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IDEASQUARE COFFEE-PAPER

Harnessing butterflies for creating innovation tornadoes

In addition to its main purpose of publishing experimental innovation research related results, CIJ also publishes more light, inspirational food-for-thought intended "IdeaSquare Coffee Papers". These pieces are collaborative efforts prepared by visiting researchers from various walks of life visiting or staying at CERN IdeaSquare premises. The identity of the contributing authors is kept anonymous (although known) but helpful hints can be found in the literature references. Editors of this section are Dr. Markus Nordberg and Dr. Valeria Brancolini.

EXECUTIVE SUMMARY

The purpose of this paper is to offer a "Gedankenexperiment" related to the question of amplification of innovation. We assume a simple innovation ecosystem in which its different actors (research communities, industry and public and private investors) interact in parallel but pursue different (but not necessarily incompatible) goals. Our approach is inspired by chaos and non-linear dynamical system theories and the famous "butterfly effect". An arm-chair recipe on how to amplify innovation is casually offered and some concrete examples are outlined.

INTRODUCTION

Why this "Coffee Discussion Paper"? In the spirit of the IdeaSquare Project[1], we experiment how to connect basic research mission with society-driven challenges in a new, mutually beneficial way, with the aim of scaling up the results. This involves our research community, the industry, expert innovation organizations, universities and alike to try out new things. Working together both with practitioners and academics, we use the unique opportunities offered by IdeaSquare also to carry out socio-economic studies and "out-of-the-box" intellectual exercises in the domain of innovation. We thus offer a short paper outlining a simplistic vision how to boost innovation. It is intended to ignite fruitful thoughts and discussions in our regular Tuesday-morning coffee (croissants regularly offered free of charge as an incentive to show up).

Although our point of reference is obviously CERN – 22 funding European Member States in the domain of particle physics research with a global reach of over 12 000 registered users across the world – our scope is intended here to be wider and geographically or scientifically not bounded to the above.

Our purpose is thus to remain general in our argumentation and conclusions, but restricting to an operational environment we are used to work in: many different countries, languages, best practises, experiences, different decision-making processes, different funding streams, different reporting experiences etc. As just one example, and used here as a guiding experience, is the way the large LHC physics experiments, CMS[2] and ATLAS[3], were set up and how they are currently run, each comprising over 3000 active scientists and engineers and being funded by over 40 countries each.

The current paper was triggered by a question whether and how innovation can get amplified. Long before mankind coined the term innovation, and about birds and the bees, during the Cretaceous age flowers began to evolve colours and scents that signalled the presence of pollen to insects. Simultaneously, insects developed by natural selection organs to extract the pollen and, randomly, fertilized other flowers with it. Over time, the flowers further evolved supplementing the pollen with energy-rich nectar to lure the insects into the rituals of pollination. The symbiosis between flowering plants and insects leading to the production of nectar ultimately created an opportunity for much larger organisms—the hummingbirds—capable of extracting nectar from plants. But to do that they evolved an extremely unusual form of hovering mechanics. Evolution changed forever the art of flying[4].

These are the quantum leaps that evolution makes constantly. In this case, this ended up in one of the most astonishing physical transformations in the evolutionary history of birds.

The history of innovation works this way too. Consider Johannes Gutenberg's printing press[5]. It changed the way information was stored and shared, triggering multiple revolutions in science and theology and art. But it also had a crucial

[1] http://www.cern.ch/ideasquare
[2] http://cms.web.cern.ch/
[3] http://atlas.ch/
[4] Douglas Warrick et al., *Hummingbird flight*, Current Biology, Volume 22, Issue 12, 19 June 2012, Pages R472–R477.
[5] Steven Johnson, *How we got to now: six innovations that made the modern world*, Riverhead Books, 2015 also PBS Series http://video.pbs.org/program/how-we-got-now/

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unexpected effect on an apparently unrelated field: demand for spectacles. The new practice of reading made Europeans suddenly realize that they were farsighted. The unexpected consequence was a market demand for spectacles. This encouraged a growing number of people to produce and experiment with lenses, which led to the invention of the microscope and subsequently key advances and understanding towards modern biology. It as well allowed for the development of telescopes for maritime uses leading to the discovery of new continents and planets and vastly expanding human horizons in knowledge - and in wealth.

That is the way disruptive innovative changes happen. It has a well-recognised name in chaos theory: The Butterfly Effect[6].

THE BUTTERFLY EFFECT

In chaos theory, the butterfly effect manifests as a sensitive dependence of a dynamical system on its initial conditions. Small changes in the initial state of a deterministic nonlinear system can result in large differences at a later state. In other words: unpredictable significant amplification. The name was coined by Edward Lorenz[7]. He famously gave a talk titled "Does the flap of a butterfly's wings in Brazil set off a tornado in Texas?" He was describing how, in the physical sciences, systems with large numbers of interacting parts can collectively react in seemingly unpredictable ways to very small disturbances. Feedback between these parts reinforce such outcomes. Thus, the system as a whole amplifies even minor disturbances (such as a butterfly flap) to create large-scale effects that are difficult and in some cases impossible to anticipate. While Lorenz was describing the behaviour of a physical system, "butterfly effects"[8] also appear in the realm of human organization and therefore also in innovation.

One of many examples is the unintended "butterfly" consequences that MEMs accelerometers and gyroscopes (normally used for car navigation systems) had for the video game industry.

Up until 2007, the leading console makers — Nintendo, Microsoft, and Sony—came out with a series of consoles that increased computational power providing more realistic video images and sound effects. Their core group of the customers were young males who grew up playing on such consoles and had increasing sophisticated know-how and expectations about the graphics and technologies. However, in 2007 Nintendo Wii designers did something different. They wanted to expand their market to the entire family, including girls, women, the 55+ age group, and "casual" gamers. In fact, intended for people not willing to dedicate hundreds of hours to master the traditional multiple joystick-and-buttons but willing to have just a couple of hours of fun. Nintendo created a new type of game controller, the "Wiimote," based on accelerometer technology. By 2007 the Wii console was outselling Sony's PlayStation three to one. A year later, Nintendo's share value had quadrupled and the Wii was still outselling the Xbox and the PS3. To date, the company has sold over 100 million units of the Wii console, and avid Wii players reportedly include gamers as young as 22 months, and some as old as 103 years. We are pleased to learn that even Queen Elizabeth II of Britain is a fan[9].

HARNESSING BUTTERFLIES

The "butterfly effect" suggests among other things that the reliability of e.g. weather forecasts drops sharply beyond 10 days. After the 10-day period, temperature fluctuations grow strong, giving rise to increases that are then immediately followed by decreases, and vice-versa. But while the effect is felt as soon as 10 days, the pattern itself holds for months and years, even decades. It was recently discovered that there is a natural tendency for temperature to return back to its base state. This is one of the atmosphere's expressions of its memory; an expression so strong that the effects of fluctuations that occurred a century ago can still be felt today[10].

This atmosphere's massive memory can be directly harnessed to come up with more accurate temperature forecasts compared to what usual numerical computer models can do. Accordingly, a mathematical model has been developed that could aid in improving poor forecasts for seasons as well as result in better climate projections for long periods of time. To benefit from the butterfly effect, the method treats weather as random, using historical data to influence a forecast to show more realistic climate conditions. For the moment, this method has improved predictions compared to other forecasting techniques utilizing only the short-term memory the atmosphere has.

Building on this exciting discovery our question for our regular Tuesday morning coffee meeting is thus the following:

Could we impinge "innovation memory" into an ecosystem to amplify innovation? In other words, could we systematically produce and harness "innovation butterflies" for creating innovation tornadoes? And if so, how do we organise a common public and private investment strategy?

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[6] https://en.wikipedia.org/wiki/Butterfly_effect

[7] Lorenz, Edward N. (March 1963). "Deterministic Nonperiodic Flow", Journal of the Atmospheric Sciences **20** (2): 130–141.

[8] Edward G. Anderson Jr. and Nitin R. Joglekar, The Innovation Butterfly: Managing Emergent Opportunities and Risks During Distributed Innovation, Springer 2012.

[9] https://en.wikipedia.org/wiki/Wii#Wii_Mini , https://www.marsdd.com/mars-library/changing-the-game-lessons-from-nintendos-wii/

[10] Lovejoy, S. (2015), "Using scaling for macroweather forecasting including the pause", Geophys. Res. Lett., 42.

OUR SET-UP

In IdeaSquare at CERN we are currently experimenting a very simple innovation ecosystem formed by:

- Fundamental researchers: primarily interested in fundamental research goals but with a constant need and motivation to develop and improve cutting-edge technologies.
- Industry: interested in new applications of technologies in the shorter term but also on mid and longer term if beneficial for the firm.
- Private investors: mainly interested in growing markets with a fast exit and (good) return of investment. A few of them of them are willing to be more patient if the opportunity is good.
- Public investors: Willing to use public funds to absorb research and commercial development risks and costs but want to see innovation impact of public funding.

INNOVATION TORNADOES – OUR RECIPE

Following the best traditions from many culinary books - and chefs - our self-appointed (and worse, self-taught[11]) arm chair economics and R&D&I policy team at IdeaSquare at CERN is now trying out the following fruitful recipe (Figure 1).

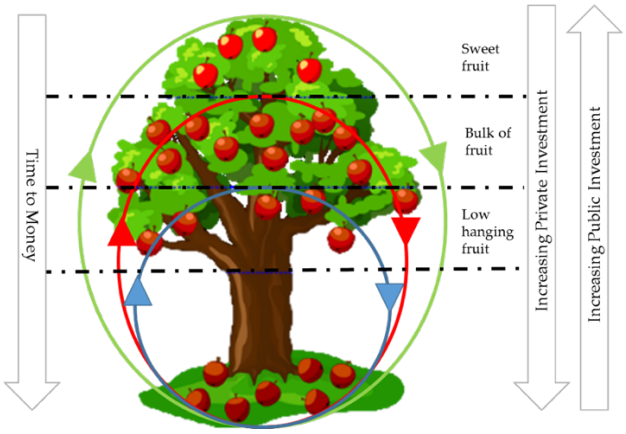

Fig. 1. IdeaSquare set-up ecosystem illustrating its innovation dynamics cycles (short = low hanging fruits, mid = bulk of fruit, long = sweet fruit).

- First ingredient: Focus on great science and technologies across disciplines pursuing unmet commercial needs. Mix them well.
- Second ingredient: Scout a large amount of innovative ideas, technology concepts, prototypes, etc. across a wide spectrum (and geography). Shake them but do not stir.
- Third ingredient: Pick and clean the fruit. Polish and package it for presentation (low hanging, bulk, sweet).
- Fourth ingredient: Bake a Fruit Investor Club cake comprising both public and private funding actors. Adjust funding mechanisms adapted to each one's interests but maintain the collective balance in taste and benefit as a whole (Pareto optimality[12]). Add a dedicated investor manager to the team to keep an eye on the baking process.
- Fifth ingredient: Apply the right dose and combination of public and private funding ingredients depending on the case (short cycle = low hanging fruit, mid cycle = bulk of fruit, long cycle = sweet fruit).
- Sixth ingredient: Allow each one to pick their own apples' benefits and replant back in the club for next harvesting.
- Seventh ingredient: Repeat the cycle without interruptions in the flow of funding so to impinge trust and a long term "cumulative innovation memory" to the ecosystem[13].

[11] Modesty prevents us from exposing how many PhD's in economics serve on our team.
[12] Pareto efficiency, or Pareto optimality, is a state of allocation of resources in which it is impossible to make any one individual better off without making at least one individual worse off. The term is named after Vilfredo Pareto (1848–1923), an Italian engineer and economist who used the concept in his studies of economic efficiency and income distribution. The concept has applications in academic fields such as economics, engineering, and the life sciences. https://en.wikipedia.org/wiki/Pareto_efficiency
[13] A simple simulation made by our team suggests that over a 10-year period, nurturing and funding 600 science-driven innovation projects within a budget envelope of 2b Euros of public and private funding amplifies economic utility by a factor 10-50 depending on the probability distribution assumed.

EXAMPLES

Rainbow Seed Fund

The Rainbow Seed Fund[14] is a privately managed £24m, early-stage venture capital fund dedicated to kick-starting promising technology companies. Created in 2002, the Rainbow Seed Fund is backed by ten UK publicly-funded research organizations and the Department of Business, Innovation and Skills (BIS)[15]. Among others it invests in projects and companies arising from the world-class research carried out in partner laboratories including those at Rutherford Appleton Laboratory, Porton Down, and Babraham Institute. It also invests in companies based at its partners' national science and innovation campuses in Oxford, Cambridge, Warrington and Norwich. Today the Rainbow Seed Fund has a portfolio of over 30 companies. Among the many milestones achieved in the last decade it is possible to highlight:

- Supported 30+ technology start-up companies in sectors such as health, environmental services, international development, and security and defense.
- Leveraged more than £150 millions of private investment from just £7 million of its own investment (a ratio of over £20 for every £1 from Rainbow).
- Bolstered the UK's exports and employment -- 75%-100% of Rainbow Seed Fund company sales are overseas and its companies have created 170+ high-value, technology jobs.
- In recognition of these achievements, in November 2013 the Rainbow Seed Fund received an additional £10M investment to support the commercialization of synthetic biology technologies. This funding was in response to the UK Synthetic Biology Roadmap.

The Fund aims to make a multiple of its investment over a period of 3-8 years, generally by an exit through a trade sale. Therefore, generally business should have high growth potential through serving large markets and establishing barriers to entry. However, the Fund does not have a fixed life and is able to make investments between £25,000 and £500,000 over the lifetime of a project. Thus, it has made investments in businesses which have modest capital requirements and market size but have a lower risk profile. The Fund only invests in projects and Small to Medium Enterprises (SME) based in the UK. Companies do not need a business plan, nor a management team which has sold several businesses before and revenues - but they all help. The Fund invests at an early stage to help companies reach significant milestones which make them attractive to later stage investors. Its portfolio companies have raised from other investors 20 times the capital invested[16].

Allied Minds Federal Innovations

Allied Minds Federal Innovations[17], Inc. (AMFI) has been established to form Public-Private Partnerships with U.S. Department of Defense's (DoD) powerful R&D laboratories and other U.S. Government agencies to commercialize their inventions and innovations. This marks the first public-private partnership formed between DoD and a U.S. technology commercialization firm dedicated to bringing government inventions to market.

AMFI collaborates with its government partners to harness innovative capabilities, create new startup companies and take new products and services to market. This historic relationship creates an institutional process for the licensing of DoD lab inventions into startup companies formed and funded by AMFI in order to:

- Build high quality commercial & dual-use technologies for both public and private sectors.
- Create high value, high-paying, high-tech jobs in the U.S.
- Increase the U.S. technology and scientific competitive advantage in cutting-edge R&D.

AMFI is dedicated to commercializing transformative technologies at federal research and academic institutions. They are strategically positioned to accelerate and institutionalize the process of transferring exciting federally-funded research to the private sector. For that they have developed a unique method based on:

Scout: Identifying the most promising early-stage laboratory research innovations with the potential to have a significant impact on commercial markets. If an emerging technology passes their due diligence, they form a subsidiary company that gives the inventors and their institutions a stake in its success. At this moment AMFI has 21 subsidiaries in different technology domains. In May 2015, the Allied Minds launched its Fellows Program[18]. It offers a unique opportunity for scholars in the STEM disciplines who are passionate about the business side of science and early-stage technology commercialization. Working alongside the Allied Minds investment team, the Fellows gain hands-on experience with scouting, diligence, and market discovery and investment analysis. The current cohort of Fellows are an exceptional group of graduate students, postdoctoral researchers, and clinical trainees from prestigious U.S. academic research institutions.

[14] http://midven.co.uk/funds/rainbow-seed-fund/
[15] https://www.gov.uk/government/organisations/department-for-business-innovation-skills
[16] Only our modesty hinders us from revealing that one of our team members was involved in launching the Rainbow Fund.
[17] http://www.alliedminds.com/subsidiaries/AMFI
[18] http://www.alliedminds.com/fellows

Fund: Unlike typical venture-backed startups, their subsidiaries are, in most cases, wholly funded by a single parent company, Allied Minds. Each venture becomes part of their network for sharing expertise and resources.

Manage: They staff their subsidiaries with a talented team that knows how to create excellent products. Leading each venture is a seasoned director who manages each stage of the product development cycle, from prototyping and manufacturing to overseeing legal and regulatory issues.

Build: Finally, they build enterprises that bring innovations to market. Once a venture is generating revenue and profits, they enable the next level of success, which could result in a liquidity event such as an IPO or acquisition[19].

CONCLUSIONS

In this short arm-chair journey we have started with flowers and insects in the Cretaceous age and we have seen how nature randomly amplifies innovation resulting in the staggering flying mechanism of hummingbirds. We also have given examples on how man-made breakthrough innovations such as the printing press or accelerometers bring unexpected benefits that are also themselves game changers. All in all, random consequences of the "butterfly effect" are well-known in nonlinear dynamics.

The crucial question thus follows, whether or not innovation amplification can be created "by design". In other words: can we systematically harness butterflies to create innovation tornadoes? Again, Mother Nature gives us clues in the shape of the long-term memory of atmospheric cycles: "injecting innovation memory in your system". We have given examples showing that this appears to be possible and have offered our recipe for innovation amplification and related simulation results. Indeed, we think it is possible[20].

APPENDIX : ATTRACT INITIATIVE AS A CASE EXAMPLE

Information about the ATTRACT initiative can be found in the website http://www.attract-eu.org/. The purpose of this Appendix is just to highlight how ATTRACT follows the recipe given in the previous section.

- First ingredient: ATTRACT focuses on breakthrough Detection and Imaging technologies generated for pursuing the fundamental research done in European Research Infrastructures (RIs). In parallel they will constitute the competitive advantage for tomorrow's industry and of the interest of private investors.
- Second ingredient: ATTRACT "butterfly effect" (i.e. innovation amplifying) mechanism starts with scouting a large amount of breakthrough ideas, technology concepts, prototypes, etc. across EU Member States R&D&I groups (Figure 2). Public funding (~100kEuros/project) will be used as an intake fuel to stimulate the proponents of these novel ideas. Special emphasis will be put in the participation of SMEs, together with RIs and large companies.

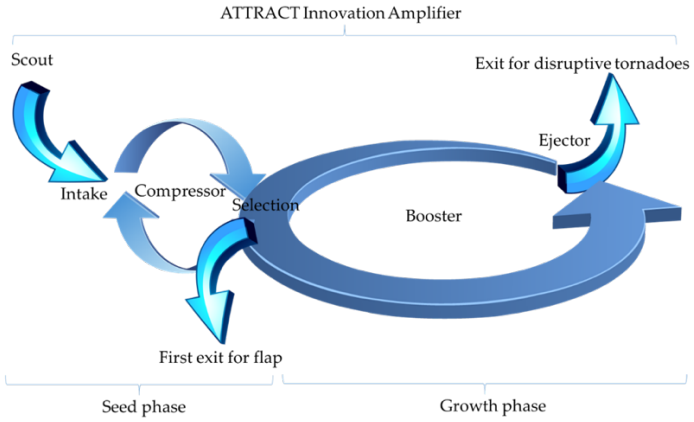

Figure 2. ATTRACT Innovation Amplifier.

- Third ingredient: An Independent R&D&I committee will select a number of ideas that have breakthrough potential for their distance from the market (high risk) and need to be grown further ("bulk and sweet fruits"). As well, "low hanging fruit" will be identified. This will allow private investors also to chip in (see Figure 2, First exit for flap). Private investors will focus their attention on SMEs and potential start-ups.

[19] Our team has had nothing to do with AMFI but by now we wish he had.

[20] Stay tuned for our next Coffee discussion paper. We will put our team brains and hands on how to deal with Intellectual Property in an Open Innovation ecosystem. Surprises and fun are assured.

- Fourth ingredient: ATTRACT proposes an open innovation alliance between RIs-Industry-Private Investors. Pareto optimality is achieved by respecting the keeping principles:
    (a) Respect the mission of RIs for pursuing fundamental research.
    (b) Allow large Industry and SMEs to own Intellectual property for generating products down the innovation value chain.
    (c) Provide private investors with a "first peek & invest" opportunity.
- Fifth ingredient: After the seed phase and selection of promising ideas, to support them by 4M Euros/project to allow them to grow. At the end of this growth phase (see Figure 2) many major breakthrough technologies will be ready for private investment as public funding would have absorbed a substantial part of the risk. It will mean that private investors will be more prone to chip in (Figure 2, Exit for disruptive tornadoes).
- Sixth ingredient: Over time an "ATTRACT Fund of funds" is created with the right governance and tailored instruments to combine public and private agile financing.
- Seventh ingredient: Repeat the ATTRACT cycle (Figure 2, Seed+ Growth phases) without funding interruptions, ensuring a longer term "innovation memory" to emerge in as well as the "innovation amplification" (harnessed butterfly effect). According to our calculations a total financing of the ATTRACT initiative with 1 B Euros (period 2018-2027) using public funding will generate a minimum of 600 breakthrough technological opportunities ready for the market.