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User Communities and the "Dark Energy" of Open Innovation

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Abstract: Spending on R&D in the United Kingdom is in decline. A report by the University of Sheffield stated that research and development investment in the UK is now less than 2% of GDP, mainly explained by cost reductions by firms (Jones, 2013). Yet, innovation is needed more than ever for firms to remain competitive. What can be done to redress the balance? The idea of tapping into the "dark energy" (Anderson, 2012, p. 128) (also known as "the cognitive surplus" (Shirky, 2011, pp. 9-10)) of a "community of users" to enhance a product is as old as the Whole Earth Catalog, which was first published in 1968. This method can also be used to invent new products. This paper will discuss this form of "open innovation" in three distinct contexts: first, in the creation and enhancement of Stewart Brand's "Whole Earth Catalog" between 1968 and 1971, second, by the Chinese mobile phone manufacturer Xiaomi in the development of its MIUI software, and third, in an Internet of Things design competition hosted by the electronics engineering community, element14.com, in collaboration with Texas Instruments, Cisco, and the Eclipse Foundation. Using these examples, the paper argues that the "dark energy" proffered by user communities is a key resource which can be effectively deployed as part of firms' innovation models. The paper also argues that the arrival of low cost tools such as the Raspberry Pi and the 3D printer, as well as access to so-called "hackerspaces", means that online communities can do more than just generate software, ideas and designs, they can now produce working prototypes of physical products. The paper finally argues that using the context of design challenges can provide intensive focus and direction for innovative activity.

Keywords: open innovation, online communities, user-led innovation, user communities, maker movement

Introduction

In 2013, Nathan Broadbent, a New Zealand-based inventor, decided that he was not satisfied with the functionality of his microwave oven and set about to reinvent it. He took his existing oven apart and replaced its on-board circuitry with a Raspberry Pi computer. He also replaced its keypad. He also added new functionality, including:

1. **Voice commands:** Mr. Broadbent can speak to his microwave and tell it to cook his food at a particular setting and time.
2. **A barcode scanner:** Mr. Broadbent attached a barcode scanner to the oven, which he then linked to an online database. In future, he only needs to scan the packaging and the appropriate cooking times will be picked up automatically.
3. **Twitter notifications:** when the food has finished cooking, the microwave sends a message via Twitter indicating that the meal is ready.

At the time of writing, Mr. Broadbent's project summary video has accrued more than 717,000 hits. Despite queries about patenting the new appliance, he stated that he will not be turning it into a manufactured product. Nevertheless, he has imbued his invention with innovations which to the author's knowledge do not exist in any mass produced product, despite the fact that many of these features have been patented by microwave oven manufacturers.

This example highlights a problem and an opportunity. The problem is that product innovation may have stalled in certain instances. The economist Robert Gordon stated in his recent tome "The Rise and Fall of American Growth" that a "golden period" of innovation ended approximately in 1970. His stated rationale is: compared to inventions such as the washing machine, the internal combustion engine, indoor toilets, and electric lights, all other innovations pale in comparison and will not create the same amount of economic growth nor improvements in living standards as experienced by Western societies after 1945. However, this "plateau of innovation" may not be due to an organic limit to human ingenuity: rather, decisions to invest or

not to invest may bear at least part of the blame. For example, spending on research and development in the United Kingdom has declined. According to Professor Richard Jones of the University of Sheffield, investment in Research and Development in the UK has decreased from approximately 2.5% of GDP in 1980 to about 1.7% in 2011 (Jones, 2013, p. 4). The 2012 Kay review of equity markets suggests that this decline is due to, in Professor Jones' phrase, "irrational short-termism". (Jones, 2013, p. 5)

The opportunity, as exemplified by Mr. Broadbent's microwave, is that the tools of innovation are more accessible than ever: Mr. Broadbent utilised the Raspberry Pi microcomputer to control his microwave. The price point for a Raspberry Pi is approximately \$30: it has remained so since it was first launched in 2012, despite the fact that each subsequent model has had greater processing power and more features than its predecessor. A new variant of Moore's Law may be in effect: increasing processing power now sticks at a low price point. As this phenomena unfolds, there is a subsequent increase in complexity of applications that an individual inventor may create.

However, Mr. Broadbent could not have created the invention solely with cheap hardware and an open source operating system (the Raspberry Pi runs a variant of Debian Linux). Open source tools, which are community developed by nature, are increasing in number, variety and complexity: for example, Mr. Broadbent made use of the open source voice recognition software, PocketSphinx. His innovation also would not have been possible without an online knowledge base, whose ultimate expression may be in the form of a community of experts assembled from across the globe within the context of an online forum. The stalled paths in the current innovation paradigm may unblock if firms can access this amalgam of the "dark energy" of user creativity and expertise, combine it with inexpensive tools, and utilise open innovation principles.

Example One: Stewart Brand and "The Whole Earth Catalogue"

Utilising the "bricolage" provided by a community of experts pre-dates the mass availability of the internet. In 1968, the writer, entrepreneur and counterculture thinker Stewart Brand created the first edition of the "Whole Earth Catalog". The catalogue intended to provide "tools for living", so that individuals choosing to "live off the land" could have access to necessary items.

The catalogue contained seven sections, categorising the items for sale –

- Understanding Whole Systems
- Shelter and Land Use
- Industry and Craft
- Communications
- Community
- Nomadics
- Learning (Turner, 2006, p. 80)

The first edition was written mainly by Brand himself; its selection was relatively limited and was 61 pages long. By 1971, this had expanded to 448 pages; most of the items were selected by catalogue users. Brand had opened his catalogue up to user feedback, and provided that it met his basic criteria, an item was included. These criteria were:

1. Useful as a tool,
2. Relevant to independent education,
3. High quality or low cost,
4. Not already common knowledge,
5. Easily available by mail. (Turner, 2006, p. 91)

Brand was well placed to access a potent user base. As Fred Turner noted in his 2006 book, "From Counterculture to Cyberculture": "Brand became a key link between very different countercultural, academic and technological communities. When he founded the Whole Earth Catalog in 1968, he gathered those communities into a single textual space. That space in turn became a network forum - a place where members

of these communities came together, exchanged ideas and legitimacy, and in the process synthesised new intellectual frameworks and new social networks." (Turner, 2006, p. 72)

Brand also set up an innovative mechanism to gather user ideas: "he called for readers to suggest and review items for the Catalog, offering them ten dollars for an accepted evaluation" (Turner, 2006, pp. 89-90). And: "Those who first suggested or reviewed an item would have their name listed in the Catalog." (Turner, 2006, p. 90). But why? "In this way, Brand accomplished several entrepreneurial purposes: he enlarged the range of the Catalog's contents by appealing to "experts" outside his organisation: he increased his readers' sense of commitment and involvement. He also increased the Catalog's own value to the community it served. In the process, he invited the reader to become a producer of economic value, a contributor to a textual community and still a buyer of the Catalog." (Turner, 2006, p. 90)

Later, Brand was one of the first to spot the collaborative potential of the internet; he founded the WELL (Whole Earth 'Lectronic Link), an early online community; other spinoffs of his movement included the Homebrew Computer Club, which subsequently led to the founding of Apple Computer.

Example Two: Xiaomi

The coalescing of user expertise has not remained solely within a western context. It is a key part of the Chinese mobile phone manufacturer Xiaomi's development model.

Xiaomi is one of many emerging manufacturers to come out of the People's Republic of China, along with Huawei (a manufacturer of phones and networking equipment) and Haier (domestic appliances). Xiaomi differs from its peers in its use of user engagement as part of its innovation model. According to a 2015 report published by Deloitte, "Product managers spend approximately half their time in user forums, and the company can incorporate user suggestions in a matter of weeks." (Hagel, *et al.*, 2015, p. 32) Xiaomi is particularly reliant on user innovations for its MIUI user interface software: Lei Jun, Xiaomi's founder, estimated that one third of improvements extended from user feedback (Shirky, 2015, p. 34). Releases are scheduled weekly on what Xiaomi calls "Orange Fridays"; each release is followed by a user questionnaire. This focus on user feedback has been successful: approximately five out of every eight mobile phones activated in China are made by Xiaomi (Shirky, 2015, p. 15). Engaging with users also aids sales; the "company spends almost nothing on traditional advertising, preferring to stage launch events that the press will cover, and helping their users proselytise on behalf of the company." (Shirky, 2015, p. 32)

Example Three: element14.com

The Whole Earth Catalog was a mosaic of individual written contributions. Xiaomi fosters a community and gathers user feedback to progress its products. But what of user-driven product development which includes both hardware and software? Thanks to the aforementioned price reductions in microcontrollers, this form of inventive activity is now more accessible in the online community context.

The electronics engineering forum element14.com was initially set up to provide additional marketing and product information for the electronics distributor Premier Farnell. The online forum developed aspects of a "community of practice" or "collaborative circle" (Farrell, 2001, p. 2) whereby engineers discussed projects and turned to each other for assistance when they encountered difficulties. Premier Farnell purposefully layered programmes on top of this culture in order to stretch the innovative capacity of the participants.

Element14's Design Challenge programme is a leading example. Premier Farnell set challenges in collaboration with leading suppliers such as Texas Instruments and partners like the Eclipse Foundation (a creator of open source software), in order to solve a problem. Tasks that were set for engineers included the efficient deployment of Energy Harvesting technologies and alternative uses for Wireless Power (Charging) besides recharging mobile phones. In the case of Energy Harvesting, an engineer named Wojciech Gelmuda created a carbon monoxide alarm that does not require batteries (Gelmuda, 2013). Similarly, Wireless Power was used in a rechargeable waterproof transponder for embedding in life jackets (Rüland, 2014).

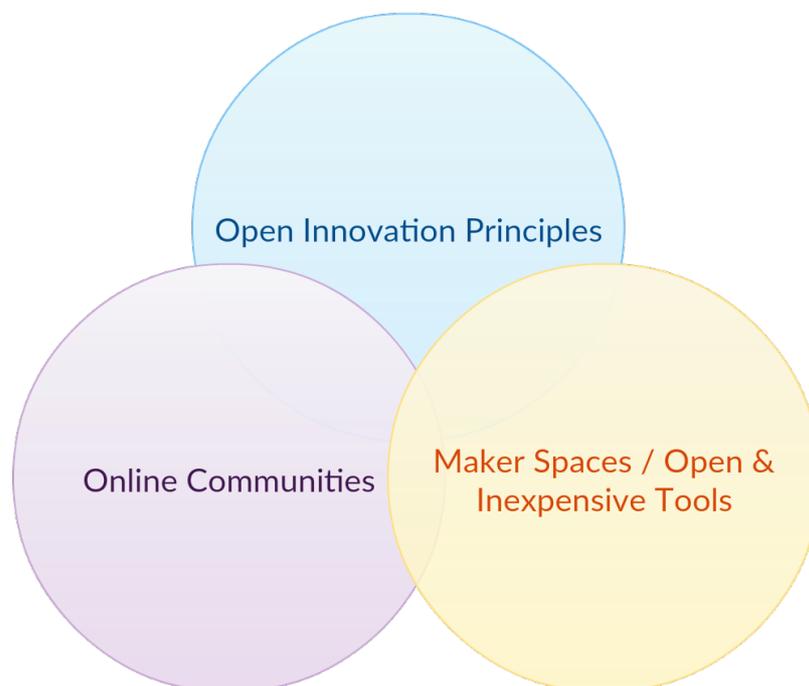
In 2014, in collaboration with Cisco, Texas Instruments, the Eclipse Foundation and Sierra Wireless, element14 set the following challenge: engineers were asked to develop an internet-connected pollution sensor which would provide meaningful data for citizens, businesses and governments. The title of the challenge was "In the Air". As in previous design challenges, a kit was provided to those who put in the most detailed applications. A grand prize was set as a reward. Applications came from engineers as geographically dispersed as Latvia, New Zealand and Singapore. The proposals represented a variance in the type of pollution which was most important to the inventor: a Singaporean engineer named Gan Eng Swee proposed a dust sensor, as he and his neighbours find this form of pollution particularly troublesome (Swee, 2014). A Latvian inventor named Janis Alnis detailed a carbon dioxide monitor for schoolrooms to help enhance the student environment (Alnis, 2014). A Filipino engineer named Ryan Labutap decided to assess a different form of pollution: potentially poisonous algal blooms in water supplies (Labutap, 2014).

The winner was an engineer from New Zealand named Christever del Rosario. He created a "Total Carbon Footprint Monitor": his invention used networked sensors that fed back information to an application on his mobile phone (del Rosario, 2015). This allowed the user to assess how much carbon had been released in the course of a day. At the time of writing, this invention is being perfected for mass market production.

All these prototypes were created in the inventors' spare time, thus utilising what Clay Shirky has referred to as the "cognitive surplus" (Shirky, 2011, p. 9). The tools involved were low cost: so inexpensive that the participants were given to them for free by the manufacturers (additional budgets were provided by Premier Farnell in some cases). Yet, the innovative ideas which arose within the four months of the challenge were potentially groundbreaking. The individuals had access to the knowledge base and advice on element14, instructional videos in the form of manufacturer webinars, and aid from individual community members: this created an environment for accelerated innovation.

A Felicitous, if Flawed, Convergence

There are a number of key factors that underpin the innovation model in the three aforementioned examples. The positioning of these elements can be best visualised utilising a Venn Diagram:



Not all the examples sit at the convergence point of all three circles, and definitions require a degree of flexibility. Stewart Brand's "Whole Earth Catalog" can be said to be adhering to Open Innovation principles, though the concept did not fully enter the consciousness of the wider public until the publication of Henry Chesbrough's 2006 book, "Open Innovation: The New Imperative for Creating and Profiting from Technology". Furthermore, Chesbrough spoke of accessing knowledge from start up firms and universities rather than end users via the context of an online community. Nor can Brand's "community" be accurately described as "online": its connections were maintained via the traditional methods of post, telephone and face-to-face contacts. Nevertheless, it could also be described as "online" in a broader sense, as Brand had created a "virtual network" with himself and his operation acting as a hub.

Xiaomi uses (albeit not overtly stated) Open Innovation principles and the input of its "fans" from its online communities, but nevertheless doesn't utilise the third element, the arrival of inexpensive tools that change the potential manufacturing context. While Xiaomi invites active user engagement in the development of its MIUI software, Xiaomi still retains a closed model for developing its handsets. Nevertheless, this element is becoming more accessible; in 2015, a kit that allowed inventors and hobbyists to build their own cellphone was launched (Allan, 2015).

Element14's example is positioned at the centre of this felicitous, if flawed, convergence: inexpensive tools combined with an online community and a development model that emphasized knowledge sharing; however, this example also contains quirks. At present, neither element14 nor its partners have a formal, established process to appropriate inventions and turn them into mass-produced products. Design Challenges are highly dependent upon capturing the interest of the community's user base. Timescales for rapid innovation also need to be appropriately calibrated: what was apropos for the development of an internet connected pollution sensor is not necessarily correct for creating a wearable sensor to measure impact events in sports (DeFeo, 2014).

Clarifications

In order to add depth to a potential innovation model as described by the "felicitous convergence", it is necessary to clarify the definitions and potential scope of each of the elements.

Online Communities

An "online community" is not necessarily an "online forum". An online forum is a software tool, a context in which an online community can be formed. An online community is a community in a broader, sociological sense, namely, "a social, religious, occupational, or other group sharing common characteristics or interests and perceived or perceiving itself as distinct in some respect from the larger society within which it exists" (community, 2016). This definition has become somewhat obscured by the tendency of firms to label their online forums as "communities".

Element14.com, Xiaomi and the Whole Earth Catalog all qualify as "communities", given that the participants share common interests and are "distinct": element14.com caters to electronics engineers, Xiaomi has set up its online forum for its community of product enthusiasts, the Whole Earth Catalog provided an aggregate for those who sought alternative, sustainable lifestyles.

Additionally, within the "online community", there should be perceived potential for what Eric von Hippel has described as "user-led innovation" (von Hippel, 2006, p. 53). This form of innovation, whereby the users of a product lead efforts to improve it, is nothing new: it was common in the English iron industry in the 19th century (von Hippel, 2006, p. 78). Chris Anderson, in his 2012 book, "Makers: the New Industrial Revolution", further described this potential:

"When you share, community forms, and what community does best is remixing, exploring variation in what a product can be and in the process improving it and propagating it far faster than any individual or single company could." (Anderson, 2012, p. 74)

Furthermore, it is beneficial if the community offers the potential for "collaborative circles" to form (Farrell, 2006). As described by sociology professor Michael P. Farrell, these circles form contexts for bursts of creativity. Farrell has described the example of the French Impressionist circle, among others. He stated that such circles could potentially form in an online milieu:

"As internet communication becomes more common, it may be that circles will form among widely scattered, like-minded people who discover one another through electronic communication. In addition, Internet communication may make it easier for marginalised people in a discipline to discover one another." (Farrell, 2006, p. 293)

However, he also expressed doubts about online circles' efficacy:

"Future collaborators may discover that Internet communication provides the right mix of intimacy and distance to nurture collaborative pairing, egalitarian openness, and instrumental intimacy... I do not think it allows for...in-depth dialogue that leads to meaningful personal development and creative work." (Farrell, 2006, p. 293)

It may be that Farrell was unduly pessimistic; in Anderson's view, distance "matters less and less in manufacturing these days - ideas trump geography" (Anderson, 2012, p. 47). What could be described as a "collaborative circle" formed on element14.com; there is evidence that it played a role in stimulating creativity. In 2014, element14, in collaboration with the Raspberry Pi Foundation, EnOcean, Tektronix, the Eclipse Foundation and OpenHAB, created a design challenge entitled "Forget Me Not" to build internet of things applications (DeFeo, 2014). Community participants expressed a common fondness for the "Minions" from the Pixar film "Despicable Me"; they referred to themselves as "Minions" and used images of the characters as avatars. The "Minions" as a collaborative circle found expression within the "Forget Me Not" challenge as a series of "challenges within the challenge", namely the most creatively productive competitor over a weekly period would receive a "Minion" related prize. (DeFeo, 2014).

Finally, online communities should be meritocratic from within rather than necessarily reference outside credentials. As Chris Anderson stated in his 2012 book, "Makers: the New Industrial Revolution", had he not operated his 3D Robotics company and community in this way, he would have "missed the cake maker, the graphics artist working for the Brazilian ad agency, the guy who runs the Italian ambulance radio company, the retired car-dealership owner, the Spaniard working for an energy company in the Canary Islands" (Anderson, 2012, p. 149).

Open Innovation

The concept of Open Innovation is based on a premise which was expressed by Bill Joy of Sun Microsystems: "No matter who you are, most of the smartest people work for someone else" (Anderson, 2012, p. 144). As articulated by Chesbrough, given that knowledge generation activities within a traditional R&D setting are unlikely to be broad enough in order to sustain a modern firm, organisations need to be sufficiently flexible to identify, appropriate and encourage generation of knowledge outside of their traditional boundaries. Eric von Hippel's concept (labelled "Democratising Innovation") extends to utilising end users in the generation of new products; he also suggests the development of "toolkits" to enable user-led product development to take place (von Hippel, 2006, p. 147).

Open Innovation is not necessarily "Open Source", i.e., the free sharing of patentable information, designs or code. However, the aforementioned "felicitous convergence" is dependent on open innovation combining with open source. For example, Anderson describes how his grandfather created an automated sprinkler system in the 1940's: this was a highly individual endeavour, incurring expense and without the benefit of knowledge sharing via an online context. The innovation process was more time consuming and expensive than it would be using present day tools (Anderson, 2012). Sharing is essential; it is also nothing new. The design of the Jacquard loom in the 19th century was not patented, but rather shared by manufacturers within the city of Lyons; this was essential for the city's emergence as a centre of silk weaving (Foray, 2006, pp. 174-178). Knowledge creates what von Hippel describes as "spillovers", rather than is hermetically contained (von

Hippel, 2006). What of patents and their value? Anderson states that value is created within retaining users in an ecosystem (Anderson, 2012, p. 113).

Maker Spaces / Open & Inexpensive Tools

In addition to the Raspberry Pi, the availability of open source software is critical for the convergence to be effective. According to the co-owner of Adafruit, Phillip Torrone, in 2011 there were approximately "over 300 open source products available representing \$50 million in revenues" (Anderson, 2012, p. 107). Just as important are the tools now available for small-scale manufacture; Anderson lists the "3D printer, CNC machine (mill), Laser Cutter, 3D scanner" (Anderson, 2012, pp. 82-84). Even if an individual user could not afford to purchase these tools, access to these "desktop factories" has improved thanks to the emergence of Maker Spaces in which these tools, and instruction, are often available.

Tools are not solely geared for the small-scale production of electronics products prototypes; von Hippel identified the use of toolkits by Nestle to encourage the development of new cooking sauces (von Hippel, 2006, pp. 160-161). Maker facilities now provide the means to create new biological innovations (Biohackers of the World, Unite. 2014). Levi's, the clothing manufacturer, is also utilising the creativity of Makers via its "Levi's Makers" programme (Voight, 2014).

Discussion

The previous paradigm of product innovation may have plateaued or stalled: in order to maintain shareholder value, firms are obliged to be focused on the short term rather than make long term investments. This shift in priorities has led to a decline in Research and Development spending in the United Kingdom. A lack of substantive innovation has also led to the perception, as stated by economic historians like Robert Gordon, that the era of high GDP growth in the United States (an example of an advanced economy) is over.

However, knowledge is also much more diffuse than it was previously: research and development has moved from solely within the context of being within a large laboratory or a university and into the home of an individual with (for example) a computer, a Raspberry Pi, and a 3D printer. The individual may not be inventing as part of any paid work, rather, tapping into the "dark energy" of spare time which otherwise remains un-utilised. This research and development is globally networked via online communities and knowledge bases, and dependent upon a culture and a context for sharing.

Innovative firms will find a means by which to create a "felicitous convergence", whereby it can adopt open innovation principles, create or ally itself with online communities, and utilise the availability of inexpensive tools to inspire and develop new ideas.

Design Challenges are a potent means by which this convergence may be stimulated. Challenges to stimulate innovation are as old as Napoleon III's competition to create a butter substitute: this yielded margarine (Adamczyk, *et al.*, 2012). Personal incentives, such as having one's suggestions incorporated (as in the case of Xiaomi), or receiving a credit (in the case of the Whole Earth Catalog) or potentially a grand prize (as with element14.com) have a part.

"Toolkits", as described by von Hippel, also may serve as a point of focus. In the case of element14, all design challenges began with a basic toolkit, such as a Texas Instruments Launchpad with software and sensors.

The "felicitous convergence" presents a set of research challenges: it is by no means a static model. Rather, it continues to evolve alongside the technologies that make the convergence possible. Furthermore, its application is uneven across industry and technology areas. Further research will be required to look into these variances.

Further study will be necessary in order to add rigour to the model; additional research will explore a network map of key stakeholders and discover what types of links exist between them; this entails a systems analysis view of these networks and will enable precise questions as well as a quantitative view. There will also be exploration of a potential "checklist" of necessary features, inputs and outputs of an innovation generating community.

Additionally, the examples provided by General Electric's work with its "FirstBuild" community and the invention forum "Quirky" and Local Motors' community provide additional avenues for study. Furthermore, the following aspects of the new paradigm merit additional investigation:

1. **The creation and management of online communities by firms:** what is the model or set of models by which a firm can create an online community through which innovation can be inspired?
2. **The sociological aspects of online communities:** what social factors enable a community in which practical innovation work can take place? What are the individual motivations of community members? What levels of trust and interaction are required? How does such a community move from "forming" to "performing"?
3. **The challenges of appropriation:** as identified by Burcharth, Knudsen, and Søndergaard in a 2014 paper, firms can find it difficult to appropriate the products of open innovation if a "Not invented here" culture prevails. Additionally, the possibility of a consistent process whereby community generated prototypes can be turned into manufactured products should also be researched.

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