

Minimum-Factor Value Co-Creation in Urban Digital Economies: An Ecological-Constraint Framework for Differentiated Growth Models

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Abstract: Urban digital economies exhibit pronounced regional heterogeneity: some cities scale rapidly through platform-led networks, others expand through digitally enabled industrial symbiosis, while still others rely on deep user participation and demand-driven innovation. This conceptual paper integrates value co-creation theory with an ecological limiting-factor perspective grounded in Liebig's Law of the Minimum. A minimum-factor value co-creation framework is developed in which the evolution of a city's digital business ecosystem is shaped by a binding ecological constraint that conditions the dominant co-creation pathway and, consequently, the prevailing growth model; iterative feedback then reconfigures ecosystem capabilities and boundaries over time. Building on four schematics, three archetypal urban growth models are delineated—platform-driven, enterprise-symbiotic, and user-enabled—and their respective bottlenecks are specified: policy adaptability for platform-led ecosystems, technology compatibility and innovation capacity for enterprise symbiosis, and user scale and engagement, reinforced by data trust, for user-enabled ecosystems. The framework advances ecosystem research by explaining city-level model differentiation as a constraint-activated selection among co-creation pathways and by translating minimum-factor logic into a governance toolkit centered on dynamic monitoring and targeted interventions across infrastructure, talent, market demand, policy institutions, and competition-cooperation structures.

Keywords: Value Co-Creation; Digital Business Ecosystem; Urban Digital Economy; Limiting Factors; Minimum-Factor

Framework; Differentiated Development

1. Introduction

The deepening of the digital economy has fostered multi-actor business ecosystems in which platforms, enterprises, users, and complementary partners jointly create value rather than operating through a linear producer-led value chain [1,2]. Digital technologies (e.g., APIs, cloud services, data analytics, and algorithmic coordination) reduce coordination and transaction costs and enable scalable interaction architectures, accelerating information flows and supporting role transformation, including the shift of users from passive consumers to active contributors (“prosumers”) through data generation, feedback, and creative participation [3].

Despite these common mechanisms, urban digital economies do not converge to a single trajectory. Cities differ in industrial foundations, institutional environments, market size, and talent pools, which yields differentiated growth patterns and governance challenges [4,5]. Existing research has provided rich micro-level explanations of value co-creation, for example in firm-customer or platform-user contexts [6,7], but fewer meso-level theories explain why entire cities gravitate toward distinct digital-economy growth models [8].

This paper develops a city-level explanation by integrating value co-creation theory with an ecological limiting-factor perspective. In ecology, limiting-factor reasoning emphasizes that growth and ecosystem functioning are constrained by the scarcest essential condition, and that improvements in non-binding conditions yield limited returns when the bottleneck persists. A similar minimum-factor logic is expected to operate in urban digital business ecosystems, where infrastructure, talent,

market demand, policy institutions, and competition–cooperation structures jointly shape ecosystem scaling and transformation. Accordingly, the binding constraint influences which co-creation pathway can scale and which urban digital-economy growth model becomes dominant.

The contributions are threefold. First, an integrative conceptual architecture of digital value co-creation is specified at the city level, linking data-centric value creation to platform orchestration and ecosystem interdependencies. Second, three archetypal growth models are theorized as distinct co-creation configurations under different binding constraints. Third, the framework is translated into differentiated governance strategies and a dynamic monitoring system aligned with the institutional and policy conditions of digital transformation.

2. Theoretical Foundations and an Integrated Framework

2.1 Value Co-Creation in Digital Business Ecosystems

A digital business ecosystem (DBE) can be understood as a socio-technical system in which multiple interdependent actors coordinate through digital infrastructure and data-enabled interfaces. Value is co-created through interaction, resource integration, and reciprocal service provision among platforms, enterprises, users, and complementor. Compared with traditional value chains, DBEs rely on shared digital infrastructures, data as a generative resource, and modular architectures that lower coordination costs and expand the space of collaboration.

From a co-creation perspective, three actor categories are particularly salient in urban DBEs: digital platforms that orchestrate shared networks, enterprises that provide products, services, and complementary capabilities, and users who contribute demand signals, data, and co-innovation activities. Co-creation can occur along multiple relational channels (platform–user, platform–enterprise, and enterprise–user), and the relative intensity of these channels shapes ecosystem structure and growth.

2.2 Ecological Constraints and Liebig’s Minimum-Factor Logic

Urban digital economies are embedded in local environments characterized by uneven

distributions of enabling factors. Analogous to ecological systems, DBEs depend on interacting ecological factors such as digital infrastructure, human capital, market demand, institutional rules, and patterns of competition and cooperation, which jointly condition ecosystem functioning and stability [9]. These factors are not unlimited; they vary across cities and can become binding constraints that shape digital transformation trajectories and governance challenges [10].

Applying Liebig’s Law of the Minimum, DBE evolution is expected to be constrained by the least-developed essential factor at a given stage. When the minimum factor is insufficient, ecosystem growth and co-creation intensity remain limited even if other factors are abundant. This logic shifts attention from single-factor explanations toward a configurational view in which technology, institutions, and markets co-evolve and are selectively activated by the binding constraint, consistent with ecosystem accounts that stress interdependence and alignment among actors and rules.

2.3 Integrated Architecture: Constraints → Co-Creation Pathway → Growth Model

Figure 1 summarizes the integrated architecture. Data sits at the center of value co-creation, linking users, applications, and collaborative enterprises to a digital platform layer that is supported by digital infrastructure and bounded by policies and regulations. This architecture highlights two theoretical claims. First, the city-level DBE can be analyzed as a layered socio-technical system rather than a simple industry cluster, because digital infrastructures and platform architectures shape how data flows enable interaction and innovation [11]. Second, the same architecture can generate different growth models depending on which co-creation pathway becomes dominant under the city’s minimum-factor constraint [12].

Urban digital-economy differentiation can therefore be conceptualized as a selection process in which ecological constraints determine which co-creation pathway can be scaled and stabilized, while the resulting growth model feeds back to reshape constraints by reallocating capabilities and triggering new governance demands [13]. For example, platform expansion can attract talent and capital, whereas rapid user growth can elevate privacy and security requirements and reshape the trust

conditions of data-enabled co-creation [14].

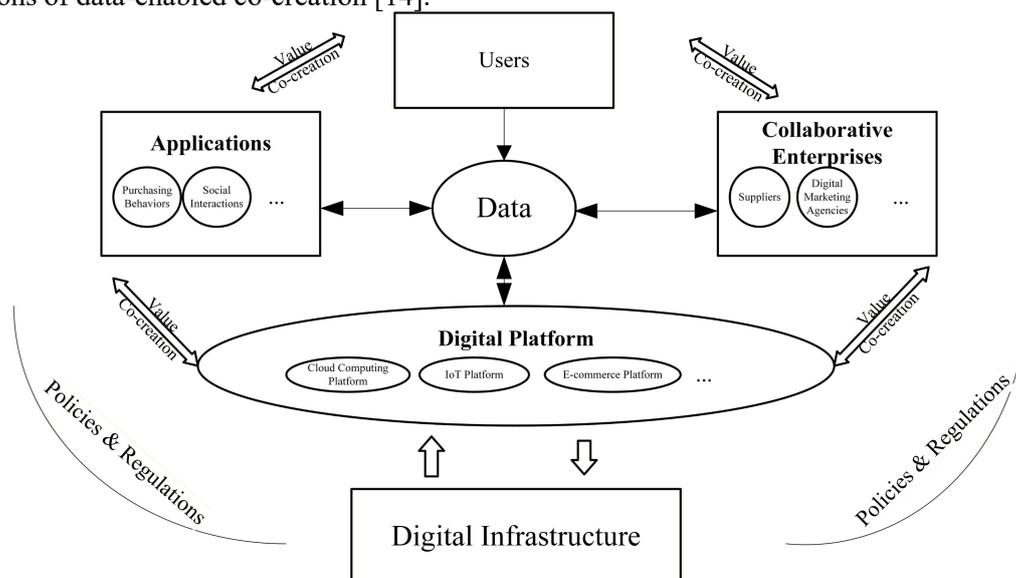


Figure 1. Integrated Architecture of Value Co-Creation in an Urban Digital Business Ecosystem (DBE)

2.4 Research Propositions

Proposition 1 (Digital enablement). Digital technologies enlarge the feasible space of value co-creation in urban digital business ecosystems by lowering coordination and transaction costs, increasing connectivity, and enabling modular interaction architectures. In service and interactional perspectives, value is not produced unilaterally by firms but emerges through continuous interaction and resource integration among multiple actors, including platforms, enterprises, and users [15]. The rise of platform-based organizing forms further amplifies these interactional mechanisms by providing shared infrastructures and boundary resources that allow heterogeneous participants to plug in, recombine resources, and innovate at scale. User participation becomes particularly consequential in digital contexts because user behaviors generate data, feedback, and creative contributions that can be transformed into innovation inputs, thereby strengthening the co-creation cycle and improving service and innovation outcomes. Accordingly, a city's digital technology diffusion and digital business capability are expected to raise co-creation intensity and ecosystem performance.

Proposition 2 (Minimum-factor constraint and non-substitutability). The development ceiling of an urban digital business ecosystem is constrained by the scarcest essential ecological factor at a given stage, such that the abundance of other factors cannot fully compensate for the

binding constraint. This proposition adapts ecological reasoning in which ecosystem functioning and evolutionary dynamics are shaped by limiting conditions and resource constraints rather than by the simple accumulation of "more inputs" [16]. In urban digital economies, candidate ecological factors include digital infrastructure, talent supply, market demand, policy institutions, and local competition-cooperation structures; each is necessary for scaling co-creation but may become a bottleneck when underdeveloped. The implication is a configuration logic: improvements in non-binding factors yield diminishing marginal returns if the minimum factor remains unaddressed, and ecosystem upgrading requires targeted interventions that relax the binding constraint [17]. This view aligns with research emphasizing that digital transformation outcomes depend on contextual capability endowments and institutional conditions rather than technology adoption alone.

Proposition 3 (Constraint-activated selection). Urban heterogeneity in digital-economy growth models can be theorized as a constraint-activated selection process in which the binding factor privileges certain co-creation pathways while suppressing others. Ecosystem scholarship highlights that innovation and growth depend on alignment across interdependent actors, and strategic success requires matching the focal innovation logic to ecosystem conditions. In digital business ecosystems, interdependencies across platforms, complementors, enterprises,

and users create multiple potential channels for co-creation, but the scalability of each channel is contingent on the local enabling environment and governance structure [18]. When policy adaptability is the most binding factor, platform-led orchestration and shared-network expansion face the strongest constraints; when interoperability and innovation capacity are limiting, cross-firm symbiosis becomes difficult to sustain; when user scale and trust are constrained, demand-driven co-innovation is attenuated. Thus, city-level differentiation is expected to manifest as the dominance of the co-creation pathway that is least constrained under local minimum-factor conditions, forming distinct growth-model archetypes consistent with different interaction structures and governance requirements.

Proposition 4 (Feedback and evolution). Dominant growth models generate endogenous feedback that reconfigures ecosystem capabilities and may shift which ecological factor becomes binding over time, creating the possibility of path-dependent evolution and model transition. As ecosystems scale, successful co-creation can attract talent, capital, and complementary partners, strengthening

digital business capability and reinforcing performance advantages [19]. At the same time, expansion can increase coordination complexity, intensify competition, and trigger tighter regulatory and governance requirements, thereby elevating institutional adaptability and risk management as new constraints [20]. Research on capability dynamics across digital ecosystems suggests that actors continuously search, redeploy, and redeem capabilities across ecosystem boundaries, implying that constraint relaxation and capability upgrading can unlock new co-creation pathways previously infeasible under the earlier minimum factor. Consequently, ecosystem evolution is expected to follow a dynamic pattern in which the binding constraint and the dominant pathway co-evolve; governance and strategic investment that alleviate the minimum factor can enable shifts from one dominant co-creation configuration to another, rather than locking cities permanently into a single model.

3. Three Constraint-Activated Growth Models

3.1 Platform-Driven Growth: Shared Networks and Policy Adaptability

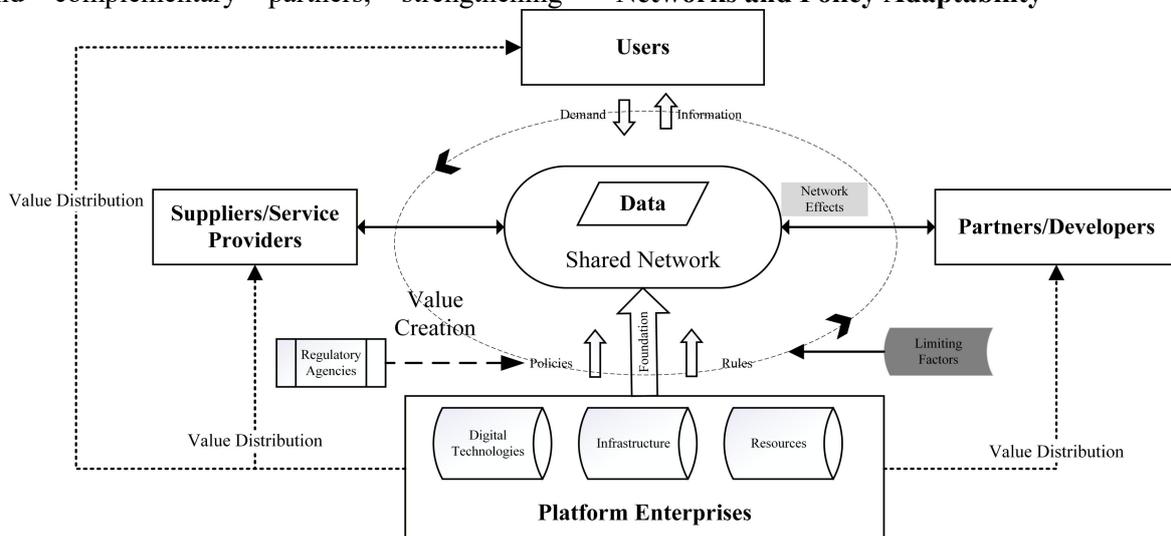


Figure 2. Platform-Driven Value Co-Creation: Shared-Network Orchestration, Network Effects, and Policy-Bounded Scaling

Platform-driven cities grow through platform enterprises that orchestrate shared networks connecting users, suppliers/service providers, and partners/developers. As depicted in Figure 2, platform enterprises invest in digital technologies, infrastructure, and resources to build a data-rich shared network. Interactions on this network generate network effects: as participation increases, the value of the network

rises, reinforcing further participation and accelerating ecosystem maturation.

The platform-led co-creation cycle typically includes (i) capability and infrastructure input by the platform, (ii) interaction and data aggregation among ecosystem participants, (iii) joint value creation via matching, personalization, and modular innovation, (iv) value distribution through fees, commissions, or

incentive schemes, and (v) reinvestment to sustain competitiveness.

Binding constraint. While technology and capital matter, the most distinctive bottleneck of platform-driven ecosystems is policy adaptability. Platform networks require rules for data governance, privacy, security, and fair competition. When regulatory frameworks lag behind platform innovation or are inflexible, the shared network cannot scale efficiently and may face legitimacy and compliance risks. Hence, policy and regulatory institutions often act as the minimum factor shaping platform-driven urban growth.

3.2 Enterprise-Symbiotic Growth: Interoperability, Innovation, and Collective Efficiency

Enterprise-symbiotic cities grow through digitally enabled collaboration among firms within industrial and supply-chain structures. Figure 3 depicts a co-creation process in which enterprises jointly invest resources (talent, capital, facilities) and utilize digital technologies

(IoT, cloud computing, AI, blockchain, big data analytics, CRM systems) to enable information sharing, knowledge spillovers, business model innovation, and coordinated operations. These mechanisms build symbiotic relationships that generate collective competitiveness, more efficient division of labor, and improved customer outcomes.

Binding constraint. The minimum factor in enterprise-symbiotic ecosystems is typically technology compatibility and innovation capacity. Symbiosis requires interoperable standards, compatible systems, and sufficiently aligned digital maturity levels across firms; otherwise, data sharing and collaborative processes remain fragmented. Moreover, sustained symbiosis depends on innovation capabilities that continuously upgrade the shared technological base. Where interoperability is low or innovation capabilities are uneven, co-creation intensity and ecosystem benefits are constrained.

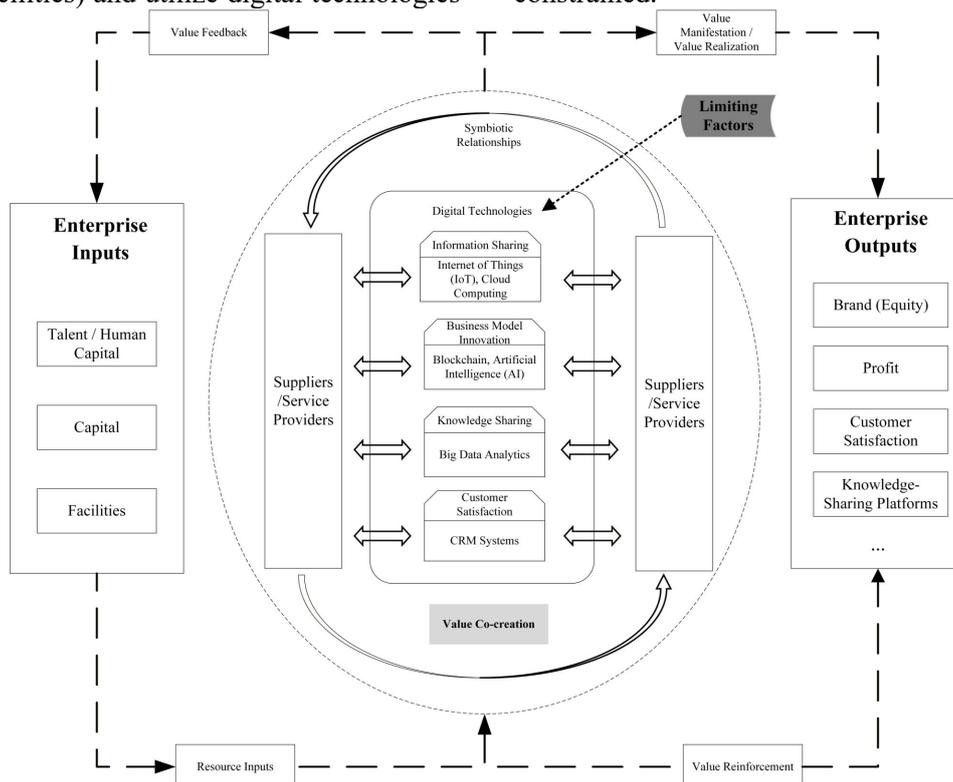


Figure 3. Enterprise-symbiotic Value Co-Creation: Digital-Technology Mediation between Enterprise Inputs and Collective Outputs

3.3 User-Enabled Growth: Participation, Data Trust, and Demand-Driven Innovation

User-enabled cities grow by mobilizing large-scale and diverse user participation to drive continuous demand feedback, product innovation, and service optimization. Figure 4

conceptualizes user-enabled co-creation as a resource-integration process: users contribute time and energy, data and information, skills and knowledge, and reputation diffusion; enterprises contribute analytics, information exchange mechanisms, product innovation capabilities, and community-building tools. These resources

form a shared resource base (user-generated data resources plus enterprise-provided analytics tools) that supports value co-creation. Value outputs accrue to both sides: users gain better experiences, reduced search and transaction costs, and knowledge/skill acquisition; enterprises gain market share, operational revenue, knowledge accumulation, and brand influence. The model requires both a user-side capability foundation (engagement, information seeking, skill acquisition) and an enterprise-side capability infrastructure (data

acquisition, processing, and utilization). Binding constraint. The minimum factor in user-enabled ecosystems is user scale and engagement, reinforced by trust in data privacy and security. Without high participation rates, enterprises cannot learn from demand signals or co-innovate effectively; without credible privacy and security practices, user trust erodes and participation declines. Hence, market size and engagement—underpinned by data trust—constitute the key limiting factors for this model.

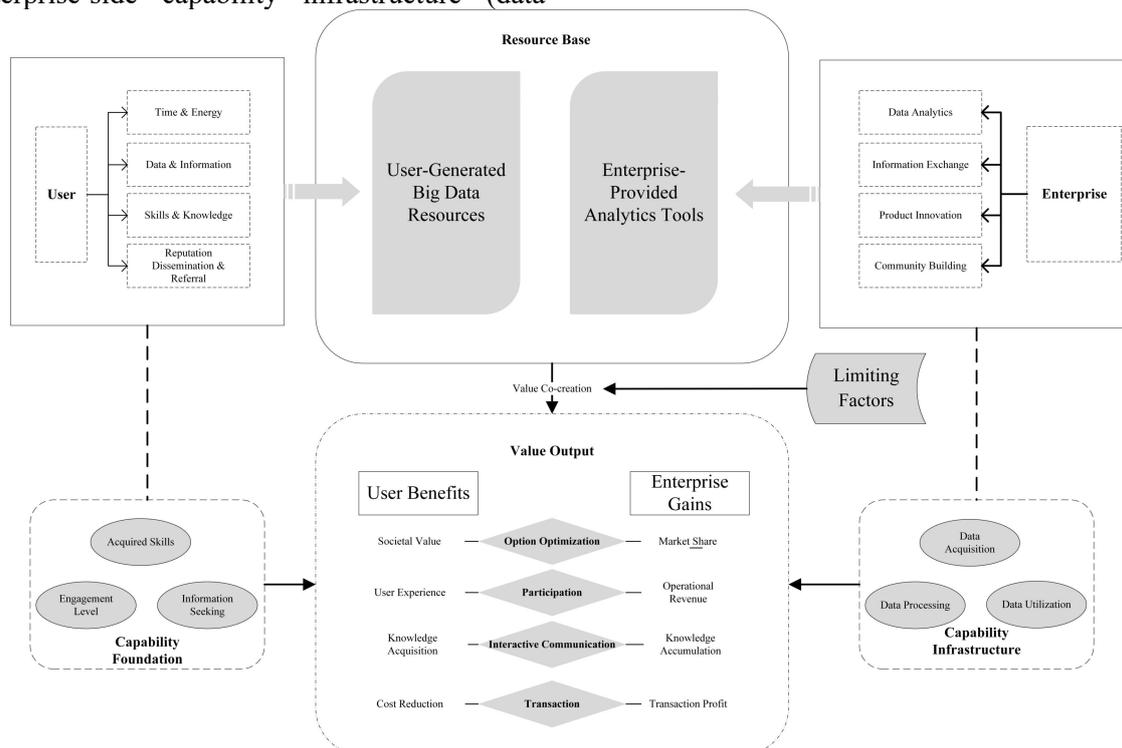


Figure 4. User-Enabled Value Co-Creation: Resource Integration, Capability Conditions, and Dual-Sided Value Outputs

4. Comparative Logic: Model Selection and Evolutionary Transitions

4.1 Theoretical Contributions

The minimum-factor value co-creation framework advanced in this paper makes four primary theoretical contributions to the literature on digital business ecosystems and urban economic development. First, it introduces a constraint-activated selection mechanism that explains urban digital economy differentiation not merely as a function of strategic choice or initial resource endowments, but as an outcome of binding ecological constraints that selectively enable certain co-creation pathways while suppressing others. This mechanism, grounded in Liebig's Law of the Minimum, provides a

parsimonious yet powerful explanation for why cities gravitate toward distinct archetypal growth models.

Second, the framework elevates value co-creation research from a predominantly dyadic, micro-level focus (e.g., firm-customer interactions) to a meso-level, city-scale ecosystem perspective. It elucidates how the complex, multi-actor interactions among platforms, enterprises, and users collectively constitute and shape the overarching structure of an urban digital economy. Third, the framework incorporates an evolutionary logic with dynamic feedback loops. It posits that as a dominant growth model scale, it reconfigures the city's factor endowments and institutional landscape, which can, in turn, shift the identity of the binding constraint itself, thereby enabling

potential transitions across growth pathways over time—a process analogous to ecological succession. Finally, it redefines governance not as an external supporting factor but as an integral boundary condition for co-creation. Policy and regulatory institutions are shown to directly define the permissible space for data flows, competitive conduct, and ecosystem legitimacy, thereby becoming constitutive elements of the co-creation architecture itself. Collectively, these contributions offer a more dynamic, configurational, and ecologically grounded theory for understanding heterogeneity in urban digital development.

4.2 Boundary Conditions and Research Agenda

The framework is most applicable to urban contexts in which data-intensive interactions and digital infrastructures are central coordination mechanisms. It also implies testable research directions: (i) measuring “pathway intensity” (platform-, enterprise-, and user-centered interactions) and examining its association with urban productivity; (ii) identifying minimum factors through configurational methods (e.g., QCA) and testing whether they predict pathway dominance; and (iii) tracing longitudinal transitions as factor endowments and regulations change.

The three growth models are not mutually exclusive; rather, they represent dominant configurations that emerge when a particular co-creation pathway becomes scalable under local constraints. The minimum-factor logic provides a parsimonious explanation of model selection: cities tend to develop along the pathway whose enabling conditions are least constrained, while bottlenecks prevent alternative pathways from scaling.

Model transitions are possible as cities invest to relax constraints. For example, improvements in data governance and regulatory agility may allow an enterprise-symbiotic ecosystem to spawn influential platforms; strengthened interoperability standards may enable platform-driven ecosystems to deepen industrial coordination; and expanded digital inclusion and trust mechanisms may transform platform cities into user-enabled innovation hubs. In this sense, urban digital-economy development resembles ecological succession: the ecosystem moves from initial niche formation to greater diversity and then to a more stable balance as constraints

shift and actors co-evolve.

5. Governance Implications: A Dynamic Monitoring and Differentiated Policy Toolkit

The minimum-factor framework suggests that “one-size-fits-all” digital-economy policies are inefficient. Instead, governance should start from diagnosing the city’s binding constraint and then applying model-consistent interventions that expand the feasible space of value co-creation.

5.1 Dynamic Monitoring System

Cities can operationalize the framework through a monitoring system that tracks at least five factor groups: (i) infrastructure (connectivity, computing, data facilities), (ii) talent (digital skills, entrepreneurial and managerial capabilities), (iii) market (user base, diversity of demand, purchasing power), (iv) policy institutions (data governance, regulatory agility, rule clarity), and (v) competition–cooperation structures (industry alliances, platform governance, openness of innovation networks). Monitoring enables early warning when the minimum factor shifts—for instance, when rapid technological iteration creates a talent gap, or when user growth intensifies privacy and security risks.

5.2 Model-Specific Governance Priorities

The minimum-factor framework necessitates a differentiated approach to governance, where policy interventions are strategically aligned with the dominant growth model and its corresponding binding constraint. A one-size-fits-all strategy is inherently inefficient; instead, governance must be tailored to relax the specific bottleneck that limits the scalability of the primary value co-creation pathway.

For cities exhibiting a platform-driven growth model, where the binding constraint is policy adaptability, governance priorities should center on creating a regulatory environment that is both agile and legitimate. Key interventions include establishing regulatory sandboxes that allow for controlled experimentation with new business models, developing clear and forward-looking data governance frameworks that balance innovation with individual rights, and crafting competition policies that prevent the abuse of market dominance without stifling the network effects essential for growth. The objective is to provide a stable yet flexible rule-set that enables platforms to orchestrate their shared networks

effectively, as illustrated by the interactions bounded by policy in Figure 2. This involves proactive engagement with platform actors to co-create standards and ensure that regulations evolve in tandem with technological advancements.

In contrast, the governance of enterprise-symbiotic growth models must prioritize overcoming the minimum factors of technology compatibility and innovation capacity. Effective policy here functions as a catalyst for interoperability and collective capability building. This can be achieved by fostering industry consortia to develop shared technical standards, investing in or incentivizing the creation of neutral industrial data spaces and cross-firm digital platforms, and providing support for collaborative R&D projects and workforce upskilling programs. The governance focus shifts from regulating platform orchestration to facilitating the digital-technology mediation that enables resource integration and symbiotic efficiency among enterprises, a process depicted in Figure 3. The goal is to reduce transaction costs for collaboration and build a robust foundation for sustained, innovation-driven symbiosis.

Finally, governing user-enabled growth models requires a fundamental focus on cultivating the user scale and engagement that are the lifeblood of this pathway, underpinned by robust data trust. Policy instruments should aim to amplify participation and ensure its integrity. This includes implementing digital inclusion policies to broaden the user base, enforcing strong consumer and data-rights protection laws to build confidence, promoting privacy-by-design principles in business practices, and digitizing public services to raise everyday user engagement and digital literacy. As shown in Figure 4. The health of this ecosystem depends on a virtuous cycle of resource integration between users and enterprises, which can only be sustained if users trust that their contributions are secure and valued. Therefore, governance in this model is primarily about creating a safe and incentivizing environment for participatory innovation.

6. Conclusion and Future Research

This paper reorganizes the analysis of urban digital-economy development around four schematics and advances a minimum-factor value co-creation framework. By integrating

value co-creation theory with an ecological limiting-factor lens, we explain why cities exhibit differentiated growth models and identify the binding constraints that shape each pathway. The framework contributes a city-level, ecosystem-based theory of digital-economy heterogeneity and offers a practical governance logic centered on diagnosing and relaxing the minimum factor.

Future research can extend the framework in three directions: (i) explicitly modeling government as an ecosystem actor participating in co-creation, (ii) developing measurement systems and empirical tests (e.g., comparative case studies or panel data) for minimum factors and pathway intensity, and (iii) exploring cross-country institutional comparisons to understand how different regulatory traditions reshape constraint-activated selection.

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