What is an Innovation Ecosystem?

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The analogy with biological ecosystems

One expects there to be a conceptual analogy between an innovation ecosystem and the biological ecosystems observed in nature. The biological ecosystem is a system that includes all living organisms (biotic factors) in an area as well as its physical environments (abiotic factors) functioning together as a unit. It is characterized by one or more equilibrium states, where a relatively stable set of conditions exist to maintain a population or nutrient exchange at desirable levels. The ecosystem has certain functional characteristics that specifically regulate change or maintain the stability of a desired equilibrium state.

In the biological system , the *equilibrium* state is described by modeling the energy dynamics of the ecosystem operations?[1] In this context, the energy is simply the way the predator-prey relationship and the plants transfer energy; calories are burned consuming prey, thereby transferring the energy of the prey to the predator and as plants die and decompose, their energy is transferred to the soil where it is taken up again by other plants. Because the energy dynamics are a complex function, an ecosystem can only be considered as a whole, not piecemeal, as every part of the ecosystem has a functional effect on another.

In summary, a biological ecosystem is a complex set of relationships among the living resources, habitats, and residents of an area, whose functional goal is to maintains an equilibrium sustaining state.

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[1] http://www.sustainablescale.org/ConceptualFramework/UnderstandingScale/BasicConcepts/EcosystemFunctionsServices.aspx

In contrast, an innovation ecosystem models the economic rather than the energy dynamics of the complex relationships that are formed between *actors* or *entities* whose functional goal is to enable technology development and innovation. In this context, the actors would 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 (VC), 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 knowledge economy, which is driven by fundamental research, and the commercial economy, which is driven by the marketplace. Of necessity, however, the two economies are weakly coupled because the resources invested in the knowledge economy are derived from the commercial sector; this includes government research and development (R&D) investments which are ultimately derived from tax revenues.

Why do we care about developing the innovation ecosystem?

The two ways to increase economic output within an economy are to (i) increase the number of inputs in the productive process, or (ii) think of new ways to get more output from the same number of inputs. The latter is the essence of what is broadly meant by innovation, which is defined as the introduction of new or significantly improved products (goods or services), processes, organizational methods, and marketing methods in internal business practices or the marketplace. Innovation is believed to be the fundamental source of significant wealth generation within an economy. This belief is foundation of the current administration's strategy for the economic recovery [2] and undergirds the National Science Foundation's efforts to nourish the nation's innovation ecosystem[3]. In particular, because high-tech industries offer higher growth potential, the best way to spur job creation and economic growth is by facilitating more

[2] Executive Office of the President (2009). A strategy for American Innovation: Driving towards Sustainable Growth and Quality Jobs http://whitehouse.gov/assets/documents/SEPT_20_Innovation Whitepaper FINAL.pdf.
[3] The Role of the National Science Foundation in the Innovation Ecosystem; http://www.nsf.gov/eng/iip/innovation.pdf

efficient translation of innovations from the knowledge economy into the commercial sector. Given today's economic down turn, with its high unemployment rates and low tax revenues, federal, state, and local governments entities are now actively seeking new ways to grow their economies by creating jobs. The higher growth rate for high-tech industries, in particular, offers a strong incentive for government entities to actively develop and nurture innovation ecosystems that leverage the technology research of university faculty.

An important feature of an innovation ecosystem is that the resources available to the knowledge economy are coupled to the resources generated by the commercial economy, usually as some fraction of the profits in the commercial economy. Another feature is that the ecosystem is usually strategically developed around a specific technology. Two high profile examples of focused ecosystems are the Department of Energy's Innovation Ecosystem Development Initiative[4] which is focused on speeding up the adoption of *energy* innovations and the European Innovation Initiative's Digital Ecosystem technologies[5]. These national level strategic initiatives are just two examples; clearly innovation ecosystems can be structured around almost any subject matter. The Engineering Research Centers (ERC) program[6] at the National Science Foundation is an example of smaller scale innovation ecosystems developed to push selected technology niches which are centered around transformative engineering systems. This program, originated more than 25 years ago within the NSF's Engineering Directorate, has been very effective at initiating and maturing ecosystems that are stable enough for the ERCs to continue operating after NSF funding sunsets at the end of 10 years. The current success rate for graduated ERCs is 82%. [7]

[4] http://www.topgovernmentgrants.com/grants_gov_display.php?program=DE-FOA-0000356
[5] http://www.digital-ecosystms.org/
[6] http://www.erc-assoc.org/
[7] James E. Williams, Jr. and Courtland S. Lewis, *Post Graduation Status of National Science Foundation Engineering Research Centers: Report of a Survey of Graduated ERCs,* Prepared for the National Science Foundation by SciTech Communications LLC, January 2010.

An innovation ecosystem is said to be thriving and healthy when the resources invested in the knowledge economy (either through private, government, or direct business investment) are subsequently replenished by innovation induced profit increases in the commercial economy. At that point, the two economies (knowledge and commercial) exist in balanced equilibrium and the innovation ecosystem is deemed to be healthy.

$$P = P_0(I_{R\&D}) + \Delta P = P_0(1 - a) + \Delta P \quad (1)$$

where P_0 is defined as the initial profit before the investments in fundamental research are made,

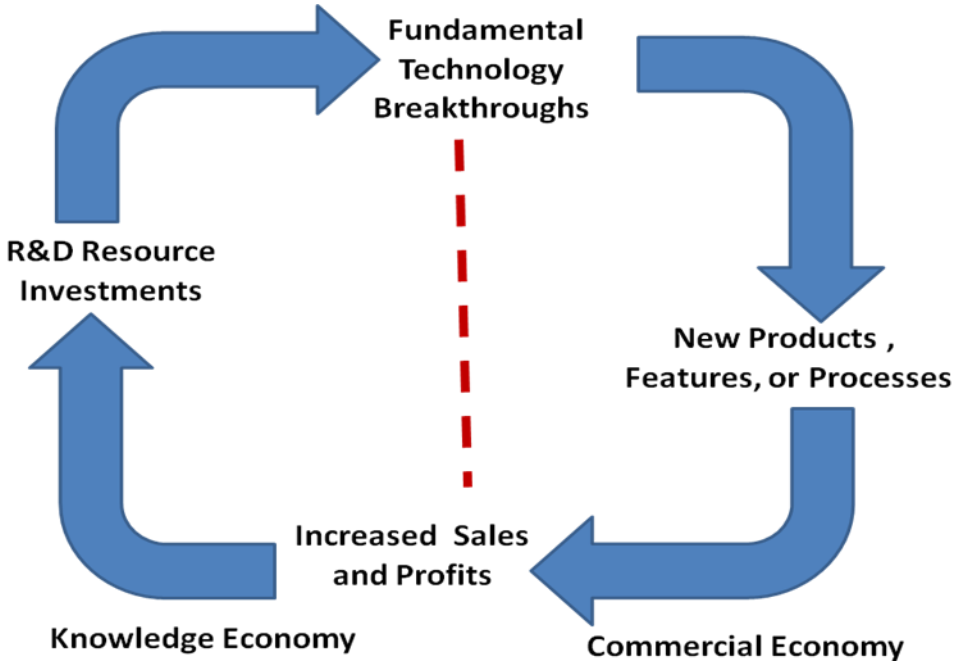

Figure 1. Virtuous cycle depicting how R&D resource investments are replenished through increased profits in the commercial economy in a thriving innovation ecosystem.

P is defined as profits corrected for investment, $P_0(I_{R\&D}) = P_0(1 - \alpha)$, $I_{R\&D} = \alpha P_0$, is defined as the commercial economy's research investment in the knowledge economy, and ΔP is the innovation induced

growth in the economy. Thus a small amount of profits, $I_{R\&D}$, are sacrificed in order to finance fundamental research. The result is a feedback loop, known as the virtuous cycle, which is depicted in Figure 1.

When the innovation induced increase in profits exceeds the initial R&D investment, instead of being balanced, the innovation ecosystem is said to be growing. Clearly the goal of most of today's government entities that fund innovation is to put their economies into a growth phase where:

$$P > P_0(I_{R\&D}) + \Delta P = P_0(1-\alpha) + \Delta P \qquad (2)$$

Innovation spectrum

The challenge to creating a growth situation for an ecosystem is figuring out how to turn the breakthroughs of R&D efforts into products that lead to profits. Achieving this goal is complicated by the fact that the two economies operate on different reward systems, thereby making it difficult to link discoveries derived from fundamental research with innovative products that can translate into profits in the market place, unless the cycle is internal to a firm.

Another challenge is the scarcity of implementation resources, $I_{TD\&D}$, for technology demonstration and development. In Figure 2, the innovation spectrum shows the distribution of resources invested in activities aimed at discovery, technology demonstration, technology development, and commercialization. At the far left of the spectrum (i.e. in academia), there is a heavy concentration of government investment in fundamental research; while to the far right of the spectrum (i.e. in the commercial marketplace) there is a much higher level of industry investment in direct product development. This gap in resources for technology demonstration and development (TD&D) is colloquially known as the *Valley of Death*. The actors engaged in moving innovations from discovery through commercialization are academia, small businesses, the investor community, and commercial industry. For these actors, it is within this *valley* that many potential innovations die for lack of the

resources to develop them to a stage where industry or the investor community can recognize their commercial potential and assess the risk associated with bringing them to market.

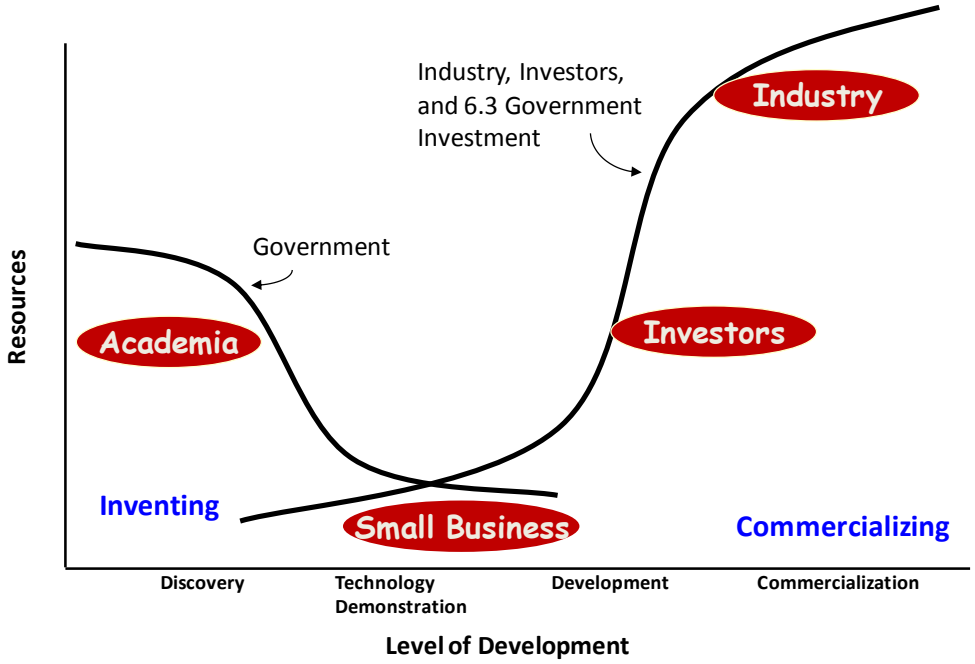

Figure 2. Innovation Spectrum

One might naively assume that the most efficient way to improve the rate at which technology translates across the Valley of Death is to substantially increase the TD&D resources. Though this may successfully move some innovations into the commercial sphere, it doesn't guarantee that the innovation ecosystem will thrive as a result. However, when the system is constrained by the requirement that it must maintain a virtuous cycle, the investment in TD&D further reduces the initial profits in the economy so that a higher growth in net profit is needed to maintain a virtuous cycle.

$$P \geq \{P_0(1-\alpha) - I_{TD\&D}\} + \Delta P \qquad (3)$$

To make things worse, 99.9% TD&D enterprises presented to investors fail[8], which means that the magnitude of the losses from the failed TD&D investments, $I_{TD\&D}$, in equation 3 can be significant. So the best strategy is to limit the losses by judiciously screening the projects selected to receive translational funding.

The high loss rate can sometimes be mitigated by teaming with professionals experienced in translating technologies across the gap such as successful entrepreneurs, angel investors, or venture capitalists. But even with the extensive resources and conservative due diligence practices of venture capitalists, only one out of every 10 of venture capitalist investments are considered to be commercial successes[9]. The reason that venture capitalists cannot guarantee the success of the innovation enterprises they select is because there are many uncontrollable factors in the market place that cause enterprises to fail. Common reasons[10] for failure are misjudging the market place, government created roadblocks in approval (FDA, FCC, FAA, etc.), no market for the product; stronger competition than expected; technologies that do not work as expected; bad management decisions; bad luck; the required funding outgrowing possible financial rewards; unexpected government changes to laws or regulations, etc.

Statistically, for every 10 enterprises a venture capitalist invests in, 50% fail outright, 30% are marginal in that they don't fail, but also don't experience growth, 10% grows at a rate of about twenty percent a year, and 10% grow significantly faster, providing returns in excess of 1000%. Venture capitalists only classify an investment enterprise as successful if its return on investment (ROI) exceeds a factor of 10. The reason venture capitalists require a minimum ten-fold ROI is to insure that they can recover their investments on the other nine investments that fail. Like the venture capitalists, the innovation ecosystem must experience enough growth to recover all of the TD&D investments in failed enterprises in order for the innovation ecosystem to be healthy and thriving.

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[8] Jeffry A. Timmons, Andrew Zacharakis, and Stephen Spinelli, *Business Plans that Work*, McGraw Hill Companies, 2004, p. 17

[9] http://ezinearticles.com/?Improve-Venture-Capital-Returns-With-IP-Portfolio-Management&id=1420039

[10] http://www.questia.com/googleScholar.qst?docId=5001285456

This high risk to investors leads to several important conclusions about healthy innovation ecosystems. First, the increased productivity from success must be profitable enough to compensate for the monetary investment in both fundamental research *and* in the failed enterprises. Because there is a high probability most enterprises launched in the ecosystem will fail, a healthy ecosystem should be structured to handle failures in a way that encourages cutting investment losses in the early stages of the enterprises, thereby making it easier to close the loop on the virtuous cycle. Ideally, the ecosystem is also structured to recover and recycle resources (including human capital) that are released upon failure of an enterprise.

Nurturing the culture of the innovation ecosystem

In the context of nurturing the innovation ecosystem's culture, successful enterprises are considered to be those that are self-sustaining. Given that standard, the above statistics on venture capitalists success rates suggest that at least 50% of the venture capitalist investments in a technology arena become viable enough to contribute to the culture of their ecosystem by helping to create jobs, helping to create a competitive environment, and through participation in the ecosystem's ideation and innovation dialogs. Though difficult to quantify, both types of contributions play important roles in the ecosystem's dynamics.

Besides assembling the actors who will contribute to the innovation ecosystem, a healthy ecosystem also provides a mechanism for building relationships and other intangibles between the actors, and entities within the ecosystem. It is the development of trust relationships that helps the deals to go though when that stage is eventually reached. Besides directly funding individual enterprises, finding intangible ways to accelerate the passage through the *Valley of Death* improves the efficiency of the innovation economy, and makes it easier for it to become self-sustaining. Common approaches for developing these intangibles are relationship building activities or one time investments in infrastructure that make the overall operation more efficient, and thus benefit everyone within the ecosystem. Investing in the

development of these intangibles is wise because it casts a broader net that benefits all efforts to cross the *Valley of Death*.

Turning Valley of Death into a Challenge Basin

What are some of the intangible ways of enhancing the chances that technology innovations will successfully bridge the *Valley of Death*? There is no set recipe for developing relationships within an ecosystem because it depends on the specifics of the technology, the cultures of the ecosystem entities, and the personalities of the players. The best way to describe how to approach the development of these relationships is to start by viewing the "valley" in a metaphorical sense (see Figure 3). In this context, the intangible relationships of the innovation ecosystem comprise all of the things that one does to the infrastructure to effectively move the academic side of the valley wall further to the right; or to move the commercial side of the valley wall further to the left in order to improve the chances of an innovation venture successfully spanning the *Valley of Death*. For example, training a cadre of champions whose job it is to ferry an innovation concept across the valley by championing it until it becomes commercially viable will effectively move the academic side to the right. Ideally, healthy ecosystems that have made such a human capital investment will find ways to keep their champions engaged and circulating within the innovation ecosystem by providing a means of subsistence or incentives for them to stay within the ecosystem. For example, the marginal and moderate growth enterprises that are considered failures in the venture capital scenario could serve as habitats for champions between enterprise ventures. The designers of healthy innovation ecosystems realize that the experience of failure is just as valuable on the resumes of champions as the experience of success. Indeed, some might argue that the experience of failure is more valuable, because it teaches the champions to know when to cut their losses.

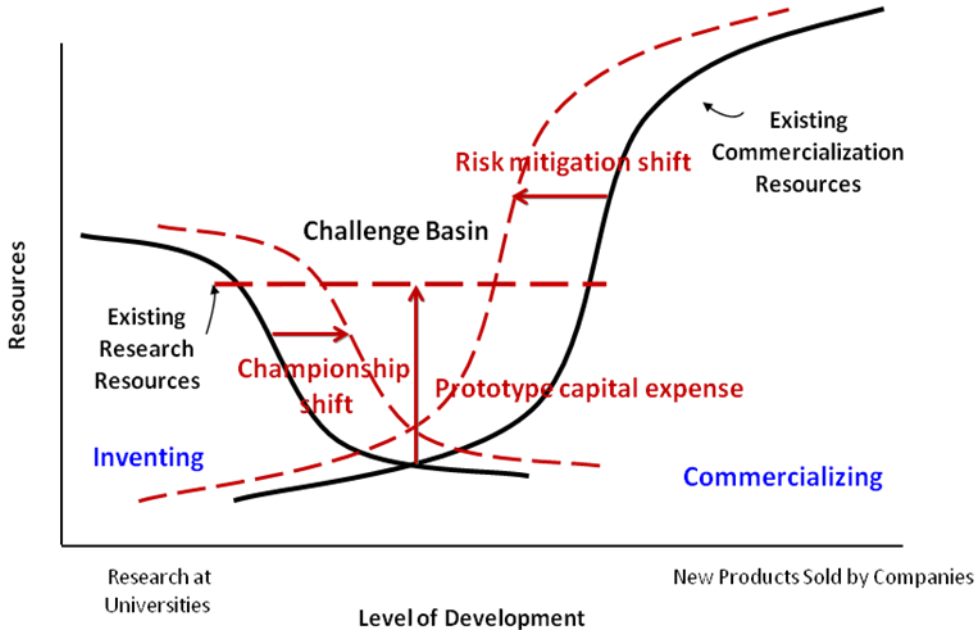

Figure 3. The innovation ecosystem consists of the actors, entities, and intangibles. The intangibles are the complex relationships that effectively move the valley walls inward and the valley floor upward in order to replace the deep walled valley of death with the gentle slope of a challenge basin.

An effective strategy for moving the commercial side of the valley wall further to the left would be to find ways of lowering the perceived risk for investors. For example, ecosystems that find ways to translate knowledge of discoveries developed in the academic community into a context that is relevant to the industry investors reduce the perceived risk for the investor so that he/she might be inclined to invest in the technology at an earlier stage. Another approach would be for the academics to find ways to establish regular brainstorming dialogs with members of the investor communities about nascent technology and it potential capabilities thereby leveraging the industry and investor community's first-hand knowledge of the market sectors and the unfilled needs that a nascent technology might potentially address.

Beyond the intangibles, there are infrastructure investments that are designed to benefit the innovation ecosystem as a whole which can reduce the negative impact of failures on the virtuous cycle feedback loop. For example, putting in place rapid prototyping infrastructure is beneficial to the innovation ecosystem because it (i) lowers the entry costs for start-ups to engage in innovation and (ii) it raises the

success rate by increasing the number of attempts at translating the *Valley of Death*. It is the type of investment that government entities may be more willing to make because it spreads their risk among a larger number of tries, thereby increasing the chances that they will have invested in an enterprise that creates jobs. The best examples of this are the Semiconductor Research Corporation (SRC) for integrated electronics [11] and the ERC proof of concept testbeds. The Engineering Research Center for Structured Organic Particulate Systems (C-SOPS), for example, recently established a continuous tablet manufacturing prototype testbed facility[12,13] for the benefit the pharmaceutical industry. Other infrastructure investments might involve finding ways for champions and other actors involved in the innovation process to reside within the ecosystem between enterprises (e.g. innovation post docs, professors of practice, etc), thus creating a ready manpower pool which is available for launching innovation enterprises.

In summary, fundamental research is a necessary ingredient for the development of transformational innovations that have potential for impacting economic growth. Given that the investment in fundamental research comes at the expense of profits, a healthy innovation ecosystem is one that closes the feedback loop between R&D investments through innovations that increase profits in the commercial economy.

[11] Semiconductor Research Corporation—http://www.src.org/
[12] http://showcase.erc-assoc.org/accomplishments/2010/2010-CSOPS1-D-pharmaprocess_DL-CLedit.html
[13] http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0951845