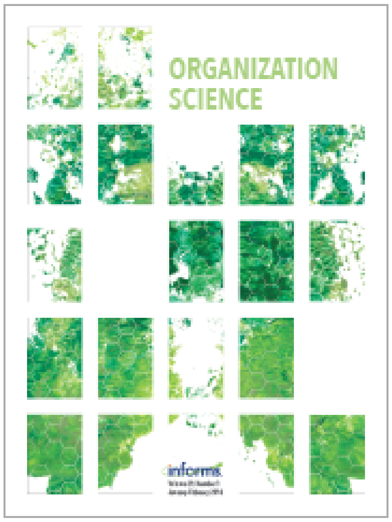

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Technology Ecosystem Governance

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Technology platform strategies offer a novel way to orchestrate a rich portfolio of contributions made by the many independent actors who form an ecosystem of heterogeneous complementors around a stable platform core. This form of organising has been successfully used in smartphone, gaming, commercial software, and industrial sectors. Technology ecosystems require stability and homogeneity to leverage common investments in standard components, but they also need variability and heterogeneity to meet evolving market demand. Although the required balance between stability and evolvability in the ecosystem has been addressed conceptually in the literature, we have less understanding of its underlying mechanics or appropriate governance. Through an extensive case study of a business software ecosystem consisting of a major multinational manufacturer of enterprise resource planning software at the core and a heterogeneous system of independent implementation partners and solution developers on the periphery, our research identifies three salient tensions that characterize the ecosystem: standard–variety, control–autonomy, and collective–individual. We then highlight the specific ecosystem governance mechanisms designed to simultaneously manage desirable and undesirable variance across each tension. Paradoxical tensions may manifest as dualities, where tensions are framed as complementary and mutually enabling. Alternatively, they may manifest as dualisms, where actors are faced with contradictory and disabling "either … or" decisions. We identify conditions where latent, complementary tensions become manifest as salient, contradictory tensions. By identifying conditions in which complementary logics are overshadowed by contradictory logics, our study further contributes to the understanding of the dynamics of technology ecosystems, as well as the effective design of technology ecosystem governance that can explicitly embrace paradoxical tensions toward generative outcomes.

Keywords: technology ecosystems; platforms; governance; paradox; tensions
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1. Introduction

Technology ecosystem governance has become a focal topic for the numerous technology platforms that organise the complements and services that extend the overall value of a core product. Platform strategies are well known from smartphone platforms but are also common in gaming consoles, social media platforms, as well as industrial sectors, where core products in software, manufacturing, or scientific machinery nourish an extended community of service organisations that operate as semiautonomous value-added resellers (Aguilar 1998, Weisenfeld et al. 2001). Moreover, platforms can also explicitly encourage innovations that go well beyond the original product portfolio of the core. Using purposefully designed governance mechanisms, such platforms can promote contributions of autonomous actors to create complementary products and services to address the needs of a large, globally heterogeneous group of end users in a manner that would be prohibitively difficult for the platform core to do alone. These activities go beyond the mere design, development, and distribution of predefined products toward a strategy of purposefully cultivating an ecosystem of complementors for generativity. *Generativity* refers to the ability of a self-contained system to create, generate, or produce a new output, structure, or behaviour without any input from the originator of the system (Tilson et al. 2010). It includes the technology artefacts as well as the social meanings and behaviours that constitute their larger system of use (Avital and Te'eni 2009).

However, the reliance on an ecosystem of autonomous partners is not without risk. Where generativity and local agility is desirable, uncontrolled creative output is not always positive for the health of the ecosystem (Hagiu and Halaburda 2010). Stated colloquially, letting a thousand flowers grow can also produce low-quality services and complements, resulting in a negative customer experience and thereby seriously harming the reputation and economic sustainability of the product platform (Boudreau 2012). So the design of governance mechanisms for technology ecosystems is not a trivial task; the challenge is to establish governance mechanisms that appropriately bound participant behaviour without excessively constraining the desired level of generativity. This governance problem has been broadly called the "paradox of change" (Tilson et al. 2010, p. 6) in the literature, referring to the need for technology ecosystems to be simultaneously stable and evolvable. Without evolvability, the platform cannot adequately adjust to changes in customer requirements, market shifts, and technology evolution. Without demonstrated stability, complementors and customers would have little assurance that their substantial financial and human resource investments can yield long-term returns.

Although the stability–evolvability tension has been addressed conceptually in the literature (Tilson et al. 2010, Tiwana et al. 2010, Yoo et al. 2010), the research lacks substantial empirical and theoretical insight into how this tension is manifested, as well as how technology ecosystem governance can address it. Stability–evolvability in technology ecosystems refers to the products and services of the platform. These outputs are produced by complementors who work autonomously to meet client needs but must simultaneously subsume their actions and outputs to some form of direction giving (Demsetz 1997) to control quality and encourage contributions to the public goods of the ecosystem. This suggests that the general stability–evolvability paradox is manifested across a number of underlying dimensions that produce tensions pertinent to technology ecosystems. As argued in the literature (Boudreau 2010, 2012; Hagiu and Halaburda 2010; Messerschmitt and Szyperski 2003), balancing these tensions is one of the main goals of technology ecosystem governance. It is essentially a design problem (Simons 1995), where specific governance levers, if properly implemented, can direct these tensions toward a sustainable equilibrium. If improperly implemented, ineffective governance can result in a degenerative evolution of the ecosystem. As existing research offers limited insight into what these underlying tensions are, the first stage of the design of effective ecosystem governance is to identify the most pertinent tensions and thereafter consider the design of governance mechanisms to effectively address them. Accordingly, we formulate our first research question.

Research Question 1. How are the main tensions in technology ecosystems addressed in technology ecosystem governance?

Scholars have broadly defined the term "paradox" in a managerial context as meeting competing demands simultaneously (Cameron 1986, Poole and Ven 1989), implying a need to balance contradictory tensions. However, the literature suggests that there are differences in the manner in which tensions can be framed or leveraged (Smith and Lewis 2011). Conceptually, tensions can manifest as contradictory trade-offs that present "either … or" decisions in the form of discrete alternatives, as a dualism. Alternatively, tensions can function as complementary and mutually enabling attractors in a holistic system, as a duality (Farjoun 2010). Given the centrality of tensions in ecosystem governance, our second research question explores how contradictory or complementary logics manifest in the ecosystem and how they are governed.

Research Question 2. Tensions can manifest themselves as either contradictory or complementary logics. Are contradictory and complementary logics present in technology ecosystems? If so, how are they governed?

One industrial sector that has successfully developed a vibrant ecosystem of third party complementors for generativity is enterprise resource planning (ERP) software. Providers of commercial accounting and manufacturing software suites, such as SAP and Oracle, have long benefited from the expertise of local or regional implementers to make country-specific modifications, sector specific add-ons, and company-specific customisations that meet the local, distinct needs of their clients.

The use of third-party partners to do this is largely driven by the extreme heterogeneity that characterises the enterprise resource planning software market. Using one standard software suite to meet the different requirements of sectors as diffuse as paper processing, healthcare, financial services, manufacturing, or education is a formidable challenge. Exacerbating the problem is the fact that the major ERP software packages mentioned above are designed to function in diverse global markets of more than 100 legal and accounting regimes. Orthogonal to national differences, myriad sector differences require modifications and add-ons to meet the needs of a wide range of entities from manufacturing to service organisations in the private and public sectors. Consequently, these ERP software manufacturers wisely consign localisation tasks to regional partners with far greater expertise in their native markets (Ceccagnoli et al. 2012, Sarker et al. 2012).

Accordingly, our analysis studies one such major vendor of ERP software that is of interest for several reasons. First, it is one of the few empirical examples of how technology platforms function in a for-profit, business-to-business context (Ceccagnoli et al. 2012, Sarker et al. 2012). Second, given the severe heterogeneity across customers, complementors, and complements, ERP ecosystems represent an extreme form of technology ecosystem. As such, the manner in which ERP ecosystem governance accommodates the most salient tensions, embracing them as either contradictory or complementary logics, is likely to be one of the more illustrative and subtle exemplars where such effects are discernible.

This empirical context allows us to make the following contributions. We identify three specific tensions pertinent to technology ecosystems that are characterised by high levels of heterogeneity: standard–variety, control–autonomy, and collective–individual. We then highlight the specific ecosystem governance mechanisms designed to simultaneously increase desirable variance and decrease undesirable variance across each tension. We further delineate how paradoxical tensions can be manifested as either complementary or contradictory logics, and we describe how these opposing logics can be accommodated by governance mechanisms, exploring their causes, effects, and potential managerial responses to them as a problem of technology ecosystem governance design. These specific insights contribute to the understanding of the actual mechanics of the stability–evolvability paradox in technology ecosystems, as well as providing theoretical and normative insights into how technology ecosystem governance can be designed to direct these tensions toward generative outcomes.

2. Conceptual Development

Technology ecosystems are often described as product platforms defined by core components made by the platform owner and complements made by autonomous companies in the periphery. These ecosystems have two primary characteristics: (1) they should perform an important function within a "system of use" or solve an important technical problem within an industry, and (2) it should be easy to connect to or build on the core solution in order to expand the system of use and allow new and even unanticipated end uses. The core firm's product has important, but limited, value when used alone but substantially increases in value when used with complements (Gawer and Cusumano 2002, 2008).

The term "ecosystem" alludes to the biology and ecology disciplines (Chapin et al. 2004, Folke et al. 2002, Holling 1973). A central concept is resilience, i.e., the ability of an ecosystem to maintain its own inertia yet adapt to exogenous shocks with an innate generative ability to evolve endogenously. Generative ability refers to the capacity of a self-contained system to create, generate, or produce a new output, structure, or behaviour without any input from the originator of the system (Avital and Te'eni 2009, Tilson et al. 2010). For technology ecosystems, this ability to evolve is particularly valuable when consumer patterns are heterogeneous, technologies are fragmented, and overall market trajectories are uncertain (Baldwin and Woodard 2008, Boudreau and Hagiu 2009). Yet excessive evolvability without some degree of stability and inertia can render a system fragmented in use, financially unsustainable, and irrelevant in the marketplace. Accordingly, maintaining equilibrium between stability and evolvability is a central challenge to technology ecosystems. By making some components variable, platforms become adaptable to future technological developments, social or business trends, as well as uncertain or unanticipated environmental changes. By keeping other components stable, they encourage the reuse of standardised processes and outputs that benefit the ecosystem as fully amortised investments, leverage economies of scale, and generate positive externalities and social goods.

To cultivate evolvability, ecosystem governance requires some elements that increase desirable variance and enable its evolution. Likewise, to maintain stability, ecosystem governance requires mechanisms to limit undesirable variance (Tilson et al. 2010, Yoo et al. 2012). Desirable and undesirable variance typically refer to *outputs*, i.e., the products and services that offer value, persuading customers to adopt one specific platform instead of another. Outputs are created by complementors, autonomous *actors* who channel entrepreneurial instinct to address client needs with novel innovations. Actors are driven by self-interested motives to respond to market needs yet must simultaneously contribute reusable knowledge to the greater collective good and cohesion of the ecosystem. Therefore, actors must simultaneously manage multiple *identifications* with their own interests as well as those of other groups and subgroups within the ecosystem. Consequently, we identify three distinct yet related tensions where this stability–evolvability trade-off can manifest in the ecosystem and must be embraced by technology ecosystem governance: (i) outputs, (ii) actors, and (iii) identifications.

2.1. Outputs: Standard and Variety

The economic logic of platforms suggests that a high standardisation of the core enables economies of scale and the amortisation of fixed costs. Yet on the periphery, economies of scope can be realised through the creation of specialised complements and constant experimentation (Baldwin and Clark 2000), where complementors respond to the needs of users with a level of speed or specialisation that would otherwise be prohibitively difficult for the core. By design, stability is leveraged to maximise variety.

Variety, however, is not limited to the periphery or complements of the platform. As Baldwin and Woodard (2008) highlighted, core components of a system will also need to change over time, if for no other reason than to embrace basic technological advances in underlying technologies. What remains stable through the evolution of the platform are the interfaces or thin crossing points (Baldwin 2008) that govern interaction between the layers (Baldwin and Woodard 2008). These architectural control points (Woodard 2008) govern the relationships between the core and complements, creating bottlenecks where platform operators can, via property and other legal rights of exclusion, grant or deny actors access to the system (Boudreau and Hagiu 2009, Jacobides et al. 2006, Rochet and Tirole 2003).

As such, the interfaces between components, either loosely or tightly coupled, are one of the most important levers of mechanism governance to balance a standard–tension. Loosely coupled ecosystems are characterised by very thin interfaces between components, enabling generativity to emerge at different layers of the platform architecture (Messerschmitt and Szyperski 2003, Yoo et al. 2010). Where loose coupling facilitates greater generativity, it risks greater fragmentation, inefficiency, inferior user experience, and overcrowding. By contrast, tightly coupled architectures tend to be closely nested or fixed, with closed product-specific interfaces that protect the market position of the product via lock-in and asset specificity. High levels of cohesion and integration with core components can increase an intrinsic protection from appropriation, as well as a more holistic and cohesive user experience; at the same time, however, they can stifle innovation and constrain the level of platform evolvability and user adoption (Parker and Van Alstyne 2005, Rochet and Tirole 2003). Consequently, technology ecosystem governance must balance the tension between standard and variety in outputs through variance decreasing or variance increasing mechanisms that often work simultaneously across diverse dimensions to achieve an optimal aggregate effect.

2.2. Actors: Control and Autonomy

The logic of technology ecosystems is based on the idea that, although it is possible to cultivate generativity within the boundaries of a single firm, generative potential is substantially increased in a looser arrangement of heterogeneous actors who pursue self-interested, innovative activities in a distributed and scalable ecosystem (Busquets et al. 2009, Yoo et al. 2010). As autonomous actors, complementors act as entrepreneurs, invoking the speed of market mechanisms while focusing their own portfolio of domain expertise, sector knowledge, and relational capital to create locally relevant solutions.

However, in letting a thousand flowers grow, unchecked variance in quality can lead to agency costs where the platform core bears the negative costs of the poor quality of the complementor or its applications (Wolter and Veloso 2008). As an example, Hagiu and Halaburda (2010) found that Atari's inability to control the overcrowding of low-quality games and subsequent downward price pressure in their ecosystem was central to the platform's demise. In other words, 200 well-designed flowers can be more beneficial to the sustainability of the ecosystem than 1,000 of a variable quality. This suggests that the focus of control levers is not limited to output quality but should also address issues of overall complement quantity, the distribution of complementor efforts across heterogeneous market niches, the frequency of complement releases, and other managerial decisions that directly or indirectly influence the quality, character, distribution, and availability of complement supply.

Accordingly, technology ecosystems must simultaneously realise a form of constrained serendipity (Faraj et al. 2011) by employing variance reducing mechanisms to control poor complement quality (both process and output), ensure professional business conduct, and constrain excess supply. Yet these ecosystems must also use variance increasing mechanisms to leverage autonomy for innovative responses to client requirements and market evolution, generating a sufficiently large high-quality portfolio of complements to encourage user adoption.

2.3. Identifications: Individual and Collective

In technology ecosystems, individual complementors work toward their own benefit for financial compensation, career advancement, or other extrinsic motivations. Yet where much generative work is localised with a specific client or application, the ecosystem itself still requires some sense of cohesion and consistency across niche-focused efforts, a larger social good, a canon of best practice, and a portfolio of reusable knowledge that further enables the scalable exploitation of common innovations. As a large system of distributed innovation, a governance infrastructure must be developed that embraces entrepreneurial, self-interested motivations; fragmented knowledge; diverse expertise; and market contexts and yet simultaneously directs disparate contributions to the greater collective benefits of the ecosystem (Boudreau 2011).

Yet the challenge of aligning individual and collective incentives is exacerbated in industrial ecosystems by the fact that complementors often work in consortia to deliver a good or service to the customer, risking problems of group or collective responsibility (Collins 1990). This "joint action interdependence" (Caglio and Ditillo 2008, p. 877) generates a team production environment where nonsequential, complementary processes are prominent, and direct lines of accountability may be difficult to define, let alone enforce (Miller et al. 2008). In these conditions of large-scale collective creativity (Adler and Chen 2011), it is important to establish incentives for members to invest in complementary innovations—that is, to work together in assembling different capabilities and expertise to create effective and holistic solutions for clients. This requires the simultaneous identification with multiple foci of commitment: (a) the immediate task/client, (b) the organisational group (e.g., partner consortia), and (c) the entire ecosystem. Consequently, ecosystem governance must simultaneously cultivate community identifications to reduce undesirable variance; that is, they must maximize contributions toward reusable knowledge, positive externalities, complementary innovations, and the ecosystem's social goods, as well as individual identifications increasing desirable variance to encourage creative, explorative, and entrepreneurial responses to client requirements and market developments.

2.4. Synopsis

The preceding argument can be summarised as follows: ecosystems require resilience, i.e., a combination of stable and evolvable attributes. In technology ecosystems, we identify three main dimensions across which the stability–evolvability equilibrium must be managed: (i) outputs, (ii) actors, and (iii) identifications. For technology ecosystem governance, we argue as follows.

- Stability and evolvability in *outputs* is achieved through (a) variance-reducing mechanisms to ensure *standards* and (b) variance-increasing mechanisms to generate *variety*.
- Standard and variety in outputs is realised by *actors* whose actions and behaviour must be simultaneously controlled and autonomous. This is enabled by (c) variance-reducing mechanisms to *control* actors and (d) variance-increasing mechanisms to leverage the *autonomy* of actors for innovative responses to client requirements.
- Achieving an appropriate balance between controlled and autonomous behaviour by actors is enabled by a combination of individual and collective *identifications*, where (e) *collective* identifications reduce undesirable variance toward contributions to the social goods of the ecosystem and (f) *individual* identifications increase desirable variance to encourage explorative and entrepreneurial responses.

A focal theme in this argument is achieving the appropriate balance. Hence, the consequences of extreme imbalances across each dimension are worth considering. For outputs, excessively strict governance could restrain the breadth and innovativeness of the complements, whereas excessively liberal governance could permit unrestricted growth in inferior quality complements and inferior service levels. For actors, excessively strict governance could suffocate entrepreneurial responses to client needs, whereas excessively liberal governance could permit the uncontrolled diffusion of poor business practices. For identifications, excessively strict governance could inhibit the agility of client responses and creativity of complements, whereas excessively liberal governance could allow the neglect of investments in collective, reusable knowledge or process innovations of the platform.

Indeed, although this conceptualization implies that some equilibrium across the three dimensions is desirable, a skewed weighting toward one extreme or the other may be appropriate for specific types of technology ecosystems at different stages of maturity (young versus established) or with dissimilar objectives (for-profit versus open-source).

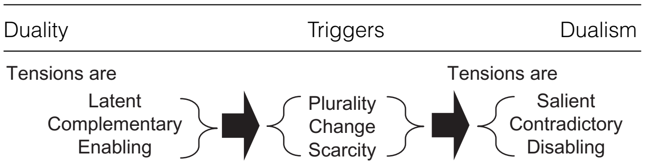
2.5. Managing Tensions in Ecosystem Governance: Framing Paradox

If technology ecosystem governance must simultaneously increase and decrease variance across outputs, actors, and identifications, then it is useful to review the literature on framing paradox that explores how organisations can simultaneously meet competing demands (Smith and Lewis 2011). Managerial research has conceptualised a paradox as either dualism or duality (Farjoun 2010). The idea of dualism is the view typically associated with trade-offs, conflicting alternatives framing tensions as mutually exclusive, either…or, or exhaustive classes (Farjoun 2010). Perhaps the most widely acknowledged dualism in the management literature is the classic view that exploration and exploitation are exclusive trade-offs (March 1991). In simple terms, the resource "pie" is fixed, and exploration efforts are, by definition, efforts not spent in exploitation. The choice between two competing options is always a zero-sum game (Farjoun 2010).

The concept of duality, by contrast, views the two options not as competing and mutually exclusive but rather as complementary, mutually enabling, and constituent of one another (Farjoun 2010). Exploration cannot be achieved without the economic sustainability provided by exploitation. Likewise, current exploitation is enabled by past exploration. Admittedly, this is not entirely inconsistent with the internal logic of a dualism. Dualisms, via a premise of competing alternatives and zero-sum games, also acknowledge that trade-offs require balance and an appropriate mix of both options. The main difference and augmentation of a duality perspective is to emphasise the complementary and interdependent characteristics of each option. Hence, a contradictory logic of zero-sum games is replaced by a complementary logic of positive-sum games.

If technology ecosystem governance must simultaneously increase and decrease variance, then effective ecosystem governance should frame this paradox to direct tensions toward complementary, not contradictory, outcomes. Informing this challenge, paradox scholars have suggested that paradoxes render complementary outcomes when they are latent, not salient (Smith and Lewis 2011). The process of organising produces latent tensions that exist in an interdependent, complementary duality. In this state these tensions remain dormant, unperceived, or ignored. So although the tensions exist, any perceived negative outcomes resulting from the tensions are immaterial. The authors cited the example of the introduction of the personal computer. Although many predicted a swift decline of mainframe computing, mainframe revenues continued to increase for more than 20 years. However, certain environmental conditions may bring paradoxical tensions to the foreground as salient, contradictory dualisms. Smith and Lewis (2011) offered three factors, which they termed *triggers*, that can render paradoxical tensions salient: (1) plurality, (2) change, and (3) scarcity. Plurality increases options that can manifest as competing goals to be evaluated with limited cognitive resources or comparative abilities, resulting in uncertainty. Likewise, change also highlights new options and competing opportunities, thus increasing uncertainty. Finally, resource scarcity raises

Table 1 Tensions in Duality and Dualism



the well-known problems of trade-offs; a decision to allocate limited resources in one area is a decision not to use these resources in another area. This is summarised in Table 1.

In the context of technology ecosystems, several potential affects can be intuited. Plurality is pertinent where an overpopulation of the ecosystem by numerous complements creates an abundance of similar options for potential clients, exacerbating uncertainty and paralyzing decision making. Scarcity becomes relevant in conditions of elevated competition in the ecosystem, where many complementors compete for few valuable clients, thus discouraging cooperation in product consortia and hindering the sharing of best practice. Finally, a high degree of change, either in the evolution of the base technologies or in the market conditions in which the products will be used, can generate uncertainty about the potential economic return on investments in skills, organization capabilities, and specific complements as revenue-generating products. Table 2 presents hypothetical scenarios where tensions manifest as either contradictory or complementary.

3. Technology Ecosystem Mechanisms

3.1. Case Background

To illustrate how these tensions can be governed, we analyse a case of a complex technology ecosystem characterised by significant heterogeneity and generative activity. Our case analysis originates from a provider of an ERP software suite ("software vendor"). The vendor is an international organisation present in more than 45 countries throughout Europe, Asia, and North and Latin America. The software is targeted at organisations that have between 50 and 5,000 users. As such, small and medium enterprises (SMEs) constitute the majority of the vendor's clients. Given the scale and scope of such a heterogeneous and dispersed client base, the software vendor has cultivated a sophisticated ecosystem of third-party implementation and solution partners to configure and modify the software, as well as develop focused complements/add-ons to the base software suite.

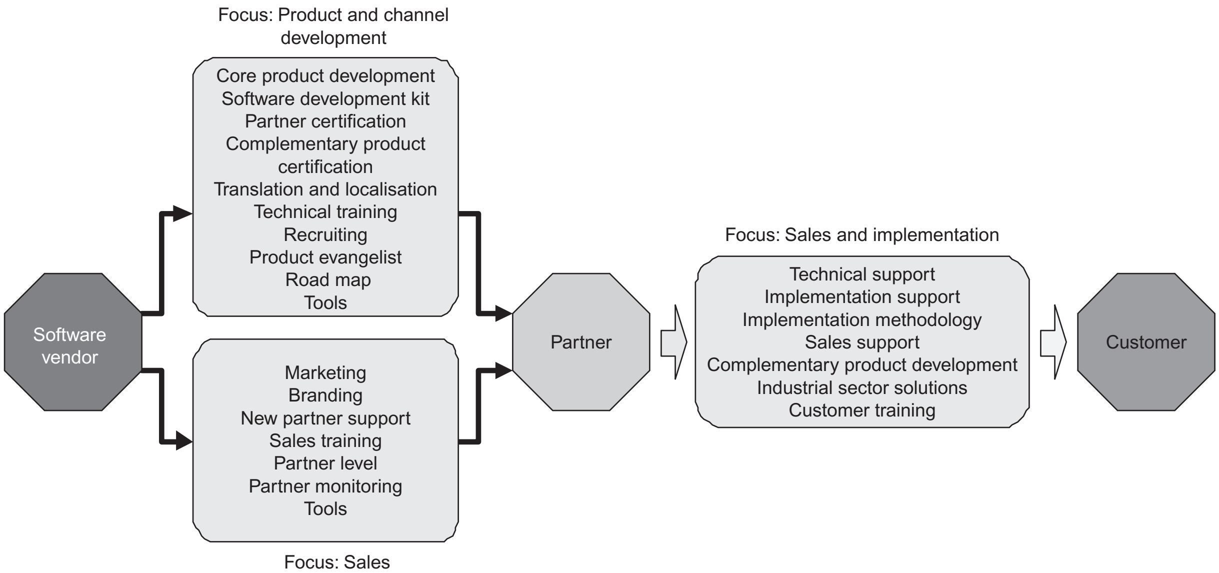
Activities in the sales and implementation processes fall in three main categories: (a) product and channel development, (b) early-stage sales, and (c) implementation and late-stage sales. These activities are illustrated in Figure 1.

The process begins with the direct marketing efforts of partners with potential clients. Once the customer chooses the implementation partner, the partner and customer decide which software products to implement and how to implement them. The software's open-source code enables partners to configure and customise the core software to match customer requirements. The licences for core products are owned by the software vendor; licence revenues are shared between the software vendor and partners, whereas the licence for any partner solutions or add-ons is owned by the developing partner. Multiple partners often collaborate, including single-module implementations as well as mixed-module implementations composed of complements from multiple partners. In these cases, revenue sharing is negotiated

Table 2 Contradictory and Complementary Scenarios in Technology Ecosystem Governance

Tension	Contradictory scenario (duality)	Complementary scenario (dualism)
Standard–variety (outputs)	Niche-oriented complementors develop customised innovations that excel at meeting customer requirements. Yet their artisanal qualities limit reuse despite overlaps and redundant features across competing complements. A lack of common interfaces and economic incentives limits sharing. Ecosystem-level synergies are limited.	Predictable standards provide complementors with assurance of the eventual scalability and reuse of their innovations across different contexts and users. Efficient communication of the core evolution path allows complementors to maintain compatibility over time. Increased investments in complement quality and quantity.
Control–autonomy (actions)	Diagnostic control mechanisms are used to reduce undesirable variance in quality yet focus punitively on errors and foster defensive responses that discourage risk and undermine creativity, thereby restricting generative responses by complementors.	Control is not random but purposefully targets elements that reduce undesirable process and outcome variance that can threaten the ecosystem at critical points. By reducing risk in specific areas (e.g., interoperability), control enables autonomous, option-creating responses to clients in other areas (e.g., functionality, services).
Collective–individual (identifications)	Excessive focus on individual gain results in a highly competitive situation between core and complementors, detracting from the efforts of standardisation and constraining direct and indirect network effects and public goods (Ibarra et al. 2005).	Complementors knowingly or unknowingly subsume their self-interested conduct to some form of direction giving (Demsetz 1997) that orients their individual identifications toward the desired collective outcomes of the ecosystem. Collective identifications enable communal contributions without having adverse effects on the creative efforts of individual actors.

Figure 1 Platform Mechanisms in the Software Ecosystem



on a case-by-case basis with guidelines provided by the software vendor.

Customer training and support are the responsibility of the partner; the software vendor provides support to partners depending on their level of platform certification. Likewise, maintenance and upgrade of both core software and partner solutions are the responsibility of partners. The software vendor offers some support to the implementation partners via sales support for larger clients; technical expertise; online tools; and templates for presales proposal preparation, project management, and implementation tools. The eventual solution is the result of choosing certain modules, configuring and customising the software source code when appropriate, integrating the core software with partner vertical solutions and third-party software, and changing the customer's business processes when necessary.

Where we use the generic term "partner," it must be acknowledged that there are a wide variety of companies included in this group. The companies differ in many dimensions such as size; nationality; regional versus national versus international focus; type (independent software vendors, value-added resellers, etc.); as well as application development partners, implementation partners, and those who focus on both development and implementation. In our subsequent analysis, we equate all partners as "complementors" from the platform literature. Partners may focus on a single role or may develop competencies in multiple roles. Finally, partners may specialise in one or more industry sectors and develop complements and perform software implementations for these specific sectors.

Consider the following examples:

• *Complementor A* is a German partner with a broad profile that specialises in accounting, finance, tax, and human resource (HR) modules. As such, the firm could be considered a generalist partner that provides support, training, and implementation in the German market, with deep knowledge of the accounting, tax, and HR regimes.

• *Complementor B* is an American partner that has developed a global customer relationship management (CRM) add-on to support advanced online marketing, segmentation, and pricing. It does not handle generalist implementations but simply develops and supports its product across all regions and industries.

• *Complementor C* is a vertical specialist with deep knowledge of the food processing industry. It performs general implementations for clients across a broad geographical region (e.g., South America), and it sells and supports several of its own vertical add-ons for specific industries.

This heterogeneity is illustrated in Table 3.

It is evident that the profiles, activities, and markets of these complementor archetypes differ substantially, rendering a level of heterogeneity that, according to the software vendor, often leads to excessive variance in the quality of both complementors and complements.

3.2. Methods

Our research design used an inductive, grounded theory approach in accordance with the exploratory nature of the study. The data collection and analysis were completed in two main phases, largely in accordance with the two main research questions. Data collected for both phases included 31 semistructured interviews conducted between November 2007 and June 2010. We used a theoretical sampling approach, selecting subjects for their similarities as well as their differences. Software vendor employees ($N = 16$) were chosen from a wide selection of functional areas within the software vendor to

Table 3 Complementor Activities and Domains

	Domain		
Activity	Geographic (national, regional, international)	Functional (SW package, accounting and finance, manufacturing, HR, CRM, etc.)	Industrial (consumer goods, light/heavy manufacturing, chemicals, transportation, hospitality, etc.)
Support	A, B, C	A	C
Training	A	A	
Implementation/customisation	A, C	A	C
Add-on development	B, C	B	C

Notes. A, B, and C refer to their respective complementors described in text. SW, software.

acquire an understanding of the breadth of mechanisms and programs in place. These employees include channel management partners, development managers, and research and development (R&D) directors. In addition, we interviewed a selection of independent software development and implementation partners ($N = 10$). Partners were chosen on initial recommendations from software vendor management and subsequent recommendations from the interviewees, with the objective of interviewing a representative cross section (size, industry, geography). We also attended two three-day international partner conventions and attended (as participants) a variety of presentations and workshops designed to support implementation partners. Finally, we interviewed a selection of customers ($N = 5$) in distinct industry sectors to incorporate the end user perspective. The interview process was concluded when no significant additional insights were obtained from additional data points and theoretical saturation was achieved. All interviews were attended by a minimum of two researchers. The third researcher validated the interview transcription, seeking expansion or qualification when required. In addition, substantial archival data available from the software vendor were used to complement data gathered from the respondents. Insights were also cross-validated from industry literature, particularly competing software platforms. Finally, five validation incidents were staged to cross-check information provided by partners and customers with representatives from the software vendor, and vice versa (three in phase 1 and two in phase 2).

The first phase of our research sought to understand the underlying purpose and mechanics of the ecosystem, including the main actors, behaviours, and micro- and macro-level outcomes. We further delineated the various goals of the actors to define convergent and divergent incentives. This analysis permitted us to converge on the three main tensions we identified, as well as the underlying ecosystem governance mechanisms to address such tensions. The second phase of our research explored the framing of such tensions by the various actors. As the general aim of phase 1 was to understand the overall scope, purpose, and mechanisms of the ecosystem, the interviews in phase 1 of the research were far more open ended. In phase 2, our questioning narrowed substantially as we had a well-developed understanding of the ecosystem structure and processes and could then explore how actors framed and responded to specific issues. Major themes in the second phase included questions such as the following: Did the partners view their relationship with the core as positive or negative? Were they proud and appreciative of the membership in the ecosystem, or did they view it as a necessary evil? How did they work with the other partners? All together, the two main research phases were decomposed into eight specific stages.

The data were analysed by identifying general concepts (open coding), organising the concepts into categories defining their properties and relationships (axial coding), and finally integrating the categories to theorize about the overall ecosystem as an aggregate phenomenon (selective coding) (Glaser and Strauss 1967). Categories were chosen by triangulating four main sources: the software vendor's partner program guidelines (archival data), interviews with representatives from the software vendor, interviews with partners and customers, and prior literature and theory reviewed in §2. A detailed description of each stage, with exemplary questions, thematic coding, and outcomes, is provided in Table A.1 of the appendix.

4. Findings

4.1. Research Question 1—Technology Ecosystem Tensions and Governance

In the following section, we provide an operational description of specific ecosystem governance mechanisms and how they are designed to accommodate the three main tensions identified.

4.1.1. Outputs: Standard–Variety. Initial entry into the ecosystem as a registered partner is not particularly difficult; it requires approval and some validation by the software vendor. Partners seeking to develop skills and experience in the development and implementation of the software application can contact new partner support and training centres run by the software vendor or third-party training entities, although this is not obligatory.

The open-source code is consistent with the positioning of the software toward SMEs, who typically do not welcome large changes to their own business processes but would rather change the software to fit their existing business structure. Consequently, the acquisition or development of coding skills required for advanced implementations requires substantial effort. To address this requirement, the software vendor has created a number of utilities and training support centres to enrich creative responses to client demands, including extensive code libraries, technical support, integrated development environments with proprietary coding language, financing facilities, centralised sales and marketing support, as well as a community-based platform that enables the sharing and recombination of tested code, modules, or vertical applications.

The mechanisms developed to reduce undesirable variance in process and output quality include an advanced regime of certification of both employees and partners for technology competencies that affect higher quality standards across outputs. Complements and solutions are also tested and certified. These certifications require that the partners use development and implementation templates that help ensure that requisite quality levels in functionality and intercomponent compatibility are maintained. Additional reinforcement of the best development and implementation practices is achieved through training centres and community platforms with code libraries and consortia-based project management templates.

Table 4 identifies the specific governance mechanisms for increasing desirable variance for output variety and decreasing undesirable variance for output standardisation. All of these mechanisms are designed and enacted by the ecosystem core for use by the ecosystem partners.

A theme that emerges in our analysis is that many of the mechanisms simultaneously serve to both constrain undesirable variance and facilitate desirable variance, working across different dimensions of the same process. For example, the integrated software development tool serves to increase complementor productivity, functional exploration, and creative problem solving. At the same time, it constrains specific technological attributes that ensure quality and compatibility. The embedded, dual function of these mechanisms is a commonly found characteristic in many of the governance mechanisms we identified.

4.1.2. Actors: Control–Autonomy. The main mechanism used to negotiate control–autonomy tension is self-selection. Stated simply, partners are granted very high levels of autonomy when they enter the ecosystem. Via self-selection, they choose the level and nature of control that is appropriate for their business portfolio based on the perceived benefits realised by adopting higher control levels. Table 5 identifies five levels of elective control in the software vendor ecosystem across the dimension of partner certification level, describing the infrastructure mechanisms and incentives available to participants at each level. Entry into the software vendor ecosystem begins at level 1. Partners have the option of remaining at this level perpetually. However, if they find advancement to higher levels beneficial, they can self-select themselves for higher levels by meeting the requirements.

Table 4 Governance Mechanisms Fostering Standard and Variety in Outputs

Concept	Case data
Mechanisms fostering output variety (*increasing desirable variance*)	• Open-source code of core applications/protected source code for partner solutions • Specialised integrated development environments and development language • Ease of customisation • Code libraries • Integrated development utilities • Technical support • Financing facilities • Sales and marketing support • Community solution catalogues
Mechanisms enforcing standardized output (*reducing undesirable variance*)	• Configuration tools and templates • Multipartner project management templates • Certification of partner solutions • Certification of personnel • Education and training facilities • Third-party verification of solution compatibility • Required use of implementation tool/process • Training centres • Community platforms to facilitate code application reuse

These levels are, with limited exceptions, inclusive (level 3 is a small business specialist), meaning that the requirements and benefits of a higher level build on those of the previous level. Advancement to levels 4 and 5 is permitted by the acquisition of internal points, which are awarded for a variety of achievements and are valid for a limited time. Points are awarded for many activities, including technical certifications of personnel, specialist competency designations, demonstrated competencies in specific application areas, validated customer references, technical testing of applications, successful participation in customer satisfaction surveys, and the volume of licences and/or revenue generated by the sales of the core platform product in specific markets.

Note that the key concept in the design of governance mechanisms is that each level of control imparts some additional value to both the periphery and core; that is, a value proposition is subsumed in the control infrastructure. For example, partner support and productivity centres offer support and training to newer partners who benefit from stimulus to achieve critical mass. This additional training also improves quality control in the final products and services. Likewise, higher levels

Table 5 Partner Levels, Requirements, and Value Proposition

Partner level	Requirements	Value to periphery partners	Value to core
Fifth (*highest level*)	• Maximum point threshold • Partner personnel certified • Core vertical solutions certified • Demonstrated competency in a focused strategic area • Participation in customer satisfaction surveys • Dedicated software vendor account manager for large clients • Validated customer references	• Highest level of cobranding • Maximum suite of software licences • Access to development libraries • Priority listing in solution finder catalogues • Priority real-time technical support • Financing facility • Dedicated software vendor account manager for large clients	• Core product licence revenue • Expanded core software offering and vertical solutions • Specialist competencies • Increased licence revenue
Fourth	• Medium-point threshold • Partner personnel certified • Partner solutions certified • Customer references • Partner subscription fee	• Expanded suite of licences for development and infrastructure software • Practice management support • More qualified personnel • Use of software vendor logo/brand • Inclusion of partner solutions in a solution finder catalogue • Additional free online training • Additional sales and marketing support	• Core product licence revenue • More qualified implementation personnel • Fewer software errors • Improved software interoperability • Expanded portfolio of partner solutions
Third	• Organisational assessment • Partner personnel tested/certified	• Expanded suite of development tools • Licences for infrastructure software • Use of software vendor logo and branding • Priority technical support • Specialist community access • Financing facility	• Core product licence revenue • Subscription revenue
Second	• Subscription fees • Implementation templates	• Development tools • Productivity software licences • Online training platform • Marketing tools and support • Community technical support	• Core product licence revenue • Subscription revenue
First (*entry level*)	• Registration	• Access to peer network • Access to technical support communities • Marketing and sales tools	• Core product licence revenue

of certification for both solutions and partners require more stringent control (e.g., testing by a third party, documented industry-level implementations of solutions) yet simultaneously offer value to the periphery partners (higher-quality solutions/services, cobranding with the software vendor) and the core (expanded catalogue of high-quality partner solutions, greater scale and scope of ecosystem, additional revenue). To summarise, variance-increasing autonomy is embraced through self-selection; actors choose their desired control levels based on the perceived utility of the control mechanisms. Variance-reducing control is manifested through graduated control regimes that offer some perceived value for the complementors. Table 5 summarises the basic requirements for advancement to each level, the specific control mechanisms, and the potential value that these mechanisms impart on periphery partners and the platform core.

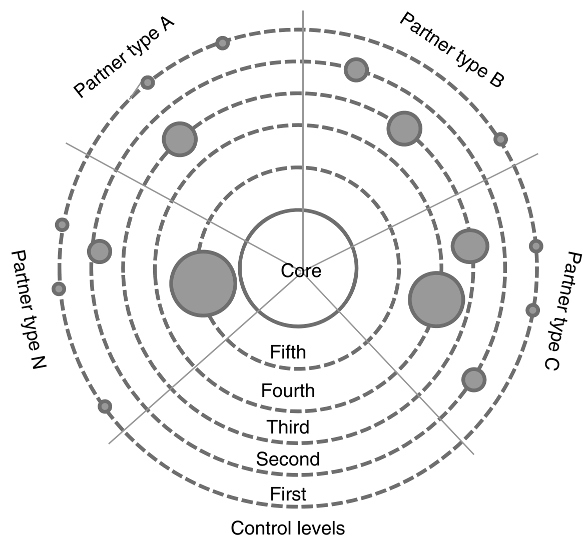
To obtain higher certification status, partners must typically demonstrate a variety of achievements (to obtain points) or willingly submit to greater levels of control over their processes and outputs. In this respect it is similar to a market transaction, where something is offered in exchange for some expected value and increased status.

An analysis of the ecosystem mechanisms suggests that the majority simultaneously imparts value to the individual partners as well as the collective ecosystem. For individual partner benefits, we can identify several that are consistent across all five levels of partners. These include access to technical development tools and software libraries, sales and marketing support, status and legitimacy via cobranding, customer service and technical support, improved quality of add-ons, implementation skills, and customer satisfaction. Benefits accrue to solution partners in increasingly higher levels commensurate with the stricter requirements placed on the solution providers.

The main benefit imparted to the platform core is the direct incentive for the partners to sell additional licences of the core products. Points are explicitly awarded for increased licence revenue for a variety of products. The secondary, but perhaps more important, benefits to the ecosystem are the indirect network effects of a larger, more vibrant ecosystem of qualified implementation partners and the availability of software applications and other subsidiary complements.

Figure 2 uses a solar system metaphor to illustrate how partners can obtain similar control levels via diverse

Figure 2 Self-Selecting Control Levels



means, with differing sizes, markets, and expertise or business portfolios.

4.1.3. Identification: Collective–Individual. Participation in a for-profit industrial ecosystem is largely premised on profit-seeking behaviour. As such, self-interested, individual identifications will be predominant among partners. Yet at various points, identifications can—and must—expand from strictly individual to include (i) the client and task, (ii) a larger group or project consortia, or even (iii) the greater collective ecosystem based on reciprocal exchange where partners both contribute to and benefit from the greater "social goods" made available on the platform. Ecosystem governance must speak to both individual and collective identifications concurrently.

Collective identifications are cultivated at the preliminary control levels. The main partner's Web portal for the software vendor identifies several hundred websites that are independently maintained and intended for use by partners and customers. These provide such services as discussion forums, blogs, white papers, listings of partner solutions (with comments and ratings), job listings, events listings, downloads, code samples, bug reports, tutorials, and advice. In this forum, end users can share best practices in areas such as partner selection, implementation processes, and total cost of ownership minimisation.

Greater levels of interdependence are cultivated through interpartner collaboration for multiple-partner projects, facilitated by the partner-finding platform. This is a directory of several hundred thousand partners who publish profiles on practice and technical specialties, thousands of registered add-on applications, and numerous broadcast opportunities for collaboration on existing jobs or future tenders. The typical motivations for partner-partner collaboration include access to specialised skills, building a suite of complementary applications, or expanding geographic reach. For example, a partner with expertise in a particular industry segment may turn to another partner for their expertise in a "horizontal" application such as tax reporting. Alternatively, a partner may wish to expand internationally and find a partner in another country who could help localise its vertical application. Although the technicalities of partner-to-partner business relationships will vary from legal region and job profile, the software vendor certainly encourages these collaborations (while not directly regulating them) and provides a number of generic best practice templates and tutorials on the commercial structure of such partnerships.

True collective identifications also require informal governance to communicate legitimacy and status. Low barriers to ecosystem entry can present challenges for complementors. On the outskirts of the periphery, new entrants can suffer from low status and illegitimacy as a result of newness (Stinchcombe 1965). Given a lack of reputation and experience, they may choose to compete directly with incumbents or attempt to carve a defendable niche and differentiate themselves as specialists. Economic theory argues that uncertainty exists concerning the quality of a firm's products in market exchanges (Akerlof 1970). As such, a high status can serve as a signal or proxy of quality to help mitigate the problems of information asymmetry and uncertainty in economic exchanges (Podolny 1994). Hence, a mechanism must be designed to (a) validate the quality of the products, services, and organisations on the periphery and (b) transfer the reputational stock to the periphery partners in a manner that is commensurate with the quality achievement of the complementor's organisation or products (where warranted) yet does not expose the core to excessive risk of reputation deterioration. In this respect, status serves as a currency that the core can award to partners on the periphery via mechanisms of affiliation based on merit (Castellucci and Ertug 2010). The clearest evidence of this is the graduated certification levels, where higher levels of certification confer greater legitimacy on the complementors. Moreover, cobranding is also a graduated device, where partners with higher certification levels are permitted to use logos and other cobranding tools more liberally than lower-level partners. As partners achieve greater certification levels, their overall image often assumes a higher degree of similarity with the core in terms of colour or appearance; we found several partner applications that were virtually indistinguishable from the core applications. Note as per the previous description, advancement to higher levels is permitted by a system of internal points that opens many avenues to higher status, thereby accommodating individual autonomy and identifications while channelling them toward collective benefits. The results are summarised in Table 6.

Table 6 Governance Mechanisms Fostering Collective and Individual Identifications

Concept	Case data
Mechanisms fostering individual identifications (*increasing desirable variance*)	• Business support services offered to partners (training, productivity, financing). • Internal currencies to enable (i) common measurement standards to assess heterogeneous accomplishments, (ii) multiple paths through higher graduations of recognition, and (iii) horizontal mobility through the ecosystem. • Process definitions to enable heterogeneous identifications to include the (i) client and task, (ii) a larger group or project consortia, or even (iii) the greater collective ecosystem.
Mechanisms fostering collective identifications (*reducing undesirable variance*)	• Communal technical utilities, partner, solution, call-for-tender directories, code repositories, socialisation and training opportunities, and collaboration platforms. • Multipartner collaboration templates and best practice norms. • Implicit incentives in hierarchical control infrastructure to facilitate reciprocity and institutionalise common behavioural patterns, expectations, and norms to improve the quality and cohesion of the ecosystem. • Status, the potential for increased status, and legitimacy serve as an incentive for individual actors to contribute to greater collective efforts in the ecosystem.

4.1.4. Research Question 1—Summary of Main Findings. We summarize our main findings by tension.

• *Tension* 1: *Outputs—standard–variety*: Variance-reducing mechanisms focus on technical compatibility and quality standards of the implementations and complements for a common product evolution, interfacing and compatibility standards, as well as the amortisation of common development costs. Variance-increasing mechanisms include the open-source code that allows full flexibility in fulfilling functional requirements and addressing different legal regimes or operational requirements. Technical specialisation permits substantial freedom of choice in complementor positioning and service portfolios offered. Although distinct, standard–variety mechanisms are complementary; they enable increased creative freedom in the exploration of functions and services yet simultaneously constrain and enforce standard technical requirements. As such, standard–variety mechanisms are often embedded and interdependent.

• *Tension* 2: *Actors—control–autonomy*: Technology ecosystems are quasi-markets with autonomous, profit-seeking agents who choose to participate in generative activity. Complementors consciously choose to submit their creative outputs to process and output based controls based on perceived value, similar to a market transaction. Ecosystem participants thus forfeit some generative liberty in exchange for a commensurate value imparted by the control mechanism, making self-selection a central factor in managing this tension. Analogous to a market exchange, the discretionary adoption of variance-reducing control mechanisms by partners concurrently addresses disparate requirements, simultaneously imparting distinct values to the complementor and core. Similar to the standard–variety tension, variance-increasing mechanisms are often embedded in the variance-decreasing mechanisms.

• *Tension* 3: *Identifications—individual–collective*: For-profit ecosystems leverage self-interested behaviour and individual identification. As such, governance infrastructures must aggregate heterogeneous, random, and specialised contributions into a more cohesive ecosystem fostering the reuse and amortisation of complements through community contributions and collective identifications. These can be cultivated through explicit incentives and variance-reducing infrastructures such as communal technical utilities, code repositories, socialisation and training opportunities, and multipartner collaboration platforms. Likewise, ecosystem governance can employ implicit incentives to facilitate reciprocity and institutionalise common behavioural patterns, expectations, and norms to improve the quality and cohesion of the ecosystem. One important mechanism is status; the potential for increased legitimacy serves as an incentive for individual actors to contribute to greater collective efforts in the ecosystem, either directly through community contributions or indirectly by higher-quality products and services. At the same time, variance-increasing effects can be cultivated by internal currencies that embrace autonomy and individual identifications, permitting (i) common measurement standards to assess heterogeneous accomplishments, (ii) multiple paths through higher graduations of recognition, and (iii) horizontal mobility through the ecosystem.

4.2. Research Question 2—Paradox Transitions Between Complementary and Contradictory Logics

Research Question 2 asks whether contradictory and complementary logics are present in technology ecosystems and how they are governed. To address this question, we analyse three cases from our interviews that exemplify each primary tension: (a) standard–variety, (b) control–autonomy, and (c) collective–individual.

4.2.1. Complement Generativity—Standard–Variety. One of the main goals of a successful platform is to attract complementors by creating substantial scale, longevity, and potential for wealth generation. Specifically, a potential complementor needs to be convinced that investments made in the platform will yield adequate long-term returns. Toward this goal, as the statement below indicates, there is clear evidence to suggest that the software vendor's brand value and common marketing strategies have substantial positive effects for the partners:

> [Software vendor]'s brand is helping partners to sell [software application] . . . . The consolidated position of [software vendor] is recognised by the market . . . . Now partners have more opportunities, especially access to big deals. (Implementation partner)

However, liberal governance of complements may have negative consequences. Complementors develop complements to the core, but a lack of definitive knowledge on the evolution of core products and services plagues their development efforts:

> Partners don't clearly know where products are going, so partners don't know if they are developing the products in the right way, because new versions of [application] can absorb the partner's developments . . . . The partners develop an add-on for a specific version of [application], but when a new version appears, it is difficult and expensive for the partner to make the add-on compatible with the new version. (Implementation partner)

As a result, some partners even expressed a desire for tighter governance and reduced heterogeneity to avoid what they perceived as excessive redundancy and a lack of financial amortisation across common complements:

> The situation where each partner creates their own verticals is a way for them to differentiate one from another, but there are many versions of a particular vertical for a client to choose from, and in the end the client ends up paying for the costs of development. Having [software vendor] put their seal of approval on a handful of partner solutions in each vertical segment would result in lower total cost of ownership for the client and greater standardisation, but it would mean less differentiation for each partner. [Software vendor] would also have to compensate the partners for their versions of the verticals. So, while it would mean lower fees for the partners, it would also mean less investment in product development. (Implementation partner)

The combination of platform evolution insecurity and overcrowding was summed up succinctly by one implementation partner:

> Since the evolution of products is not clear, partners invest in solutions with no future or with a lot of competition, and they are competing in the same accounts with similar solutions. (Implementation partner)

Despite these criticisms, the software vendor does not attempt excessive regulation of the complements. There is a clear tendency to accept that locally embedded partners are best suited to address the market's extreme heterogeneity. However, they also acknowledge the implied agency problem:

> We have to believe that our partners understand the local market conditions best. It would be impossible for [software vendor] to determine these conditions better than them . . . . So officially [software vendor] does not have any commitment to the customer. However, it always comes back to [software vendor] anyway. (Software vendor)

Permitting numerous complements to serve a specific market reflects a logic of generativity, market responsiveness, and sensitivity to unique client needs. Yet an excessive supply and redundancy of complements creates an overcrowding problem, with limited common amortisation and expertise sharing and an overall higher total cost of ownership.

4.2.2. Standardised Implementation Strategies in Heterogeneous Markets—Control–Autonomy. A main cause of the extremely high levels of heterogeneity is the various accounting and legal regimes applicable in the country of use. The very high cost of localising software is generally the greatest single cost borne by the ecosystem collectively—the core, complementor, and therefore customers. As stated by a core channel manager,

> Localisation affects three main areas: translation, legal requirements, and local business practices . . . . It's not easy to manage the localisations at the global level, continent level, country level . . . . Localisation costs remain one of our single largest concerns. (Software vendor)

In an effort to reduce these localisation costs, the software vendor developed a standardised implementation method that has been recommended for use by all implementation and is required for use for higher certification levels. The software vendor has attempted to embed a single, general-use methodology in the tool:

> [With our tool] there is a clear trade-off between quality control, project management discipline, and speed and agility. So what we have tried to do is embrace this flexibility in the tool via filters and project profiles. Partners can use the templates more or less as they like . . . . (Software vendor)

Yet the one-size-fits-all ideal of the method is admittedly utopian:

> Are we generating paper, or are we parameterising? Well—this is the ideal, but hard to achieve. We think that it is good to have a method to show to customers. On the negative side, it is still not easy enough to handle a customisation. There is a risk of over-automation and it could ruin the project. (Implementation partner)

This relates not only to the heterogeneity of client projects but also to that of partners:

> It is important to stress the differences between the different partners. Some of the large partners will operate completely differently to the smaller partners. (Implementation partner)

As a result, the implementation partners resort to pragmatic workarounds based on context and need:

> Partners think it is difficult to use a methodology completely, because there are differences between countries, markets, customers, specialisation, etc., that can affect the methodology implementation. (Software vendor)

> Partners use methodologies provided by [software vendor] when it makes sense. They use what they need and ignore what they don't. Their technicians develop their own tools to fill in the gaps of what is lacking from [software vendor]. (Implementation partner)

The software vendor recognises the trade-off and further acknowledges the difficulties and costs of implementing extensive control regimes. It therefore attempts to leverage market mechanisms to supplement its control requirements:

> You cannot test for the business functionality of the product. It is totally impossible. This is why we require the customer references—let the market speak. This is a very risky strategy, of course, because as mentioned, at the end of the day it all comes back to [software vendor]. (Software vendor)

4.2.3. Competitive Balance Between Partners—Collective–Individual. A significant issue in the ecosystem is the competitive balance between partners. This relates to the number of partners in general:

> There are no barriers to becoming a platform partner if you comply with their certification requirements. For example, they do not limit the total number of partners in the channel due to anti-trust regulations. (Implementation partner)

This can lead to high levels of competition between partners in specific markets. The frustration from the implementation partners is evident:

> [Software vendor] is too focused on sales of licences. Every month there is tremendous pressure from [software vendor] for the partners to report results. Most partners are losing money due to this excessive pressure and short-term focus. (Implementation partner)

The competitive pressures between partners have a variety of undesirable consequences. For example, complementors work together in terms of training and cooperation on projects, but at other moments, they become competitors:

> The main problems with this external training model is that it creates a conflict of interest for these "training centres," who also provide other services such as programming support for other partners, creation, and implementation of add-ons.... The partners doing the training are my competitors, and if I send my people there, well.... (Implementation partner)

Hence, there is a perception that the software vendor lacks loyalty to individual partners, and this breeds a certain defensive posture among some:

> If you ask a partner who their biggest competitor is, they'll say, "Another partner." The implication is that there is more competition between partners offering [application] than with competitors offering other software packages, like [competing packages].... If there are three partners competing for the same work, [software vendor] always wins. (Implementation partner)

The competitive situation between partners can often result in conflicts within the same project or vertical. Common country-level modifications should ideally be shared and amortised over as wide a market as possible. However, this is not always the case:

> [Software vendor] tries to integrate the local regulations of each country into their software, but there are always areas which are lacking, which need improvement, or which have errors. And each partner makes their own changes, but there's no incentive to share this with other partners or even with [software vendor]. All of the localisations created by the individual partners are different and not necessarily compatible. So all of the partners have the standard version of [application] and their own "standard plus" version. This becomes a point of differentiation, where partners claim that their standard plus is better than the others. (Implementation partner)

The statements suggest that the extreme heterogeneity of the ERP market manifests itself in legitimate modifications to the software that are driven by localisation requirements. However, there is some evidence of overcrowding in the complementor market that constrains cooperation between complementors in instances where the sharing and common development of the localisations would be optimal.

4.2.4. Research Question 2—Summary of Main Findings. Our analysis is premised on the idea that tensions exist as part of organising socioeconomic activity. They cannot be avoided or permanently resolved, but rather harnessed or directed toward complementary or contradictory outcomes (Faraj et al. 2011, Farjoun 2010).

Example 1 demonstrates how extreme competitive behaviour can produce redundant investments in complements, overcrowd markets, and reduced prices. The main conditions causing the emergence of a contradictory logic are plurality (excessive supply of competing complements) and change (uncertainty about the technological evolution of the platform core).

Example 2 establishes that resistance to the use of a standardised implementation method limits technological compatibility across complements and keeps implementation costs high. Here, the main impetus of a contradictory framing is plurality—specifically, the extreme market heterogeneity inherent in the ERP market (environmental) combined with some emotional resistance to centralised control regimes.

Example 3 shows how liberal access to the ecosystem by partners, combined with uncoordinated, self-interested behaviour, limits cooperation and the sharing of common regional standards and accelerates downward price pressure in the ecosystem. In this instance, the conditions of a contradictory framing are plurality and scarcity—specifically, the extreme concentration of complementors in some markets with scarce coverage in others. The examples and potential managerial responses are summarised in Table 7.

Examples 1 and 3 specifically resemble a classic "market failure" from the economics literature, where the outcomes are socially suboptimal as a result of self-interested behaviour, bounded rationality, uncertainty, and information asymmetries (Bator 1958). As such, potential managerial responses to both of these problems are analogous to public policy responses—namely, some form of quasi-regulation. For example 1 (overcrowding of complements), governance could be developed to limit the number of entrants into specific functional areas, awarding some protected status to complements in exchange for commensurate levels of increased investment and quality in the complement. The existence of several very high-quality complements could be diffused through the ecosystem. In example 2 (fragmented implementation strategies), the extreme heterogeneity of the market may inevitably limit the adoption of standard implementation methods. In such a case, a pragmatic response may be to legitimise variance in use and leverage the variance as a legitimate source of improvement to the standard process to make it more comprehensive. Finally, in example 3 (excessive competition among complementors), governance could be developed to limit complementor entry into highly competitive markets while seeding new complementor entry into underserved markets.

Table 7 Complementary and Contradictory Logics: Diagnosis and Response

	Examples		
	1	2	3
	Complement generativity	Standardised implementation strategies in heterogeneous markets	Competitive balance between partners
Primary tension	Standard–variety	Control–autonomy	Collective–individual
Complementary logic (*duality*)	Liberally governed complementors use market mechanisms to respond to local market requirements. More complements imply increased choice and platform value.	Standardised control methods permit consistent quality control of implementations with increased technical compatibility across complements.	Liberal access of partners generates growth and value for ecosystem. Market mechanisms will dictate distribution of partners and facilitate quality control.
Contradictory logic (*dualism*)	Overcrowding and excessive competition between complements. Lack of coordination creates redundancy, hindering amortisation of functions that are common at the legal or sector level.	Implementation partners ignore standardised implementation methods, either selectively or completely. Increased fragmentation. Localisation costs remain high; technological compatibility across complements is constrained.	Overcrowding and excessive competition among partners. Consequent downward price pressure limits potential revenue, cooperation, and reuse of common regional modifications or best practices across partner consortia.
Triggers	Plurality and change	Plurality	Plurality and scarcity
Diagnosis	Large numbers of partners generate similar complements for individual clients. Where sharing, reuse, and complement "best-in-class" development is constrained by redundant efforts.	Standard methods insufficiently comprehensive to accommodate extreme heterogeneity resulting from disparities across legal, geographic, or industrial sectors and partner profiles. Disdain for centralised control.	Liberal complementor entry renders hypercompetitive conditions in some markets, with limited coverage in others. Limited reuse and collaboration across markets constrains social goods in the ecosystem.
Possible governance response	Interventions to limit the number of complement types in defined areas. Increase coordination to reduce redundancies.	Allow for graduated use of standard methods, legitimising variance from standard use in certain cases. Establish feedback mechanisms to incorporate legitimate variance into future versions.	Elect market winners in regions with overcapacity. Seed markets with undercapacity.

Considering the conditions making contradictory logic salient, vis-à-vis complementary logic, it is noteworthy that plurality is such a dominant source of transition between complementary or competing tensions. Smith and Lewis (2011, p. 390) stated that "plurality expands uncertainty and surfaces competing goals and inconsistent processes (Cohen and March 1974)." Our case analysis confirms this position. Likewise, scarcity played a strong secondary role. Interestingly, we found evidence that suggested that although change did create uncertainty in our interview respondents, it was not a major factor. This may be because technology ecosystems are designed for evolvability, and the participants are accustomed to this reality.

5. Implications and Conclusions

Research Question 1 asked how the main tensions in technology ecosystems are addressed in technology ecosystem governance. We identified three main tensions across outputs, actors, and identifications, and we thereafter identified governance mechanisms used to either increase desirable variance or decrease undesirable variance for each tension. For *outputs*, undesirable variance is constrained by processes and tools focused on technical standards and quality, with an emphasis on the programmatic compatibility of heterogeneous complements with the core and across and between complements. Desirable variance is fostered through the open-source code of the core application that permits customisation of the application to client requirements. For *actors*, variance-reducing control is manifested through graduated control regimes that offer some perceived value for the complementors. Variance-increasing autonomy is embraced through self-selection; actors choose their desired control levels based on the perceived utility of the control mechanisms to their business as implementation and development partners. For *identifications*, undesirable variance is constrained through communal utilities and socialisation to common behavioural norms; status is conferred by the core to the complementors for direct and indirect contributions to the social goods of the ecosystem. Desirable variance is enabled through business support services to aid entrepreneurial action and internal currencies that accommodate heterogeneous accomplishments and multiple trajectories through control mechanisms.

Research Question 2 further questioned whether contradictory and complementary logics, as well as their effective governance, are present in technology ecosystems. Our analysis suggested that the architects of our case's ecosystem governance acknowledge this possibility and explicitly aim to leverage these tensions as mutually complementary forces. However, environmental, operational, and cognitive conditions cause transitions between complementary and contradictory logics. Consistent with theoretical arguments, we find that plurality is the main trigger for contradictory logics, where the alternative triggers of change and scarcity have a similar, but lesser, influence. In operational terms, plurality, expressed in the extreme heterogeneity of the ecosystem across geographic and functional markets, renders standardized processes and outputs problematic. Liberal access for complementors and limited regulation of complements created problems of excess supply of variable quality and overcrowding in complementor markets, negatively impacting partner profits. Finally, limited coordination rendered some geographic regions underserved while others experienced hypercompetitive conditions, further discouraging collaborative efforts to cultivate common best practices and social goods in the ecosystem. Change caused uncertainty about the future evolution of the platform, discouraging investments in skills, capabilities, and complements.

5.1. Implications for Technology Ecosystem Governance

Extant research has conceptualized ecosystem governance as varying between loose or tight, with an implicit emphasis on traditional agency problems (Tiwana et al. 2010). Our research suggests that ecosystem governance must do far more than simply mitigate agency conflicts, with a far more complicated set of requirements and leverage points.

The dominant strategy for platforms has been a winner-take-all ideology, typically argued via the logics of network externalities, natural monopolies, and first-mover advantages (Eisenmann et al. 2011, Parker and Van Alstyne 2005). Where this logic remains valid, a myopic focus on a "bigger is better," excessively growth-driven strategy may have undesirable effects. So where a traditional emphasis on complement quantity and quality should persist in the governance design problem, ecosystem architects must also consider complement breadth, variety, and distribution. Where research has demonstrated a positive correlation between the number of complementors and the variety of complements, it has also established a correlation between complementor heterogeneity and complement variety (Boudreau 2012). As such, a focal lever for influencing complement variety is in nourishing complementors in specific geographic regions or sectors.

This implicitly suggests that a sustainable value proposition is not only relevant for customers but also for complementors who self-select into business niches based on potential returns. Excessively liberal access to the platform, hypercompetition, and subsequent crowding-out effects among complementors not only reduces potential economic value (Cennamo and Santalo 2013) but can also limit innovation levels (Boudreau 2012). Moreover, as we found in our own data, the level of cooperative or competitive postures between complementors and the platform core firm can also determine a sustainable value proposition for complementors. Attracting the right kind of complementors is also important; research has suggested that platform success is positively correlated with a population of higher-status complementors (Srinivasan and Venkatraman 2010). Overall, this suggests that appropriate ecosystem governance is not only a question of growing the base of complementors—the core firm must also set limits where appropriate to ensure a balanced distribution of the right complementors across sectors and geographies. On this dimension, technology ecosystems behave as semiregulated marketplaces, functioning similar to markets in terms of entrepreneurial action but also requiring coordination, boundaries, and direction giving (Katz and Shapiro 1994). As such, the presence of contradictory logics is not necessarily symptomatic of inadequate design of the governance mechanism but may simply be a property of the system that can be purposefully managed at appropriate levels to avoid extreme imbalances (Chua and Wareham 2008). Here, standard public policy and regulatory debates offer analogous recommendations.

5.2. Implications for Theory

Technology ecosystems must manage the unwieldy challenge of simultaneously effecting stability and evolvability through a combination of variance-increasing and variance-decreasing mechanisms (Tilson et al. 2010, Yoo et al. 2012). Specifically, ecosystems must strive to increase serendipity and creativity in products, solutions, and services and yet constrain inferior quality outputs and overabundance (Faraj et al. 2011, Tiwana et al. 2010). They must simultaneously harness autonomous behaviour for generativity yet subsume it to direction giving and control (Demsetz 1997). Finally, ecosystems must harness individual identifications for agile, entrepreneurial responses to client needs (Faraj et al. 2011) yet cultivate collective identifications for the larger social goods of the ecosystem (Ibarra et al. 2005). This is a complicated equation, an interwoven system of tensions that must be simultaneously optimized toward ambiguous objectives.

Given this framing, the question of what is "simultaneity" and how it can be leveraged by the governance mechanisms is pertinent. Specific mechanisms such as integrated development environments and coding libraries can serve desirable variance-increasing objectives on dimensions of functionality and customisation yet concurrently constrain undesirable variance in terms of technological quality and compatibility standards. The self-selection of control regimes allows complementors on the periphery to pursue individual benefits in exchange for some other benefit surrendered to the core, as well as to the greater ecosystem. Finally, similar to any economic transaction, governance mechanisms can simultaneously impart different values to different constituents by matching complementary assets. Stated in more general nomenclature, the requirement of simultaneity was shown (i) within individual tensions (e.g., increasing variance on characteristic alpha while decreasing it on characteristic beta), (ii) across multiple tensions (addressing them concurrently), and (iii) across multiple constituents (addressing the divergent needs of core and periphery actors concurrently). Table 8 summarizes these definitions with case examples.

Hence, simultaneity appears particularly pertinent to any system characterised by severe paradoxical tension, be it a technology ecosystem or other type of social system. In our study, we found plurality to be the main trigger in framing paradoxical tensions with contradictory logic. Intuitively, this implies that for ecosystem governance, greater heterogeneity places a larger

Table 8 Governance and Simultaneity

Governance simultaneously addresses	Definition	Case example
Single tension	Simultaneously increase characteristic alpha while decreasing characteristic beta	(*Outputs*) Development tools enable the increase of variance of functionality and customisation with a simultaneous decrease in the variance of technological quality and compatibility standards.
Multiple tensions	Simultaneously address tension *X* while addressing tension *Y*	(*Actors and identifications*) Application certification and catalogues enable complements on the periphery to pursue individual benefits (*actor* autonomy); certified complements are thereafter publicised and reused by the ecosystem (collective *identifications*).
Multiple constituents	Simultaneously benefiting different parties	(*Periphery and core*) Self-selection based on economic matching of complementary interests. Advancement to higher partner levels simultaneously offers value to both partners/periphery and core (higher status in exchange for reduced quality variance (i.e., better) complements.

emphasis on simultaneity as a governance requirement. A highly diverse population of participants would likely support a wide scope of objectives, thereby increasing the difficulty of achieving any equilibrium across tensions and perhaps reducing the theoretical probability of any balance at all. In this respect, it may well be that a main constraint of ecosystem growth is its degree of heterogeneity. Given the inherent challenges faced by ecosystem governance, there may be a pragmatic limit to how much heterogeneity any single governance regime might accommodate. As the ecosystem expands in scale and scope, plurality triggers a reframing of innate paradoxical tensions as contradictory. These contradictory logics have adverse effects on the behaviours of the actors, whose decisions may be somehow contradictory to the overall health of the ecosystem. As such effects multiply, the ecosystem becomes increasing unsustainable, and the same network effects that have enabled its growth ultimately facilitate its demise.

5.3. Future Research

Implicit in the concept of ecosystems is the idea that platforms are fundamentally dynamic. However, where our perspective on ecosystem governance does embrace change through time, we do not explicitly address ecosystem evolution directly. Research by Boudreau (2012) suggests that the churn of complementors in and out of an ecosystem might be a source of innovation and variety. Specifically, complementors at different stages of maturity may demonstrate different types of generativity, where late entrants into saturated ecosystems with crowding-out effects may provide less substantial or less valuable types of innovations than early entrants. At a population level, complementor maturity is important, as is ecosystem maturity. So where we acknowledge that generativity may result in undesirable variance, our view is admittedly a cross-sectional one. As such, future research could explore the different types of generativity and their relationship to ecosystem governance through different phases of evolution.

An evolutionary perspective is not only valid for the complementors and ecosystem, it is equally valid for governance. Traditional theorising on transaction governance has emphasised variance theories, where transactional, institutional, or environmental antecedents change and governance forms and control outcomes respond in some linear fashion (Klein et al. 2011). If evolvability is considered a focal property of the ecosystem, then governance mechanisms also need to embrace changing maturity levels of the ecosystem through time for the same set of antecedent conditions, oscillating between several archetypes or evolving with the maturity of the ecosystem (Thrane 2007). As an example, the preliminary phases of the platform's life cycle may require a loose control that facilitates the recruitment of complementors to the ecosystem and the subsequent generation of numerous complements and scale in a classic seeding process. It is assumed that there will be competing platforms; given the permeating logic of natural monopolies, achieving critical mass is important. In intermediate stages, stricter control may be appropriate as achieving critical mass and network effects become less imperative, and the ecosystem can mature and evolve at controlled rates.

Finally, there is a substantial lack of research on control mechanisms in networks that resemble technology ecosystems, including reseller, partnership, and franchising networks where responsibility is distributed across more than one entity. This problem is more severe not only from the perspective of the final purchaser but also between other members of forward distribution networks where "joint action interdependence" (Caglio and Ditillo 2008, p. 877) generates a mix of nonsequential processes that obscure accountability (Miller et al. 2008). Given the emergence of affiliate and social marketing and other Internet-based marketing structures where direct lines of responsibility are latent (Fox and Wareham 2010), additional research on this topic is desirable.

5.4. Concluding Remarks

The use of ecosystems to drive generative responses to market demands is growing well beyond pure technology sectors. Yet harnessing the efforts of heterogeneous actors in an ecosystem to meet the needs of diverse markets requires some balance; if a thousand flowers grow, inevitably, some will be undesirable and harmful to the ecosystem. In the extreme, the unconstrained growth of low-quality innovations can kill a platform. Effective governance is necessary.

Our analysis explored the implications of three salient tensions of the stability–evolvability equilibrium in technology ecosystems and described the variance-increasing and variance-decreasing mechanisms that function simultaneously within and between different tensions and constituents. It is likely that many of these conceptual properties may be generalisable to other technology ecosystems as well as other ecosystems characterised by high degrees of paradox. Yet where direct normative guidance on the architecture of ecosystem governance may be easier to infer, eliciting complementary versus contradictory logics may be more challenging. Given that we are speaking about human perception and cognition on one level and systemic, ecosystem-wide properties on another, it may be a question of trial and error, as was the case for our case ecosystem. At a minimum, knowledge of how and why these different logics emerge should serve to guide the successful architecture of ecosystem governance.

Appendix

Table A.1 Description of the Phases of Our Study

Stage	Exemplary questions	Thematic codes	Outcomes
	Research phase 1		
(1) Understand how the ecosystem functions: the main actors, their behaviours, and desired ecosystem outcomes	—What are the main partner types? —How do they differ across geographic region, technical expertise, or industry focus? —Why are these different partner types desired? —How do they each contribute to overall ecosystem sustainability?	Fragmentation Heterogeneity Homogeneity Standards Predictability Cohesion Positive and negative N/W effects Economies of scale and scope Innovation	The main roles, actions, and contributions of the ecosystem participants: platform owner, partner types, and clients Desired macro-level dynamics of ecosystem
(2) Render the ecosystem governance: infrastructure, rules, norms, and sociology	—What business opportunities or economic benefits does the platform owner offer to the partners? —What operational tools does the platform owner offer to partners? —What formal rules of conduct are partners required to obey as legitimate ecosystem members? —How are these rules enforced and what are the sanctions? —Are there informal norms or a dominant culture within the ecosystem? If so, how is it propagated?	Enabling control Coercive control Diagnostic control Procedural control Outcome control Boundary control Distributed control Reciprocity Social goods Culture	A schematic of the ecosystem architecture with its underscored incentive and control mechanisms (formal and informal)
(3) Characterise the divergent goals, incentives, and motives of the various actors	—What is the relationship of each partner type to the ecosystem core? —What is the relationship of each partner type to the other partner types? —Do the motivations of the various partners converge or diverge? —If they diverge, what consequence does this have at a micro level? —What consequence does such divergence have at a macro level?	Self-identification Client/task I=identification Group/team identification Ecosystem identification	Three main ecosystem tensions (standard–variety, control–autonomy, and collective–individual)
(4) Identify the characteristics and processes of ecosystem governance that address the tensions that emerge as a result of divergence	—How is the formal business and technical support offered by the platform to the partners designed to accommodate the tensions resulting from divergent motives? —Is this design successful or unsuccessful? Where and how? —How do the informal social norms and greater ecosystem culture interact with the tensions resulting from divergent motives?	Legitimacy Status Simultaneity Embedded mechanisms (variance increasing/ decreasing) Local action Self-selection Systemic outcomes	An assessment of where and how ecosystem governance addresses main tensions
	Research phase 2		
(5) Identify instances where tensions manifest in complementary or contradictory forms	—How do programming templates enable creative and innovative solutions to client-specific requirements yet at the same time ensure component reuse across the ecosystem? —Who are the partner's most significant competitors: vendors from a competing product or vendors from the same product ecosystem?	Options Supply Liberal platform access Agility Responsiveness Localisation costs TCO	Three examples (complement generativity, standardised implementations in heterogeneous markets, and partner competitive balance)
(6) Distinguish conditions in which contradictory logics become salient (where and why?)	—Why would one partner view the actions of another partner as detrimental to their business? —Why would a partner view the actions of the platform core as detrimental to their business? —Where would it be disadvantageous to fully comply with the process/outcome norms defined by platform core?	Overcrowding Excess supply Competition Price pressure Redundancy Resistance	Identification of how plurality, scarcity, and change influence the framing of paradoxical tensions between various actors in technology ecosystems

Table A.1 (cont'd)

Stage	Exemplary questions	Thematic codes	Outcomes
(7) Determine where ecosystem governance is designed to accommodate both complementary and contradictory logics	—Has the existence of this contradictory tension been acknowledged by the platform core? If so, what was the response? —Are there instances where the macro-level ecosystem outcomes are desirable, even where the micro-level outcomes are undesirable?	Filters Certifications Feedback Exception handling Seeding Financial stimulus Interventions	Identification of learning effects, adjustments and governance modifications by platform owner Acknowledgement of micro- versus macro-level dynamics in governance design
(8) Establish whether responses enabled by governance mechanisms are sufficient or whether additional actions are recommended	—How do partners view the efficacy of such responses? —How do the mangers of the platform view the efficacy of such responses?	Satisfaction vs. dissatisfaction Acceptance vs. resistance Individual vs. identifications Ecosystem vs. identifications Positive and negative N/W effects	Recommended policy actions and design principles for technology ecosystem governance

Note. N/W, network; TCO, total cost of ownership.

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