecting the impact of the global financial crisis; (ii) a surge from 2010 onward, attributable to expanded disclosure requirements; and (iii) a gradual decline from 2016, likely linked to policy interventions discouraging cross-shareholding. Interestingly, motif 3 is more prevalent than motif 4, which may indicate that hierarchical structures, where some firms hold shares in companies that are engaged in reciprocal ties, are more common than joint-control structures where reciprocally linked firms co-hold another company. Furthermore, the number of occurrences of motif 3 decreased more sharply than those of motifs 1 and 2 after 2016, indicating that firms controlling companies involved in reciprocal shareholdings responded sensitively to policy interventions. These findings highlight highly clustered three-node motifs as a defining feature of Japanese corporate networks, distinguishing them from other markets such as China. Cross-shareholding practices are well known in countries including Japan, Korea, Germany, and France, and our analysis further clarifies this characteristic from the perspective of network motifs. A remaining challenge is to clarify the mechanisms by which reciprocal shareholding ties are formed and sustained, which will be an important direction for future research.

References

[1] Shinichiro Tanabe and Takaaki Ohnishi. "Analysis of cross-shareholding network of Japanese listed companies". In: *Complex Networks & Their Applications XIII*. Ed. by Hocine Cherifi et al. Cham: Springer Nature Switzerland, 2025, pp. 187–199.

[2] Takaaki Ohnishi, Hideki Takayasu, and Misako Takayasu. "Network motifs in an inter-firm network". In: *Journal of Economic Interaction and Coordination* 5.2 (2010), pp. 171–180.

[3] Qian Liu et al. "A motif-based analysis to reveal local implied information in cross-shareholding networks". In: *Complexity* 2018.1 (2018), p. 7519631.

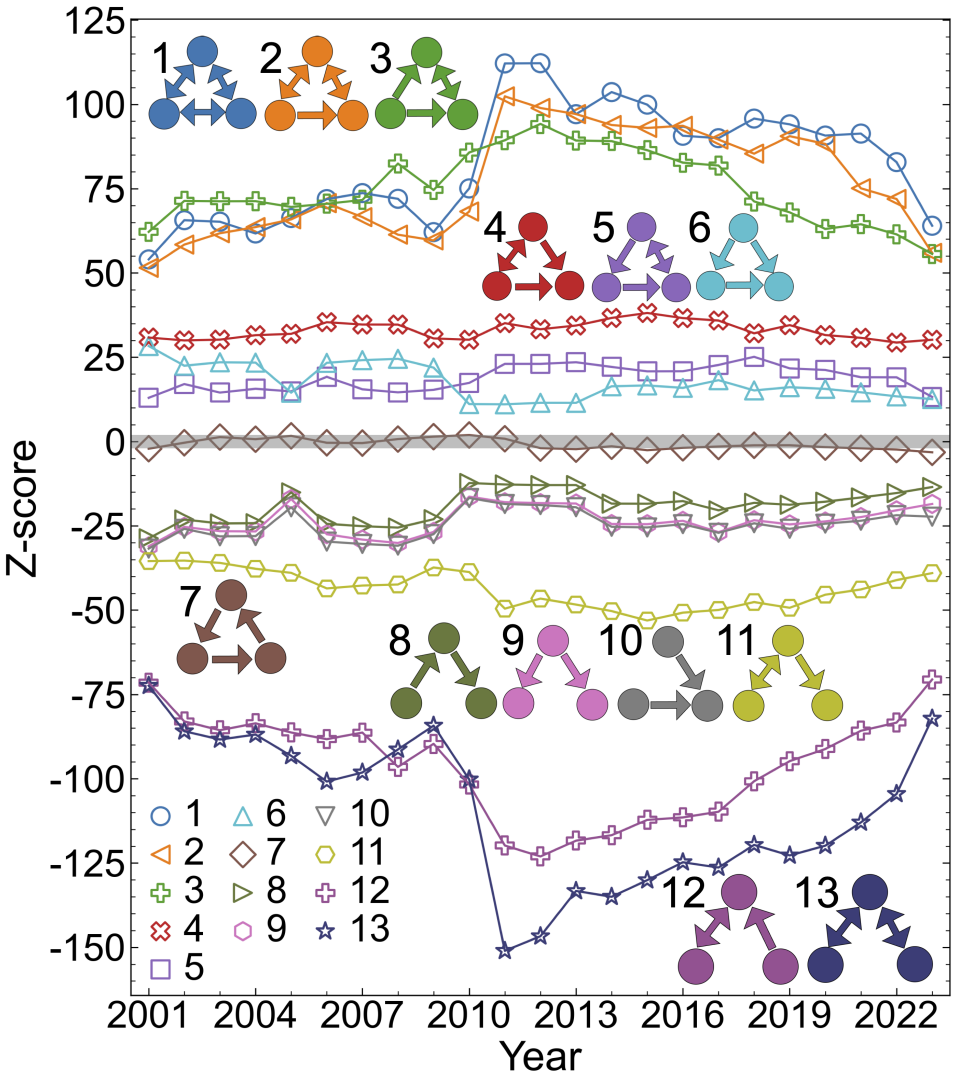

Figure 1: **Temporal variation of three-node motif Z-scores in Japanese corporate shareholding networks.** Thirteen motif types are analyzed using Z-scores against 1,000 randomized networks preserving degree and reciprocity. Gray shading indicates 95% confidence intervals. Motifs 1-6 are consistently overrepresented, while V-shaped motifs (8–13) are underrepresented. A loop motif (7) shows no significant deviation from random expectation.