From Keystone Platforms to Federated Data Spaces: Digital Platforms as Design Basis for Sectorial Data Ecosystems

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Abstract. This paper examines the design and scaling of sectorial data spaces through the lens of multi-sided digital platform (MSP) theory. While data spaces increasingly resemble platforms that connect data providers, data users, and intermediaries, prevailing frameworks still underuse established insights from platform economics and platform ecosystem research. Building on a sociotechnical view of data spaces as meta-organisations, we map core MSP constructs onto the established sectorial data ecosystem framework ranging from the business/social, governance, and technical dimensions. We argue that sectorial data spaces constitute "alliance-driven" MSPs that invert the classic platform trajectory: adoption of a shared purpose and governance precedes technical innovation. Consequently, trust, certification, identity, and enforceable usage control operate as primary design instruments, and data/standards function as collectively governed boundary resources rather than proprietary assets. Finally, we begin the translation of these insights into actionable guidance for orchestrators, proposing practical tools to support bootstrapping and sustainable scaling of sectorial data spaces.

Keywords: Data Spaces · Digital Platforms · Multi-sided Platforms

1 Introduction

The rising strategic importance of data and the pace of digital transformation necessitates the development of robust sectorial data ecosystems to enable SMEs to foster innovation and competitive advantage. Nevertheless, the successful design and scaling of these industrial networks is impeded by a lack of suitable and economically viable business models, and by governance failures that undermine trust and control in data-sharing activities. To address these critical barriers, this paper advances ongoing work by examining how a multi-sided digital platforms (MSDP) perspective can inform the design and governance of data spaces (DS).

Prior research has framed sectorial data ecosystems along three interdependent dimensions: (i) business and social elements; (ii) governance structures; and (iii) technical architecture, arguing that their alignment is critical to enable SMEs' access to advanced data-driven services. Yet, while DS increasingly resemble the digital platform model that connects data providers, users, and complementors, existing DS frameworks only partially exploit the rich body of knowledge from platform economics and platform ecosystem research. In this sense, the research question that frames this paper becomes: How can multi-sided digital platform state-of-the-art inform and support the design and scaling of sectorial data ecosystems?

The paper uses a dual method that combines a targeted literature review with a retrospective analysis of recent data space implementations. Drawing on sociotechnical views of industrial platforms as meta-organisations, it synthesises work on data spaces, shared data ecosystems, and federated governance, and then contrasts these insights with practical “friction points” from real cases. This enables a mapping of key MSDP concepts such as cross-side network effects, non-pricing coordination instruments, and boundary resources onto a sectorial ecosystem development framework. Based on this mapping, the paper proposes how MSDP tools can help orchestrators address core coordination and bootstrapping challenges (e.g., the chicken-and-egg problem and Red Queen dynamics) while guiding longer-term ecosystem evolution by balancing complementor autonomy with integration and by using evolutionary metrics (e.g., plasticity and mutation) to monitor and steer change.

The paper offers two main contributions. Theoretically, it advances DS research by conceptualizing sectorial DS as federated MSDP and meta-organizations, in which data, standards, and shared semantics operate as collectively governed boundary resources rather than proprietary platform assets. This perspective clarifies how cross-side value propositions, incentive structures, and governance instruments shape participation and coordination in federated settings. For practitioners, the paper provides a set of actionable tools and processes, such as design canvases, role architectures, and evolution metrics to support ecosystem orchestrators in designing, bootstrapping, and scaling sectorial DS, thereby fostering more sustainable and value-driven data-sharing arrangements.

The remainder of the paper is structured as follows: Section 2 positions sectorial data spaces within the MSP literature, Section 2 develops the conceptual mapping and resulting design propositions, Section 3 discusses implications and practical guidance for implementation, and Section 5 concludes with limitations and directions for future research.

2 Background

2.1 From Bilateral Exchange to Federated Data Ecosystems

The paradigm of inter-organizational data management has shifted significantly from bilateral data exchange to collaborative data sharing within ecosystems. While traditional inter-organizational information systems focused on linear, dyadic transactions to optimize supply chain efficiency, the current data economy demands a transition toward ”offense” strategies that treat data as a strategic asset for value co-creation. In this context, data ecosystems are defined as socio-technical complex networks wherein actors interact to find, archive, publish, and reuse data to foster innovation and create value.

Data spaces have emerged as the requisite digital infrastructure to operationalize these ecosystems. Unlike centralized data lakes or monolithic platforms that aggregate data under a single authority, data spaces are distributed by design. They represent a federated infrastructure enabling sovereign data exchange where data remains at the source and is shared only upon request under specific usage policies. Consequently, data spaces function as multi-sided platforms (MSPs) connecting data providers, data users, and intermediaries (e.g., service providers, app developers). However, unlike the ”keystone-driven” MSPs dominating the B2C landscape (e.g., Apple, Uber), data spaces are often alliance-driven MSPs, governed by consortia rather than a single profit-maximizing entity.

2.2 Shared Data Ecosystems and the Shift to Federated Data Spaces

The prevailing paradigm of industrial data exchange has historically oscillated between two limiting extremes: rigid bilateral integration and centralized aggregation. In the former, organizations rely on point-to-point connections (e.g., EDI, bespoke APIs) which, while secure, suffer from high integration costs and a lack of scalability, creating fragmented ”data silos” that impede sector-wide collaboration.

In the latter, the rise of cloud hyperscalers promoted the "data lake" model, where data is copied and consolidated into a central repository. While this facilitates analytics, it introduces significant governance risks regarding vendor lock-in, asymmetric power relations, and loss of control over proprietary assets once they leave the provider's perimeter.

In response to these limitations, the concept of Shared Data Ecosystems (SDEs) has emerged as an alternative organizational form. Unlike "Open Data" initiatives which treat data as a public good with non-excludable and non-rivalrous consumption, industrial SDEs typically operate under a "club goods" logic. Here, access is excludable, restricted to certified participants, and governed by specific membership rules designed to preserve commercial value. Within this broader taxonomy of SDEs, the Data Space (DS) has solidified as the reference architectural model for secure, sovereign data sharing. Fundamentally, a Data Space is defined by a shift from centralization to federation. In a DS, there is no central data store; data remains "at the source" (on the owner's infrastructure) until the moment of use. Exchange is peer-to-peer, mediated by a federated infrastructure of trusted connectors and identity providers (Otto et al., 2019; IDSA, 2023). This architecture is designed to enforce Data Sovereignty—a capability that transcends mere security. While security protects data from unauthorized access, sovereignty grants the data provider continuous, self-determined control over how their data is used, by whom, and for how long, even after the data has been shared.

Consequently, a Data Space is not merely a technical solution but a complex sociotechnical infrastructure. It consists of "hard" infrastructure (software connectors, vocabulary providers, identity management systems) and "soft" infrastructure (trust frameworks, certification rules, and governance agreements). This dual nature distinguishes DS from traditional digital platforms; whereas a monolithic platform (e.g., a marketplace) centralizes both the infrastructure and the governance authority, a DS distributes the infrastructure while federating the governance. This distinction is critical for sectorial contexts, as it allows competing firms to cooperate on data utilization without surrendering strategic autonomy to a central platform operator.

The Sectorial Data Ecosystem Framework To understand how these federated architectures manifest in specific industries, recent research has operationalized the concept of Sectorial Data Ecosystems [9]. Building on the sociotechnical perspective, prior work has conceptualized these ecosystems along three interdependent dimensions: (i) technical architecture, (ii) governance structures, and (iii) business and social elements.

The **first building block**, Business and Social Elements, addresses the critical "readiness gap" in SME-dominated sectors. The primary barrier to ecosystem scaling is often not the lack of sharing infrastructure, but the internal immaturity of potential participants. Consequently, this dimension advocates for a "bottom-up" approach centered on Data Maturity Services. These services are designed to characterize individual enterprises, assess their current information intensity, and intervene directly in business processes. The objective is to elevate the internal data management capabilities of SMEs—transforming ad-hoc data practices into robust, governable workflows—so that these actors can actively derive value from, and contribute to, the ecosystem. This dimension emphasizes that the sustainability of a data space is rooted in the operational reality of its participants; without upgrading the internal processes of the "data providers" and "data users," the ecosystem remains an empty shell.

Coordinating these actors requires the **second building block**, Governance Elements, which functions as the top-down strategic layer. Governance is not limited to compliance but extends to the architectural design of ownership, control, and value creation. This dimension calls for the identification of keystone organizations that reduce complexity for other network participants and drive ecosystem productivity. Governance also involves defining the "rules of the game," ranging from ownership structures (centralized vs. decentralized) to the specific mechanisms that balance complementor autonomy with ecosystem integrity. It is within this dimension that the tension between data sovereignty and collaboration is managed, establishing the trust policies and standard interoperability guidelines (such as those based on [5]) necessary to lower transaction costs for resource-constrained SMEs.

Underpinning the previous two dimensions is the **third building block**, Technical Elements. This dimension involves the instantiation of the foundational infrastructure that operationalizes the governance rules and business logic. This layer is responsible for the definition of tools and the deployment of boundary resources—standardized interfaces and software development kits that allow diverse actors to connect to the platform without friction. Crucially, technical architecture must be designed to support evolution, incorporating metrics for "plasticity" and "synergy" to ensure the infrastructure can adapt to changing ecosystem needs. By integrating sovereignty-protecting technologies (e.g., IDSA connectors) with value-added services, the technical elements provide the stable substrate upon which the dynamic interactions of the ecosystem occur.

Together, these three dimensions form a comprehensive vision: a federated network where Data Maturity Services prepare the actors, Governance structures the market, and Technical Elements provide the trusted medium. However, while this framework maps the necessary components, the dynamic orchestration of these elements—specifically how to ignite participation and manage the complex interplay between distinct user groups—requires a theoretical lens capable of explaining network effects and platform evolution.

3 Data Spaces as Digital Platform Ecosystems

DPs leverage the availability and diversity of information technologies, combining and (re)configuring them to orchestrate ecosystems of supply and demand [8]. Within these environments, actors utilize platform-provided interfaces to co-create complementary products or services, thereby acting as platform complementors [12,8,1]. Conversely, end-users consume these services, exchanging remuneration, data, or other forms of value in return [16,8]. To manage these dynamics, platform owners employ technical and governance mechanisms that balance centralized authority with the autonomy of ecosystem actors [16,4]. Recent conceptual advancements in platform ecosystems from [11,10] emphasize the necessity of analyzing inter-organizational perspectives, encompassing economic, business, and social dimensions. Within this discourse, [8] explicitly characterize the platform ecosystem as a composite of both high and low-autonomy complementors.

In this paper we argue that the design of digital platforms within the specific context of sectorial data spaces necessitates a departure from traditional platform approaches. While classic platforms are frequently keystone-driven by architected and governed by a single profit-maximizing entity that unilaterally defines boundary resources—data spaces predominantly emerge as alliance-driven multi-sided platforms governed by institutionalized consortia [14,4]. This structural distinction fundamentally alters the design trajectory: unlike the standard MSP lifecycle which progresses from innovation to adoption and finally to scaling, the design of alliance-driven data spaces often inverts this sequence [14]. In these environments, the adoption of the platform's purpose and value proposition by a consortium often precedes the actual technical 'innovation' and architectural design of the platform artifact [14].

Conceptualizing data spaces as MSPs is supported by the way value creation is leveraged through the facilitated interaction between different actors [2,7]. Unlike traditional centralized models, DS function as a decentralized infrastructure that coordinates these multi-sided network of autonomous actors to exchange and consume data [13]. In economic terms, DS endorses data sharing to (a) provide access to data while possessing sovereignty, and (b) develop services and applications that exploit both organization and other's data [2]. Thus, envisioning data spaces through MSP theory provides an oriented vocabulary to specify who interacts, how interactions are enabled, and how growth can be directed.

Consequently, the design process for these ecosystems has recently been framed through Action Design Research, structuring development into iterative cycles of diagnosis, design, implementation, and evolution to manage the complexity of coordinating legally autonomous entities [6,15]. Within this process, the design must address the dual nature of data as a boundary resource: it serves simultaneously as a social resource for identifying multilateral use cases and a technical resource for specifying architectural components like connectors [14]. To operationalize this, researchers and practitioners utilize prototyping as a central tool to refine abstract governance requirements into concrete technical specifications [6]. For instance, early design phases often focus on establishing common denominators regarding data sovereignty and trust, which is subsequently translated into technical boundary resources such as identity management services and usage control policies [14].

The Data Service Model (DSM) is another attempt by scholars of refining this process by decomposing the platform's functional requirements. This model separates the platform architecture into infrastructural services (e.g., identity, trust anchors) and transactional services (e.g., exchange, clearing), allowing design principles to evolve from high-level ecosystem goals into granular, actionable software components [6]. This iterative distribution of boundary resources ensures that the platform architecture remains aligned with the evolving business models and governance structures of the ecosystem participants [6]."

This perspective allows us to analyze the ecosystem through the mechanics of platform economics, while simultaneously addressing the unique organizational characteristics that distinguish federated industrial networks from consumer-grade digital platforms.

3.1 Juxtaposing the Design of Digital Platforms and Data Spaces

The most profound divergence lies in the locus of design authority. Classic MSP literature describes a "keystone-driven" model, where a single profit-maximizing entity (e.g., Amazon, Uber) unilaterally designs the architecture and governance rules to optimize network effects and value capture [14]. In this context, the design focus is on establishing centralized control points to manage complementors [8]. In contrast, data spaces are predominantly designed as "alliance-driven" MSPs [14]. The design authority is not a single firm but an institutionalized consortium of stakeholders (e.g., the International Data Spaces Association or Gaia-X). Consequently, the design process shifts from unilateral optimization to multilateral consensus-building. This structural difference impacts the speed and agility of design; while keystone firms can rapidly pivot design decisions to meet market needs, alliance-driven data spaces must navigate complex legislative and organizational coordination before technical implementation can occur [14].

When it comes to technical design of the two infrastructure, their differing goals regarding data ownership have a significant impact on data governance and management. Traditional platforms are architected around centralized data infrastructures where data is aggregated, where the design goal is often to reduce transaction costs by concentrating data assets, creating a bottleneck effect that serves to control and mediate interactions.

Data spaces on the other hand are from the begging architected as federated systems where data remains at the source and is only exchanged upon request. The central design artifact is not the platform's interfaces (programmatic or otherwise) but the Connector (e.g., IDS or Eclipse Dataspace Connector), that acts as a gateway ensuring sovereignty and policy enforcement at the edge. This distinction forces a shift in design priorities: whereas classic MSPs design for stickiness and lock-in to retain users within the walled garden, data space architectures are designed for interoperability and portability to prevent lock-in and enable cross-ecosystem data flows.

Governance and regulatory instruments differ sharply between the two models. In classic MSPs, governance relies on bundled allocation and control choices. Decision rights are divided between platform owners (who set core standards and compliance rules) and complementors (who control feature design and customer relations). To shape participation, owners utilize formal mechanisms—such as gatekeeping, performance measurement, and prescribed processes—alongside informal community norms to ensure conformity.

Conversely, B2B data spaces shift from pricing-driven coordination to prioritizing participant sovereignty. Decision rights explicitly delineate collective rules, authority enforcement, and the data holder's unilateral control over access, permitted purposes, and revocation. Consequently, governance relies heavily on ex-ante safeguards rather than transaction fees: certification, identity services, auditable compliance, and enforceable usage policies [14]. Soft norms, such as reputational effects and peer pressure, complement these strict controls to stabilize cooperation amidst legal and competitive sensitivities.

Within this governance-first orientation, pricing acts as a supporting mechanism. Subsidies, cost-allocation, and value-sharing are evaluated on their ability to sustain participation and trust rather than optimizing fee capture. Ultimately, a data space's viability depends on fair value distribution and robust technical and organizational controls that guarantee data will not be misappropriated.

Finally, the literature suggests that the design trajectory of data spaces fundamentally inverts the standard platform lifecycle, shifting from a linear progression of technical rollout to a consensus-driven organizational process.

Classic digital platforms typically follow a keystone-driven lifecycle sequence characterized by Innovation to Adoption to Scaling. In this model, a single profit-maximizing entity (the platform owner) unilaterally develops a technical innovation and defines the boundary resources (e.g., APIs) before introducing the platform to the market. The primary challenge in this phase is attracting a critical mass of users to the finished artifact to ignite network effects, often using pricing subsidies as the primary regulatory instrument. In contrast, sectorial data spaces, which function as alliance-driven MSPs, exhibit an Adoption to Innovation trajectory. Because these ecosystems are governed by institutionalized consortia rather than a single firm, the "adoption" of the platform's purpose and value proposition by the alliance members must precede the actual technical design or "innovation" of the artifact.

Another important point is that unlike classic platforms that develop rules as they scale, data spaces require "ex-ante" regulation where the ecosystem must first agree on a governance framework, trust mechanisms, and standards before the technical platform can be fully realized. Consequently, the design process is characterized by a common denominator approach where innovation activities are not driven by a single firm's vision but are initiated through a consensual process where diverse stakeholders must align on the shared infrastructure required to enable sovereign data exchange. This necessitates that organizational capabilities and role definitions be established prior to the deployment of technical services.

4 Designing Sectorial Data Spaces

In this section we translate the framing of data spaces as a specialized, decentralized evolution of the industrial digital platform model into a prescriptive and actionable set of tools for ecosystem owners and designers. By tracing a path between the classical digital platform theory and navigating the continuum between the more abstract platform economics and concrete ecosystem requirements, these tools are meant to guide the bootstrapping of sectorial data spaces.

Table 1. MSPs & sectorial data spaces characteristics juxtaposition

Design Dimension	MSPs	Sectorial Data Spaces
Governance Model	**Keystone-Driven:** Single entity ownership.	**Alliance-Driven:** Consortium/Federated governance.
Architecture	**Centralized:** Data lakes/Cloud; platform is the hub.	**Federated:** Data at source; Connectors as gateways.
Reg. Instrument	**Pricing:** Subsidies to ignite network effects.	**Trust & Sovereignty:** Certification and Usage Control.
Key Boundary Resource	**APIs/SDKs:** Technical interfaces to core functionality.	**Data & Connectors:** Data itself is the boundary resource.
Design Lifecycle	**Innovation then Adoption:** Build it, then attract users.	**Adoption then Innovation:** Form alliance, then build.

4.1 Phase I: Operationalizing Trough a Platform Perspective

The bootstrapping process begins by resolving the fundamental tension between centralized control and federated autonomy. While classic MSPs rely on keystone firms to guide the development of the ecosystem by setting the rules, the federated nature sectorial data spaces means they are typically alliance-driven, requiring a collective governance structure to establish trust among potentially competing stakeholders.

In this phase, practitioners must utilize tools such as the Organizational Decision Tree as defined in [3] to formally define the initiative's legal and strategic personality. Unlike traditional platforms where a single firm dictates terms, the sectorial context demands the establishment of a neutral governance authority, often an association or a consortium that holds the "meta-rights" to the ecosystem. This centralized steering committee functions as a temporary keystone, responsible for defining the initial value proposition and minimizing the coordination costs that typically paralyze collective action. By centralizing the initial design choices such as the profit orientation, membership criteria, and the precise definition of the "sides" (e.g., distinguishing between simple data providers and value-add application developers) the core team mitigates the "chicken-and-egg" problem [14]. This creates a stable, non-extractive venue that provides the necessary institutional trust for early adopters to join, paving the way for the gradual decentralization of control as the ecosystem matures.

4.2 Phase II: Co-Design via the Sectorial Data Space Canvas

Once the initial strategic vision is established, the design process requires to move to further align this vision with the business and technical elements of the ecosystem. In this process, the definition of value propositions, and the interacting services and transactions, along with relevant actors and stakeholder becomes a crucial process. Recognizing that standard business model canvases fail to capture the multi-lateral and sovereign nature of data spaces, we propose the Sectorial Data Space Canvas as a tool that integrates elements from the Platform Design Toolkit with the specific requirements of the IDS reference architecture.

The canvas serves as a critical boundary object that forces explicit mapping of roles, transactions, and value flows. Crucially, the utility of the canvas extends beyond static documentation; it functions as a mechanism for rapid prototyping and iterative refinement. In complex sociotechnical systems, the cost of architectural modification increases exponentially as the project moves toward technical instantiation. Therefore, the design process must embrace a "fail early" philosophy. By collectively visualizing value exchanges and governance logic on a shared medium, stakeholders can simulate ecosystem scenarios—effectively "prototyping" the business model before committing resources to code. This iterative process allows the consortium to expose structural weaknesses—such as misaligned incentives, "orphan roles" that lack economic drivers, or undefined liability boundaries in low-stakes environments. By resolving these frictions during the design phase, the canvas acts as a de-risking instrument, ensuring that the subsequent technical deployment is built upon a validated economic and organizational logic.

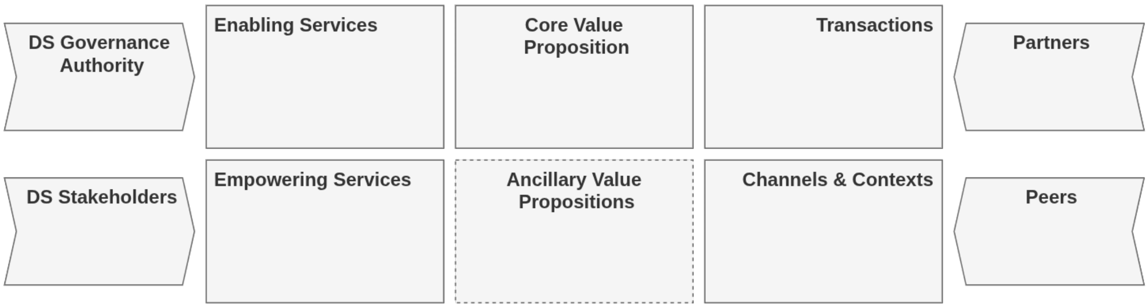

Fig. 1. Sectorial Data Space Canvas

4.3 Phase III: Technical Bootstrapping

The final phase translates the design propositions and requirements drawn from the canvas into the technical and legal rulebook, effectively converting the social contract of the ecosystem into the technical constructs and binding agreements.

Practitioners effectively operationalize the platform by instantiating the boundary resources defined in the previous phase. The DSM structures these resources into layers: the infrastructural base (identity and trust anchors), the transactional layer (connectors and gateways), and the business layer (domain-specific applications). Crucially, this phase involves the specification of the Data Space Rulebook, which codifies the governance decisions into enforceable standards, providing legal, business, and operational guidelines for data space participants. This includes the definition of usage control policy templates, machine-readable contracts that allow data owners to retain sovereignty by technically enforcing constraints on data usage. These constraints are fine-grained rules defining what must not happen to data (e.g., restrictions on data deletion and the purpose of use). They are embedded in the technical architecture through the use of a common, machine-interpretable language that all technical components understand, and are automatically enforced in every transaction through certified identities, such as X.509 certificates and dynamic attribute verification. This allows the ecosystem to transition from a high-trust, closed community to a zero-trust, open federation. The success of this phase is measured by the shift from grant-based or consortium-funded operations to a sustainable investment model, where the value captured by the transaction mechanisms covers the operational costs of the governance body, thereby completing the bootstrapping cycle.

5 Conclusion and Future Research

In this paper we argue that sectorial data spaces are not simply an incremental step in data management, but a distinct socio-technical paradigm within platform economics. By contrasting keystone-driven MSPs with alliance-driven data spaces, we show that effective design and governance require an inversion of core platform logic.

First, the design trajectory shifts from the classic innovation to adoption to scaling lifecycle to an adoption to innovation pattern: stakeholders institutionalize a shared purpose before the full technical artifact exists. This makes governance the primary design layer. Rather than relying on traditional strategies to trigger network effects, data spaces prioritize ex-ante regulation via trust frameworks, certification, identity, and enforceable usage control to make participation viable under competitive and legal constraints.

Second, data must be treated as a dual boundary resource: socially, as a vehicle for negotiating multilateral use cases; technically, as a standardized exchange object enabled by federated services (e.g., identity, metadata, clearing). The architectural implication is a move from centralization to federation: the goal is a “soft infrastructure” that preserves heterogeneous data sources while achieving interoperability. Accordingly, design authority resides less in a single platform owner and more in a meta-organization that balances participant autonomy with ecosystem-wide coherence.

Overall, the development of successful and value generating data ecosystems depends less on scaling a platform owner and more on governing federation. This calls for research that tightly couples engineering design choices with institutional economics and organizational theory, reflecting the shift from platform ownership to ecosystem orchestration.

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