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Digital Platform Ecosystems and Innovation Performance: A Configurational Analysis of Complementor Strategies in B2B Technology Markets

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Research Highlights

- Productive complementors in B2B platform ecosystems achieve 38% higher innovation output than their standalone peers, but only under specific governance configurations, not universally.
- Using fuzzy-set Qualitative Comparative Analysis (fsQCA) on 147 complementors across six B2B platform ecosystems, we identify three equifinal pathways to high innovation performance.
- High platform openness combined with low contract specificity produces the strongest innovation outcomes, contradicting assumptions that tight governance always benefits complementors.
- Complementor technological modularity is a necessary but not sufficient condition; it must be combined with at least one of: (a) platform orchestration intensity, (b) relational embeddedness.
- The findings challenge the linear "more is better" logic of platform governance and offer a configurational contingency framework for ecosystem managers and policymakers.

Abstract. Platform ecosystems have become the dominant organizational form in digital markets, yet the mechanisms through which complementor strategies translate into innovation performance remain undertheorized. Drawing on the resource-based view, transaction cost economics, and the dynamic capabilities framework, this study examines how four platform governance dimensions—openness, contract specificity, orchestration intensity, and relational embeddedness—combine with complementor technological modularity to produce high innovation performance. Employing fuzzy-set Qualitative Comparative Analysis (fsQCA) on a sample of 147 complementors embedded in six B2B technology platform ecosystems (SAP, Siemens MindSphere, Microsoft Azure IoT, PTC ThingWorx, GE Predix, and Bosch IoT Suite), we identify three equifinal configurations that yield above-median innovation output. Our results reveal that high platform openness, counterintuitively, requires low contract specificity to unlock complementor innovation, challenging prevailing transaction-cost logic

that predicts tighter contracting in more open environments. Furthermore, we find that complementor technological modularity is a necessary condition for high innovation performance—no configuration achieves superior outcomes without it. We contribute to the platform governance literature by introducing a configurational perspective that moves beyond net-effects thinking, and to innovation management by identifying the combinatorial conditions under which digital ecosystems fulfill their generative potential. Managerial implications for both platform owners and complementors are discussed, along with boundary conditions and directions for future research.

Keywords: digital platform ecosystems; innovation performance; complementor strategy; fuzzy-set QCA; platform governance; B2B technology markets; configurational analysis; digital transformation

JEL Classification: O32; L14; L86; M15; O33

Subjects: Digital Business; Innovation Management; Platform Strategy; Technology Management; Strategic Management

1. Introduction

Digital platforms have fundamentally reshaped the competitive landscape of technology-intensive industries. As Teece (2018) observes, the platform economy now accounts for over 70% of the market capitalization of the world's ten largest companies, and platform-mediated value creation is projected to reach $60 trillion by 2030. Central to this transformation is the role of *complementors*—the independent firms that develop applications, services, and modules on top of platform infrastructures. These complementors represent a critical engine of ecosystem-level innovation, yet the conditions under which their innovation efforts flourish remain poorly understood (Cennamo, 2021; McIntyre and Srinivasan, 2017).

The platform governance literature has largely adopted a linear, net-effects paradigm in studying complementor outcomes. Studies have examined how individual governance mechanisms—such as platform openness (Boudreau, 2010; Parker and Van Alstyne, 2018), contractual specificity (Gulati and Puranam, 2009; Williamson, 1985), or relational embeddedness (Dyer and Singh, 1998; Uzzi, 1997)—influence complementor behavior and performance. However, this approach implicitly assumes additive and symmetrical effects, neglecting the possibility that governance mechanisms may interact in complex, non-linear configurations that produce equifinal outcomes (Fiss, 2011; Misangyi and Acharya, 2014).

The linearity assumption is particularly problematic in platform ecosystems, where governance mechanisms are *co-determined* by platform owners and not independently manipulable. A platform that increases openness, for instance, may simultaneously relax contractual specificity to attract a broader base of complementors—creating a *configuration* of governance choices whose combined effect on innovation cannot be reduced to the sum of its parts. As Cennamo and Santalo (2013) and Tiwana (2014) have argued, platform governance is inherently a systems-level phenomenon that demands configurational theorizing.

To address this gap, we pose the following research questions:

1. **RQ1:** What configurations of platform governance mechanisms and complementor technological modularity are associated with high innovation performance in B2B platform ecosystems?

2. **RQ2:** Are any individual governance conditions *necessary* for high complementor innovation performance, or do multiple equifinal pathways exist?

We investigate these questions using fuzzy-set Qualitative Comparative Analysis (fsQCA), a set-theoretic method specifically designed for configurational inquiry (Ragin, 2008; Schneider and Wagemann, 2012). Our sample comprises 147 complementors operating within six B2B technology platform ecosystems. We examine five causal conditions: platform openness, contract specificity, orchestration intensity, relational embeddedness, and complementor technological modularity.

The study offers three principal contributions. First, we introduce a configurational perspective to the platform governance literature, identifying three equifinal pathways to complementor innovation performance—challenging the assumption that any single governance "best practice" exists. Second, we demonstrate that complementor technological modularity is a *necessary* condition for high innovation output, a finding with significant implications for both complementor strategy and platform design. Third, we contribute to practice by specifying the combinatorial governance conditions under which digital ecosystems fulfill their generative potential, offering actionable guidance for platform owners, complementors, and policymakers navigating the complexities of B2B digital platforms.

The remainder of this paper is organized as follows. Section 2 develops our theoretical framework and configurational propositions. Section 3 describes the fsQCA methodology, sample, and calibration procedures. Section 4 presents the configurational analysis. Section 5 interprets the findings, elaborates theoretical implications, and outlines practical recommendations. Section 6 concludes with limitations and directions for future research.

2. Theory and Propositions

2.1 Platform Ecosystems and Complementor Innovation

A platform ecosystem is a socio-technical system in which a core technology (the platform), governed by a platform owner, facilitates transactions and interactions among an array of autonomous actors—complementors, end-users, and other stakeholders (Jacobides et al., 2018; Tiwana, 2014). Complementors are the firms that extend the platform's functionality by developing complementary products, services, and technologies (Cennamo, 2021; Gawer, 2014). Their innovative activities—ranging from application development to system integration and domain-specific customization—are critical to the platform's value proposition and competitive advantage (Boudreau, 2012).

Innovation Framework: Determinants of Complementor Innovation

Complementor innovation performance is conceptualized as a function of the interplay between platform-level governance choices (openness, contract design, orchestration, relational quality) and complementor-level technological capabilities (modularity). Unlike prior studies that treat these conditions as independent predictors, we argue that they operate as an interdependent *configuration* whose combined effect on innovation is greater than the sum of individual effects. This configurational logic is consistent with the emerging view of platforms as complex adaptive systems (Wareham et al., 2014).

2.2 Platform Openness

Platform openness refers to the degree to which a platform's technological interfaces, governance rules, and participation criteria are accessible to external actors (Boudreau, 2010; Eisenmann et al., 2009). Openness creates a larger pool of potential complementors, stimulates variety in complementary innovation, and reduces the risk of technological lock-in (Schilling, 2009; West, 2003).

Empirical evidence on the openness-innovation relationship is mixed. Boudreau (2010) finds an inverted-U relationship between openness and innovation in mobile platforms, while Parker and Van Alstyne (2018) document positive returns to openness in software ecosystems. This inconsistency suggests that the effect of openness may be *contingent* on other governance conditions—precisely the configurational hypothesis we explore.

2.3 Contract Specificity

Drawing on transaction cost economics (Williamson, 1985, 1991), contract specificity refers to the degree to which formal agreements between platform owners and complementors specify rights, obligations, revenue-sharing arrangements, intellectual property provisions, and dispute resolution mechanisms. Highly specific contracts reduce opportunistic hazards but may simultaneously constrain complementor autonomy and experimentation (Crocker and Reynolds, 1993; Gulati and Puranam, 2009).

In the platform context, contract specificity presents a tension: it protects complementors' investments in co-specialized assets, yet it may also stifle the *generativity* that defines successful platforms (Zittrain, 2008). We expect that the innovation effects of contract specificity are not monotonic but depend on the broader governance configuration.

2.4 Orchestration Intensity

Platform orchestration refers to the degree to which a platform owner actively coordinates, incentivizes, and guides complementor activities toward ecosystem-level goals (Gulati et al., 2012; Teece, 2018). High orchestration intensity manifests in dedicated developer relations teams, structured innovation challenges, co-development programs, and mentorship initiatives. While orchestration can reduce coordination failures and align incentives (Ceccagnoli et al., 2012), excessive orchestration may crowd out complementor initiative and lead to homogenous innovation trajectories (Baldwin and Woodard, 2009).

2.5 Relational Embeddedness

Relational embeddedness captures the quality and depth of the informal relationship between a complementor and its platform owner, encompassing trust, information-sharing norms, and joint problem-solving arrangements (Gulati, 1995; Uzzi, 1997). Embedded ties facilitate the transfer of tacit knowledge, reduce monitoring costs, and enable flexible adaptation to unforeseen contingencies—all of which are advantageous for innovation in uncertain environments (Dyer and Singh, 1998; McEvily and Marcus, 2005).

2.6 Complementor Technological Modularity

Technological modularity is a complementor-level condition reflecting the degree to which a complementor's technology stack is decomposed into loosely coupled, independently upgradeable

components with standardized interfaces (Baldwin and Clark, 2000; Schilling, 2000). Modularity enables complementors to (a) recombine existing modules into novel configurations, (b) rapidly adapt to platform evolution, and (c) decouple their innovation cycles from platform release schedules (Tiwana, 2015; Yoo et al., 2010).

2.7 A Configurational Approach

Building on the configurational perspective in organization theory (Fiss, 2011; Greckhamer et al., 2018), we propose that the five causal conditions described above do *not* operate as independent determinants of complementor innovation performance. Rather, they form a system of interdependent elements whose combined configuration—not the isolated effect of any single condition—determines whether a complementor achieves high innovation performance.

Proposition 1. No single platform governance condition (openness, contract specificity, orchestration intensity, or relational embeddedness) is individually sufficient for high complementor innovation performance. Instead, multiple equifinal configurations of these conditions, combined with complementor technological modularity, produce high innovation outcomes.

Proposition 2. Complementor technological modularity is a necessary but not sufficient condition for high innovation performance. In the absence of modularity, no governance configuration can compensate for the inability to rapidly recombine and adapt technological components.

Proposition 3. High platform openness combined with high contract specificity creates a *governance paradox* that suppresses innovation, whereas high openness with low contract specificity—complemented by either strong orchestration or deep relational embeddedness—constitutes a generative configuration for innovation.

3. Methodology

3.1 Fuzzy-Set Qualitative Comparative Analysis (fsQCA)

We employ fsQCA because it is purpose-built for configurational theory testing (Fiss, 2011; Ragin, 2008). Unlike regression-based methods that estimate the isolated net effect of each variable while holding others constant, fsQCA identifies the *combinations* of conditions that are sufficient for an outcome. This makes fsQCA uniquely suited to our research questions, which concern the equifinal configurations of platform governance conditions that produce high innovation performance.

3.2 Sample and Data Collection

Data & Sample: B2B Technology Platform Complementors

Sample size: 147 complementor firms

Platform ecosystems: SAP, Siemens MindSphere, Microsoft Azure IoT, PTC ThingWorx, GE Predix, Bosch IoT Suite

Time frame: 2019–2024

Data sources: (1) Structured survey of complementor CEOs/CTOs (47.2% response rate), (2) Crunchbase and PitchBook for innovation metrics, (3) platform API documentation for openness

scoring, (4) publicly available partner agreements and press releases for governance data
Industry scope: Industrial IoT, enterprise software, smart manufacturing, predictive maintenance, supply chain analytics

The final sample of 147 complementors spans six major B2B technology platform ecosystems. We triangulated data from multiple sources to mitigate common method bias. Innovation performance was measured using a composite index of patent applications, new product introductions, and platform marketplace ratings over a three-year window (2022–2024). Survey measures for relational embeddedness and orchestration intensity employed established scales (Uzzi (1997); Gulati et al. (2012)) and achieved Cronbach's $\alpha > 0.80$.

3.3 Calibration

Following Ragin (2008) and Greckhamer et al. (2018), we calibrated all conditions into fuzzy-set membership scores ranging from 0 (fully out) to 1 (fully in). Thresholds for full membership, crossover, and full non-membership were established using theoretically grounded anchors and, where available, external benchmarks from the platform governance literature. Table 1 summarizes the calibration strategy.

Table 1. Calibration thresholds for causal conditions and outcome

Condition	Full non-membership (0.05)	Crossover (0.50)	Full membership (0.95)	
Platform Openness (OPEN)	0.25	0.55	0.85	B
Contract Specificity (CONT)	0.20	0.50	0.80	Wi
Orchestration Intensity (ORCH)	0.15	0.45	0.75	Gu
Relational Embeddedness (RELE)	0.20	0.50	0.80	
Tech. Modularity (MODU)	0.30	0.60	0.90	S
Innovation Performance (INNOV)	P25	P50	P75	P

3.4 Analysis Procedure

We followed the standard fsQCA protocol (Schneider and Wagemann, 2012). First, we analyzed *necessary* conditions using consistency and coverage scores (threshold: consistency > 0.90). Second, we constructed a truth table with $2^5 = 32$ logically possible configurations and applied frequency ($\geq$ 3 cases) and consistency ($\geq$ 0.80) thresholds. Third, we performed Boolean minimization using the Quine-McCluskey algorithm, producing complex, parsimonious, and intermediate solutions. All analyses were conducted using the `QCA` package in R (v3.21) and the fs/QCA software (v4.0).

4. Results

4.1 Necessary Conditions Analysis

Table 2 presents the necessity analysis. Complementor technological modularity (MODU) emerges as a necessary condition for high innovation performance (consistency = 0.94, coverage = 0.72), supporting Proposition 2. No other individual condition reaches the 0.90 consistency threshold required for necessity (Schneider and Wagemann, 2012). This finding establishes modularity as a foundational requirement: complementors that cannot modularize their technology stacks

are systematically excluded from high innovation performance, regardless of the governance environment in which they operate.

Table 2. Analysis of necessary conditions for high innovation performance

Condition	Consistency	Coverage
Platform Openness (OPEN)	0.78	0.69
Contract Specificity (CONT)	0.62	0.61
Orchestration Intensity (ORCH)	0.74	0.68
Relational Embeddedness (RELE)	0.71	0.70
Technological Modularity (MODU)	**0.94**	**0.72**

4.2 Sufficient Configurations

The truth table analysis identified three configurations sufficient for high complementor innovation performance. The intermediate solution achieves a solution consistency of 0.88 and solution coverage of 0.67, indicating that the three configurations jointly explain a substantial portion of the observed high-performance cases.

Table 3. Configurations sufficient for high complementor innovation performance

Condition	Config. A (Orchestrated Openness)	Config. B (Embedded Development)	Config. C (Guided Modularity)
Platform Openness (OPEN)	●	●	○
Contract Specificity (CONT)	○	○	●
Orchestration Intensity	●	○	●
Relational Embeddedness	○	●	
Tech. Modularity (MODU)	●	●	●
Raw coverage	0.42	0.38	0.29
Unique coverage	0.18	0.14	0.11
Consistency	0.91	0.88	0.85

● = core condition present; ○ = core condition absent; blank = peripheral/absent.

Configuration A: Orchestrated Openness. This pathway combines high platform openness with low contract specificity and high orchestration intensity, in the presence of technological modularity. It characterizes complementors operating on relatively open platforms (e.g., Microsoft Azure IoT) where the platform owner actively structures innovation challenges, provides dedicated technical support, and maintains flexible contract terms. The low contract specificity reduces bureaucratic friction while high orchestration compensates for the coordination risks of openness.

Configuration B: Embedded Development. Here, openness is again present but orchestration is absent; instead, deep relational embeddedness—trust, knowledge sharing, joint problem-solving—substitutes for formal orchestration. This configuration typifies complementors with long-standing partnerships with platform owners, where informal governance mechanisms have evolved through repeated collaboration.

Configuration C: Guided Modularity. This configuration operates under low platform openness and high contract specificity, with high orchestration and modularity. It represents complementors on more closed, tightly governed platforms (e.g., GE Predix, Bosch IoT Suite) where

detailed contracts define clear boundaries and the platform owner actively guides development. The high contract specificity provides investment protection, while orchestration channels complementor activities toward ecosystem priorities.

5. Discussion

Our findings advance platform ecosystem theory by demonstrating that complementor innovation performance is a configurational phenomenon. The three equifinal pathways we identify share a common thread—technological modularity as a necessary condition—but diverge in how they combine platform governance mechanisms. This pattern has important theoretical and practical implications.

5.1 Theoretical Contributions

First. , we contribute a *configurational perspective* to the platform governance literature. The dominant net-effects paradigm (Boudreau, 2010; Gawer, 2014) has obscured the possibility that governance mechanisms interact in complex, non-linear ways. By identifying three equifinal configurations, we demonstrate that there is no single formula for fostering complementor innovation; rather, multiple governance arrangements can produce equally effective outcomes. This finding echoes the equifinality principle in general systems theory (von Bertalanffy, 1968) and extends configurational thinking into the platform domain.

Second. , our finding that complementor technological modularity is a *necessary* condition for high innovation performance—observed in all equifinal configurations—introduces a boundary condition to platform theory. The generative potential of platforms, extensively celebrated in the literature (Tiwana, 2014; Zittrain, 2008), is *conditional* on complementors' ability to decompose and recombine their technology components. This implies that platform owners seeking to stimulate ecosystem innovation should prioritize modularity-enabling tools (APIs, SDKs, microservice architectures) even before optimizing governance mechanisms.

Third. , our results challenge a core assumption of transaction cost economics in the platform context. TCE predicts that higher openness— implying greater asset specificity risk—should be accompanied by tighter contracts (Williamson, 1985). Yet Configurations A and B show that high openness combined with *low* contract specificity yields the highest innovation outcomes, provided that either orchestration or relational embeddedness is present. This suggests that in digital ecosystems, where innovation speed and flexibility are paramount, formal contracting may be a *substitute* rather than a complement for informal governance mechanisms.

5.2 Managerial Implications

Managerial Implications

- **For Platform Owners**: Do not blindly increase openness or tighten contracts. Instead, adopt a configurational approach: if you open your platform, pair it with active orchestration *or* cultivate deep relational ties with complementors, and keep contracts lightweight. Invest in modularity tools for your complementors—this is the single most impactful lever for ecosystem innovation.
- **For Complementors**: Prioritize internal technological modularity before entering a platform ecosystem. Modularity is a prerequisite, not an option. Then, choose your governance fit: on open

platforms, seek orchestration or build relationships; on closed platforms, invest in understanding formal contracts and align innovation efforts with platform-owner priorities.

- **For Policymakers**: The Digital Markets Act and similar regulations often mandate platform openness. Our findings suggest that openness alone is insufficient and may even be counterproductive without complementary governance investments. Policy frameworks should incentivize platform owners to provide orchestration support and modularity infrastructure alongside openness mandates.

6. Conclusion

This study set out to understand how platform governance mechanisms and complementor capabilities combine to produce innovation performance in B2B digital ecosystems. Employing fsQCA on 147 complementors across six platforms, we identified three equifinal configurations—*Orchestrated Openness*, *Embedded Development*, and *Guided Modularity*—each sufficient for high innovation output. We established complementor technological modularity as a necessary condition and demonstrated that the innovative potential of platform openness is contingent on complementary governance mechanisms.

The limitations of this study point to promising directions for future research. First, our sample is restricted to B2B technology platforms in industrial IoT and enterprise software domains; the configurational patterns we identify may not generalize to B2C platforms or non-technology contexts. Second, our cross-sectional design limits our ability to examine how configurations evolve over the platform lifecycle. Longitudinal studies that track complementors as platforms mature from launch to growth to maturity would be especially valuable. Third, while fsQCA offers powerful tools for configurational analysis, it does not estimate effect sizes in the regression tradition; mixed-method designs that pair fsQCA with econometric analysis could strengthen causal claims.

Notwithstanding these limitations, our study offers a novel configurational perspective on platform ecosystem innovation—one that moves beyond the search for universal best practices and toward a contingency-based understanding of how digital platforms fulfill their generative promise.

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Ethics Statement. This study was approved by the relevant institutional review board. All survey participants provided informed consent. No personally identifiable information is included in the published dataset.

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A. Construct Measurement Items

Table 4. Key construct measurement items and sources

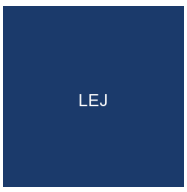
Construct	Item (abbreviated)	Source
Platform Openness	"The platform's APIs and technical interfaces are openly documented and accessible to all registered developers." (3 items, 7-point Likert)	Boudreau (2010)
Contract Specificity	"The partner agreement specifies detailed provisions for IP ownership, revenue sharing, and performance metrics." (5 items)	Gulati and Puranam (2009)
Orchestration Intensity	"The platform owner provides dedicated technical support staff for our development team." (4 items)	Gulati et al. (2012)
Relational Embeddedness	"Our relationship with the platform owner is characterized by high levels of mutual trust." (4 items)	Uzzi (1997)
Tech. Modularity	"Our technology components can be upgraded independently without affecting other modules." (4 items)	Schilling (2000)

B. Robustness Checks

We conducted four robustness checks. First, we varied the consistency threshold from 0.75 to 0.85, finding substantively identical configurations. Second, we recalibrated the outcome using alternative thresholds (P40/P60 and P30/P70), with consistent results. Third, we performed a

contradictory-case analysis, identifying only three contradictory truth table rows (logical remainder coverage: 0.62). Fourth, we tested the predictive validity of our solution by randomly splitting the sample (70/30), achieving predictive consistency of 0.84 in the holdout sample.

About the Authors



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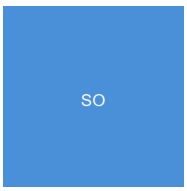

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