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Innovation ecosystems: A critical examination ☆, ☆☆

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ABSTRACT

Publications pushing the "innovation ecosystem" meme have added valuable dimensions to the economic development discussion. The phrase has captured the imagination of policy makers and has motivated public initiatives of substantial magnitude. This paper reviews the concept of innovation ecosystems as it is set forth in the academic and trade literature, and asks, "What is gained from adding 'eco-' to our treatment of national and regional innovation systems?"

The answer is, "Very little, and the risks outweigh the benefits." Innovation ecosystem is not yet a clearly defined concept, much less a theory. Moreover, the idea carries pitfalls, notably its over-emphasis on market forces, and its flawed analogy to natural ecosystems.

The prospect that the phrase "innovation ecosystem" is here to stay, in investment and economic development circles, implies a research gap, and indicates caution in using the phrase in rigorous research. The paper describes the gap, indicates directions for bridging it, and offers recommendations for prudent use of "ecosystem" terminology.

1. Introduction: "Innovation ecosystems"

The term 'innovation ecosystems' has become popular in industry, academia, and government. It is used in corporate, national, or regional contexts, in idiosyncratic ways. It implies a faulty analogy to natural ecosystems, and is therefore a poor basis for the needed multi-disciplinary research and policies addressing emerging concepts of innovation.

Frenkel and Maital (2014) find an early use of "innovation ecosystem" in a *New York Times* op-ed by William Kennard, a former Chairman of the US Federal Communications Commission. Other earlier comparisons of business environments to ecological systems include Carroll (1988), Hannan and Freeman (1989), Moore (1993), and Schot (1998). (All owe intellectual debt to Nelson and Winter (1982), though the latter's work on evolution of technology did not imply there is an ecology of innovation.) However, these researchers may not have been aware that other social scientists had already left the questionable ecosystem analogy behind; see especially Haynes (1971).

Jackson (2011) defines an *innovation ecosystem* as "the complex relationships that are formed between actors or entities whose functional goal is to enable technology development and innovation." (A supplementary file, giving more background on innovation systems and their relation to technology-based economic development, accompanies this article.) He continues,

> The actors include the material resources (funds, equipment, facilities, etc.) and the human capital (students, faculty, staff, industry researchers, industry representatives, etc.) that make up the institutional entities participating in the ecosystem (e.g. the universities, colleges of engineering, business schools, business firms, venture capitalists, industry-university research institutes, federal or industrial supported centers of excellence, and state and/or local economic development and business assistance organizations, funding agencies, policy makers, etc.).
>
> The innovation ecosystem comprises two distinct, but largely separated economies, the research economy, which is driven by fundamental research, and the commercial economy, which is driven by the marketplace.

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This paper will explore the idea that tension between these two economies may be the driver behind the newer terminology of "innovation ecosystems," as it contrasts with the older terms technopolis initiative, cluster initiative, and triple-helix initiative.

Aside from naming the actors, Jackson's definition distinguishes an innovation ecosystem from any generic system only in its *purpose* – to innovate. Thus the comparison of an innovation system to a biological ecosystem rests on a teleological fallacy (Ulrich, 1980; Chase, 1985). Furthermore, Jackson's definition does not specify the locations of the actors (geography being pertinent to innovation systems), or the kinds of interactions/relationships among them.

The private sector's affection for the eco- prefix has infected governments. A supplementary file accompanying this article describes government innovation "ecosystem" initiatives in USA, South Korea, and other countries. These efforts are somewhat systematic, but in no way isomorphic to a natural ecology. The word "system," *sans* "eco-," would have sufficed to describe these government developments.

This paper is a critical review of the 'innovation ecosystem' idea, as it compares to the more traditional notion of innovation system. Literature review, logical argumentation, and examination of national projects conducted under the ecosystem banner support our contention that loose and inconsistent use of the term 'innovation ecosystem' adds no value to the scholarly discourse and may cause harm. The innovation eco-literature makes positive contributions, but these contributions do not depend on the eco- prefix, and their eco- pretensions are metaphorical rather than rigorous. Following the examples of Linton (2009), Ruddiman et al. (2015) and Lilienfeld et al. (2015), who in their respective fields offered guidance for use of terminology, the present paper issues cautions and recommendations for researchers and policymakers, urging usages that reduce rather than increase confusion among researchers.

2. "Innovation ecosystem" literature: Differentiators, contributions and implications

Reviewing the literature of innovation environments, Durst and Poutanen (2013) found very few scholarly articles that called those environments "innovation ecosystems." Those papers they did find, they note, paid little attention to the dialog with multiple constituencies, which (as Jackson's definition implies) the topic seems to call for. Likewise Niosi (2010) addressed national and regional innovation systems (NIS and RIS) without using the prefix "eco-."

Frenkel and Maital's introduction to their 2014 book *Mapping National Innovation Ecosystems* considers biological ecosystems only as a loose metaphor. Despite the book's title, neither the ecosystem term nor the metaphor appears anywhere else in the volume. Speakers at the 2014 World Technopolis Association Workshop and UNESCO-Daejeon Global Innovation Forum used "innovation support systems" (Chen, 2014) and "innovation support platforms" (Seo, 2014) as satisfactory equivalents to "innovation ecosystems." Thus, 'innovation ecosystem' is identical to 'innovation system,' at present.

Our own literature search likewise found few academic articles using "innovation ecosystem" in a manner that would distinguish an innovation ecosystem from an innovation system. The eco-term appears in a great many trade publications (for example, Barclay, 2014; Bruns, 2013; Butcher, 2014; Feld, 2012; Hannes, 2014; Hwang, 2013; Leach, 2014; Moore, 1993; Site Selection Magazine, 2014). It is difficult to know whether these non-peer-reviewed articles, authored by industry people, use the term in an intentional way, or simply in an imitative way.

What makes "innovation ecosystems" different from the earlier concepts of S&T parks, technopoleis, regional innovation systems, science cities, or innovation clusters? The distinguishing features of recent publications using "ecosystem" seem to be:

1. *More explicitly systemic.* Rogers (1962) emphasized that innovation diffuses through a social *system*. The innovation ecosystem literature shows a greater appreciation of the connections among the many innovation actors. Enumerating the interactions among the ecosystem's component organizations (as Fetters et al. (2010, p.181)) have done, in the case of university entrepreneurial ecosystems) highlights the richness and diversity of actors that can, in principle, give rise to emergent behavior.
2. *Digitalization*. The central role of information and communication technologies (ICT) in new products and services, and in connecting the innovation actors is recognized.
3. *Open innovation.* The borrowing, licensing, open-sourcing, crowd-sourcing, and alliances that allow ideas from diverse sources to be combined into new products and services.
4. The *mimetic quality* of the term "innovation ecosystem," and its appeal to the news media.This demonstrates the public relations value of the term, but not its value in research.
5. A greater emphasis on differentiated *roles*, or "niches" occupied by organizations and industries. See Frenken et al. (1999) and Raven (2005). These niches can correspond to links in industry value chains. This emphasis contrasts with the more amorphous "It takes a village to raise an entrepreneur" and "Everybody in the community pull together" approaches taken by past technopolis initiatives.
6. Greater importance of *market forces,* relative to government- or NGO-push.

That sixth point may imply the innovation ecosystem movement is an attempt to privatize the technopolis movement, which has heretofore been characterized by triple-helix and public-private partnerships (PPPs). Though FCC Chairman Kennard was business-oriented (he had been Managing Director of a $100 billion private equity firm), he did give due credit to educational institutions and government regulatory environment for the blossoming of Internet-based innovation. Other writers, e.g. Hannes (2014) have not been as generous.

3. Ecosystem terminology: disadvantages and dangers

The ecological metaphor is in line with trends toward biomimicry and bio-inspired design, i.e., learning from natural and biological (evolved) systems. This is admirable, despite that it risks false analogies between biological and artificial ecosystems.

An innovation ecosystem is not an evolved entity. Rather, it is designed. Papaioannou et al. (2007) note innovation ecosystems differ from natural ecosystems in (i) the presence of intention and teleology, and (ii) the acknowledged importance of governance. The latter point is reinforced by the venture capital firm T2 Venture Creation, who in promoting their Global Innovation Summit (www.innosummit.com), write:

> How do we *build* startup communities? How do we *catalyze* systemic sustainable innovation across companies, cities, and countries? How do we *design* entire ecosystems to drive entrepreneurship, technology, and economic impact? [Emphasis ours.]

"Shanghai Scores As Top New Tech Hub In The World As Silicon Valley Gap Grows," reads one headline (Fannin, 2014). Another says, "Munich edges out London as Europe's top tech city" (Ranger,

2014). These geographical shifts in technology development activity support the idea that money and brains do not suffice to keep a region in the forefront of innovation. That is, they suggest a broader support structure, possibly of the nature of a well-connected innovation system, is needed, and is offered in the new forefront regions, as is a favorable cost structure. (Note China's and Germany's governments' reputations, relative to the USA, for dirigisme.)

This section, explores the confusing variety of meanings given to "innovation ecosystem" in the literature. It finds innovation ecosystem ideas are insufficiently differentiated from NIS and RIS notions. They appear to be a hope, rather than fully realized concepts. The section offers one possible reason for this: Measuring the "progress" of a co-evolving ecology – were the ecosystem metaphor to be fully embraced – would be beyond current scientific capability. The section then offers implications of the privatized innovation system that seems to be a discomfiting subtext in "ecosystem" publications.

3.1. Innovation ecosystem types

Though the literature does not yield a firm typology of innovation ecosystems, the term is mentioned in in several contexts:

1. *Corporate* (*open innovation*) *innovation ecosystems.* Zhang et al. (2014) consider these to consist of suppliers, users, partners, and other contributors to an OEM's open innovation process. They write, "Government departments, industry associations, and other… stakeholders," while "external" to the ecosystem, have an impact on the ecosystem's functioning. See also Barclay's (2014) and Hwang (2013) regarding this perspective.
2. *Regional and national innovation ecosystems.* (Morrison, 2013; Viitanen et al., undated; Urenio Research Unit, undated). Besides adding "eco-" to the RIS label, these works emphasize the open innovation and more specific role assignments noted above.
3. *Digital innovation ecosystems.* Rao and Jimenez (2011) present case studies of digital ecosystems at Apple Inc. and Google – online platforms on which customers, users and developers can build synergistic relationships, generating network externalities which increase the values of both hardware and software innovations. Thus, a digital innovation ecosystem can mean the apps, platforms, and distributors that make the technology viable. Further examples include "Apple's HealthKit ecosystem" (Tweedie, 2014) and "mobile ecosystems" (Hyrynsalmi et al., 2014). See also www.digital-ecosystems.org, UP Global (undated), Viitanen et al. (undated), and Barclay's (2014).
4. There are also new signs of *city-based innovation ecosystems and innovation districts* (Cohen et al., 2014; Morrison, 2013; Lin, 2014). These are planned by municipalities with the help of universities. They tend to focus on new and small companies, and may start with hopeful real estate development rather than active business development. As such, they are little different from the technopolis initiatives of long standing.
5. *High-tech SMEs centered ecosystems.* The best known such ecosystem is Taiwan's, as the small country's manufacturing capability is mostly in the hands of SMEs. Plans for European SME ecosystems may be seen in Frenkel and Maital (2014) and Lorré et al. (2006).
6. The managers of some *incubators and accelerators* claim their services and facilities combine to create hyper-local innovation ecosystems.
7. Finally, there are claims of *university-based ecosystems.* León's (2013) study of the Technical University of Madrid, and Graham's (2013) study of plans for the Skolkovo (Russia) Institute of Science and Technology, envision university-based innovation ecosystems built upon expert-ranked international best practices. Most university initiatives focus on the entrepreneurial subset of the innovation ecosystem, and call it an entrepreneurial ecosystem (Fetters et al., 2010).

In sum, the literature shows a lack of consistency in authors' use of the ecosystem phrase.

3.2. Innovation ecosystem success factors and metrics

UP Global (undated) finds the success factors for innovation ecosystems are talent; density of researchers, entrepreneurs, and facilitating institutions; entrepreneurial culture, access to capital, and a supportive regulatory environment. This list is nearly identical to lists of success factors for technopoleis and industry innovation clusters (see Phillips (2006, p.147)), and adds little novelty.

Wallner and Menrad (2011) comment on the culture aspect, remarking that the system thinking behind the innovation ecosystems movement is not systemic enough:

> In these linear representations, socio-cultural aspects are considered as mere contextual domains which influence the rate and direction of innovative activity…. they are not considered as a variable factor, interacting with and within the innovation eco system…. [E.g.,] although social systems learn through their members, they show greater resistance to change than do their individual members.

Moving from success prerequisites to metrics, Wallner and Menrad remark that an ecosystem is not a "trivial machine, with a defined input-output ratio." A linear approach to analysis "may well lead to absurd results" and invalid benchmarking. Graham (2013) agrees: "Many experts regarded commonly used research commercialization metrics (number of spin-offs, licensing revenue) as unreliable indicators of a university's long-term capability to support or develop a vibrant ecosystem."

This is true for a number of reasons.

- First, because many constituent groups have a stake in the innovation game, and place different values on different system outputs, whether jobs, wealth, quality of life, traffic congestion reduction, support for the arts, or others.
- Second, because performance of the system is determined less by the Taylorist tactics of making people work faster and substituting capital for labor, and more by continually identifying and relieving bottlenecks in the connections among actors.
- Finally, success hinges on the emergence of leadership, the development of people, and the willingness of authorities to tolerate innovative tactics.

3.3. Will a market-driven business ecosystem produce innovation? ecosystems and clusters

Recent trends in supply chain management (SCM) indicate companies are reducing the number of their suppliers, while increasing the intensity of information exchange with the surviving suppliers. (Dell and General Motors, among others, have been leaders in this.) The purpose of the information exchange is to drive down component prices while increasing component quality. By giving more volume to a single supplier of a component, the industrial buyer reduces the overhead and transaction costs of dealing with multiple suppliers, while enabling the surviving supplier to ride its experience curve (unit cost reduction due to total cumulative production) faster.

This forcing of the experience curve – learning to manufacture a component better and better while drastically reducing unit

price each quarter – requires innovation. However, it is a conservative kind of innovation. It will not produce disruptive innovation. It will produce current user benefits more cheaply, but it will not create new user benefits.

Realizing this, and realizing that useful, innovative new benefits may come from a wide range of sources, private ecosystem designers encourage the emergence of diverse startup companies in their local regions. "Diverse," however, does not mean the startups will fall within (or be complementary to) a strategically targeted industry. Thus, it does not constitute an innovation cluster strategy.

A market-driven innovation ecosystem movement does cause us to consider what the essential roles of other sectors (governments, NGOs, the press, and religious institutions) are in the innovation system. These roles seem to be to inject long-term thinking, as opposed to corporate short-termism; to midwife critical-mass clusters; and to assemble ecosystem elements, including civic infrastructure and certain quality-of-life factors, that *may eventually* produce open innovation synergies. This would supplement the private sector's inclination to reach out only to parties that *will benefit it with certainty in the short run.*

3.4. Innovation ecosystems, public interest, and private interests

According to Niosi (2010), "The era of the Washington consensus, where the basic advice … was simply to let markets emerge and not to interfere with their operations, now is gone …" Non-academic uses of "innovation ecosystem" reflect if not an attempted resurrection at least a nostalgia for this bygone Washington consensus.

Referring to what are now called beneficial knowledge spillover in critical-mass industry clusters, pioneering economist Alfred Marshall wrote, "The mysteries of the trade become no mysteries; but are as it were in the air…" (quoted in Hughes, 2012). Clearly, knowledge that is "in the air" provides defensible intellectual property to no particular company. *No company in a privately designed innovation ecosystem has an incentive to promote the wider Regional Innovation System.* For this reason, the present authors question whether the innovation ecosystem movement is in the public interest – as opposed to more traditional technopolis, triple-helix, and cluster initiatives that are driven or mediated by government and NGOs, that encourage many suppliers to one industry to locate in close vicinity, and that design incentives for companies and other entities to participate in the initiative.

Excluding governments and universities from the triple helix reduces ecosystem-building to an exercise in SCM. Just as "lean" SCM increases traffic congestion by requiring (for example) four truck deliveries per day rather than three per week, a privatized technopolis initiative may be expected to create substantial negative externalities. As the triple-helix innovation structure is subverted in countries where a strong central government dominates universities and all companies are state-owned enterprises, the triple helix will be likewise subverted when private industry holds all the cards – as seems to be the subtext of the innovation ecosystem movement.

In this vein, Jackson (2011) notes, "In order to foster the serendipitous investigations that are essential to innovative discovery, it is also important that the incentives driving the research economy be decoupled from the financial incentives driving the commercial economy." He reminds us that corporate R&D is funded by profits, and government R&D investment by tax revenues. The decoupling, then, is a difficult matter in today's economic and political context.

Frenkel and Maital (2014) rightly note, "Increasingly, researchers and policy makers alike recognize that innovations are generated by complex and dynamic national ecosystems that include government, industry, universities and school." These authors could have said 'systems' instead of 'ecosystems' without loss of clarity, completeness or accuracy.

3.5. 'Innovation ecosystem' is a metaphor, not a rigorous construct

This paper has noted ways in which the innovation ecosystem corpus differed from earlier ideas and methods of economic and knowledge development. These differences are valuable in that they give us new food for thought, and greater structure (e.g. more fixed roles, more attention to ICT,) than provided by earlier ideas of high tech economic development. Hugget's (2011) article likens emergent business models and support institutions to biological speciation, an intriguing insight not provided by the earlier models.

However, the innovation ecosystem notion, taken as a whole, lacks scholarly rigor and weight. As an analogy to natural ecosystems, it is flawed also.

- Innovation ecosystems are designed, engineered systems. They have a purpose, or teleology, that distinguishes them from evolved systems. The innovation ecosystem literature forces the question: what is that purpose? The public sector's purpose in encouraging innovation is the creation of jobs, exports, environmental protection, and local quality of life. The private sector's purposes are a more efficient value chain, and superior investor returns.
- Innovation ecosystems, once designed, do evolve. Different links in the value chain may become the "dominant species," capturing the lion's share of rents for a period of time. Companies succeeding in one link of the chain may expand or acquire in order to take over another link. In an evolved ecology a leopard that ingests a gazelle remains a leopard. In an innovation ecology a company that eats (acquires) another company becomes a new entity, of a different nature. See Geels (2002) and other publications by the same author for more comparisons between biological and artificial evolutionary systems; and also Huggett (2011).
- A closed (business-only) system seems inconsistent with the trend to open innovation.
- In contrast to industry *clusters*, which have measurable positive feedback and tipping point effects, the idea of innovation ecosystem offers no ready metrics.
- Suggestions (e.g., Durst and Poutanen, 2013; Zhang et al., 2014) that innovation ecosystems exhibit specific kinds of emergent, complex system behavior have yet to be substantiated. Moore (1993) was consistent in applying the ecological system metaphor to business. However, he did not establish rigorous correspondence rules between natural and business ecosystems. His paper is simply an extended (though persuasive) metaphor.
- The literature (UP Global, undated; Viitanen et al., undated; Cohen et al., 2014; Zhang et al., 2014) often mentions "sustainable ecosystems," which are not found in the natural world, as current climate changes and species extinctions demonstrate. "The early 20th-century belief that the climax community could endure indefinitely is now rejected because climatic stability cannot be assumed over long periods of time" (Pearson/Infoplease Encyclopedia, 2014; see also Phillips and Su, (2009)).
- "There is an implicit assumption in most regional innovation policy studies that once a policy has been made, the policy will be implemented. This assumption is not valid for … many countries" (Kang and Oh, 2015). Natural ecosystems, of course, do not have policies. Kang and Oh's statement shows it is preposterous to think that an innovation system displays the constant co-evolutionary adjustment that defines a natural

Table 1
Benefits and limitations of the innovation ecosystem terminology.

Benefits	*Limitations*
• Motivated successful projects • Encouraged helpful 'systems thinking' • Provided a forum for sharpening some ideas of technopolis and innovation • Resulted in good press coverage of high-tech regional economic development • May help explain geographical shifts in activity, e.g., from London to Munich; from Silicon Valley to Shanghai. • Shows willingness to learn from biological systems.	• The analogy to natural ecosystems is flawed. • Business-only ecosystem contradicts open innovation philosophy. • It offers no ready metrics. • Suggestions that innovation ecosystems exhibit special kinds of complex system behavior have yet to be substantiated. • The term is used in so many ways that no clear definition seems possible.

ecosystem. To do so will give rise to cognitive dissonance and dysfunctional policies.

- Finally, natural ecosystems are local – even if big – the Amazon river system, the desert ecosystems of the Sahara and the American southwest, for example. In contrast, innovation ecosystems may reach across the world (Broechler and de Voigt, 2013). The cross-world links of an innovation ecosystem are not weak links, but essential to local functioning. Consider "Peruvian scientists disgruntled with 'brain gain' scheme" (Portillo, 2014), which describes the paralyzing lack of facilities given in Peru to scholars who have returned from grant-supported fellowships in cutting-edge labs in Europe.

Table 1 summarizes the pros and cons of the innovation ecosystem meme as discussed in the present paper.

In sum, the 'innovation ecosystem' notion is an interesting development, built on biomimetic thinking, that injects some useful concepts into the economic development dialog. It may lead to new scientific truths and reliable methods for knowledge and economic development. However, the notion does not in itself constitute or provide such truths or methods. It has brought to us ideas which may be more systemic than those found in the NIS literature, but which (according to Wallner and Menrad (2011)) are still not systemic enough. It suggests intriguing parallels to biological systems, but these remain only suggestions, lacking empirical support or rigorous correspondence rules.

4. Where to go from here

Published incidences of the "innovation ecosystem" term seem still to be increasing. It thus falls to researchers to bring rigorous meaning and practical usefulness to the innovation ecosystem concept. This concluding section notes some promising current research, and suggests further directions.

Pietsch's (2014) work on green cities suggests the term "innovation ecosystem" might best be reserved for the interface between the artificial and the natural features of a science city. However, it is too late to stuff that cat back into its bag. Common usage lends a much broader meaning to "innovation ecosystem."

It is sensible to follow the example of "fuzzy logic," which by relaxing some of the postulates of classical logic (but rigorously following the remaining postulates) results in a consistent and useful concept which has some parallels to classical logic but is distinct from it. In the same way, innovation ecosystem theorists may relax some axioms of ecology (and perhaps introduce a small number of additional ones) in order to fit the needs of artificial "ecosystems."

Initial work has been done by Eyuboglu and Buja (2007), who address selection as the association factor in two-party relationships. In this way, they provide a theoretical foundation for applying quasi-Darwinian perspective in marketing theories. Although their theory may not be directly applicable to innovation ecosystems with multiple players, it shows biology-inspired theories need not be mere metaphors in SCM. Carayannis and Campbell (2009) suggest that knowledge systems and information architectures compete and co-evolve in innovation systems. Hage et al. (2013, p. 213) suggest the connectedness among the organizations in a sector could indicate its prospects for success. They show that knowledge and technology, key elements of innovation ecosystems, evolve through interactions among players.

Xu et al. (2007) subsumed the ecosystem concept into their TIM (Total Innovation Management) theory, which took a broad view of organizational innovation "by anyone at anytime in all processes, among different functions and around the world (p.13)." Their work, like that of Phillips (2006) and Carayannis and Campbell (2009), urges us to look beyond technological aspects of innovation ecosystems, to see the importance of non-technological elements (strategy, cultures, organization, and institution) in building up the competency of the innovation ecosystems. Hernández et al. (2007) show how hybrid organizational forms and hybrid forms of inter-firm agreements arise for purposes of cooperation, coordination, and pooling of risk.

Schot and Geels (2007, 2008) emphasize niches in the evolution of technological and socio-technical regimes. Their definition of niches – "protected spaces that allow the experimentation with the co-evolution of technology, user practices, and regulatory structures" – differs from that of the ecological niche, and is primarily oriented to explaining radical technical change. However, these protected spaces share some characteristics of innovation ecosystems.

These researchers have moved toward quasi-evolutionary and quasi-ecological theory for various parts of an artificial ecosystem. It remains to broaden and refine their ideas to encompass the entire innovation system. To this end, challenges for research include clarifying whether and how innovation ecosystems differ from national and regional innovation systems; finding ways to measure innovation system performance; further detailing similarities and differences between natural and innovation ecosystems; and reconciling the levels at which the term is used, such as within firms, cities, or supplier networks.

Until those challenges are met, clarity will be served if innovation researchers use the term "ecosystem" only with a leading modifier – for example, university startup ecosystem, IT ecosystem, incubation ecosystem – or better yet, not at all.

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