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R&D Failure and Second Generation R&D: New Potentialities

Chris William Callaghan

School of Economic and Business Sciences
University of the Witwatersrand
E-mail: chris.callaghan@wits.ac.za

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Abstract

Ample incentives exist for firms to pursue product, service, or process innovations to increase their profitability. In contrast, few incentives exist for firms to pursue innovations that provide social externalities if these are not inherently profitable. This article provides an argument that first generation research and development (R&D), or R&D that does not utilise economies of scale (as second generation R&D does), cannot effectively provide societal innovation that is not incentivised by market forces. An example of an alternative model for global societal problem solving, based on second generation R&D, is offered.

Keywords: *Social Innovation; Crowdsourcing; Open Innovation; Process Innovation; Radical Innovation*

1. Introduction

On a global scale, some argue the world faces a crisis; threats in the form of the H7N9 'bird flu' virus (Siu and Pomfret, 2013), the Middle East respiratory system coronavirus (MERS-CoV)(Zap, 2013), a strain of airborne tuberculosis that is now resistant to all known drugs (Maher, 2013), and multiple strains of antibiotic resistant bacteria ('superbugs') which may make minor injuries or even routine surgery life-threatening (Halifax, 2013). Research and development (R&D) is needed to counter these threats (Halifax, 2013).

These concerns are particularly salient in a world connected by airline travel (Maher, 2013). Previous outbreaks of microorganisms have occurred, such as the bubonic plague of 1347, the 1918 influenza epidemic, which claimed between 20 and 40 million lives, and Severe Acute Respiratory Syndrome (SARS), responsible for about 700 deaths in 2003 (Billings, 1997).

This article argues that in the face of such threats, a new form of research and development (R&D) is necessary; a new paradigm, termed 'second generation R&D' (SGR) which is substantively different from 'first generation R&D' (FGR).

The fundamental differentiation between FGR and SGR is based on the economies of scale that can be achieved with SGR problem solving. Forms of SGR such as crowdsourcing have already demonstrated success at solving complex problems. Crowdsourcing, as a form of distributed problem solving, can theoretically generate exponentially larger volumes of inputs than 'conventional' R&D, or FGR can. This article makes the argument that many societal problems can be solved *at this time* through the application of process innovations in R&D that have already demonstrated success across contexts. An example of a global model of societal problem solving is offered, that is based on the use of SGR distributed problem solving, or crowdsourcing.

Distributed problem solving, in the form of crowdsourcing, has the potential to solve problems which were hitherto considered unsolvable (Brabham, 2008). Further, crowdsourcing, as a form of distributed problem solving, exists as an "emerging, successful, alternative business model", with "non-profit applications for health and social and environmental justice" (Brabham, 2008:76). Crowdsourcing is uniquely suited to the requirements of social innovation (Fuller, Hutter and Fries, 2012). This paper makes the argument that a new paradigm of problem solving has been facilitated by the emergence of distributed systems of problem solving.

Crowdsourcing has ushered in a new era of innovative potentialities, across a wide range of fields. "Simply defined, crowdsourcing represents the act of a company or institution taking a function once performed by employees and outsourcing it to an undefined (and generally large) network of people in the form of an open call", which can take the form of "peer-production (when the job is performed collaboratively), but is also often undertaken by sole individuals" (Howe, 2006:5).

Crowdsourcing is increasingly being used to harness customer participation in product development (Djelassi & Decoopman, 2013), to conduct academic student research (Bates & Lanza, 2013), and for generating ideas both from

outside and inside organisations (Simula & Vuori, 2012). Crowdsourcing is collapsing the cost constraints associated with geographical distances between people and has emerged as a function of increasing interconnectedness in global contexts (Schall, 2013).

However, despite this growing body of literature that relates to the successes of crowdsourcing to solve problems, evidence of the application of crowdsourcing, or distributed problem-solving knowledge systems to the solving of serious societal problems is scarce. A lack of knowledge of the potential of crowdsourcing to solve large-scale societal problems can be considered a cost, the incidence of which might be borne by almost all societal stakeholders.

This article presents the argument that crowdsourcing can contribute to solving serious societal problems, because it offers new potentialities that are not yet well understood. It is also argued that the probabilistic mechanisms associated with crowdsourcing increase the chances of breakthroughs in problem solving because of the scale at which they can operate. It is argued that research and development (R&D) systems that are not based on economies of scale will not be as effective as those that are. Those that are not are considered first generation problem solving systems. Those that are, such as crowdsourcing, are termed 'second generation R&D' (SGR) problem solving systems.

One dimension of the failure of FGR systems might be associated with their inherent 'fit' with medical R&D business models. R&D that 'cures' can kill the 'golden goose'; that 'lays the golden eggs'. R&D that does not cure, but provides a solution as long as the treatment is taken continuously offers an opportunity for continuous sales.

The 'chronification' of medical R&D, therefore, is incentivised; where treatments taken continuously can provide higher pay-offs than cures. A potential eventual global market of over ten million that require HIV medication each day for the rest of their lives is an example. Or a potential market in the hundreds of millions for diabetic treatments. Ailments associated with aging also offer similar potential. FGR is therefore a successful paradigm of R&D because it matches the economic incentives of private firms in the provision of medical problem solving.

It is argued, however, that the incidence of the costs associated with a reliance on FGR and a failure to also pursue SGR fall upon all of society. The lack of a curative paradigm, however, is a function of the inherent nature of FGR, which will be discussed in sections that follow.

SGR offers a new and important potentiality for human kind; the advent of a curative paradigm in medicine. A curative paradigm associated with the advent of SGR might offer private firms even more opportunities, as gains in the effectiveness and efficiency of R&D lower input costs of firms.

At its most simplistic, this article argues that crowdsourcing represents a 'second generation' process of R&D, akin to a knowledge management system that accumulates knowledge in a way that can accelerate rates of innovation, and facilitate radical process innovation. A model of how distributed problem solving can be used to 'crash' the project timelines of research systems is derived. Implications brought to light by this model are discussed, and recommendations are made for more effective societal problem solving.

This paper is structured as follows. Firstly, the argument is made that first generation problem solving systems represent a paradigm in which R&D failure has often occurred; that these are problem-solving systems that are inherently constrained by their need to operate within a market, or profitability, framework. Secondly, in order to explain an alternative model of R&D based on SGR that can accelerate the innovation process, it is necessary to provide an argument that this is feasible. To do this, a range of different cases are presented; cases in which crowdsourcing, a form of SGR, have already been shown to generate successes. By providing evidence in the form of 'proof of concept', the core arguments made in this paper are supported. Thirdly, the article concludes with an example of a model of global societal problem-solving.

2. Theory and Literature

Theory and literature is discussed in the three sections that follow. This body of literature is related to the arguments put forward in this paper.

2.1 FGR and R&D Failure

Drawing from the process perspective of management (Langley, Smallman, Tsoukas & Van de Ven, 2013), the failure of first generation R&D (FGR) systems can perhaps be better understood as a failure of process innnovation.

If the world is viewed as comprised of processes rather than 'things', then perspectives of problem solving become perspectives of the unfolding of processes; as "focal experiences grow out of earlier experiences, interactions, and anticipations" (Langley et al., 2013:5). From "a process ontological perspective, an organisation is a dynamic bundle of

qualities", and the point where "'process' meets 'practice'" is never independent of social processes (Langley, 2013:5).

Research capable of "developing fine-grained understanding of processes at the micro level requires ...prolonged and deep engagement" (Langley et al., 2013:5). At the heart of the failure of FGR is its lack of a probabilistic mechanism, or a process that can generate exponential volumes of inputs. This is a process innovation capability. SGR can itself be theoretically conceptualised as a process innovation. Paradigms in the way systems are used can be themselves also be conceptualised as process innovation.

Process studies focus on how and why "things emerge, develop, grow, or terminate over time" (Langley et al., 2013). Central to such a process-oriented view of management is a focus on time and "the role of tensions and contradictions in driving patterns of change, and show how interactions across levels contribute to change" (Langley et al., 2013). The dominant problem, seemingly evidence in the R&D literature, seems to be the inability of the processes, or R&D systems of FGR, which is tethered to the profitability needs of firms, to solve societal innovation problems.

This tension is reflected in persistent under-investment in societally important R&D. Whereas a well-defined and developed product definition is critically important for the success of product innovations, a corresponding process definition for process development is also important (Frishammar, Lichtenthaler & Richtner, 2013). SGR is a process innovation specifically defined in terms of its capability to harness exponential volumes of knowledge inputs; in other words, it has a probabilistic mechanism that differentiates it from FGR.

However, in order to argue the merits of this 'alternative' paradigm associated with SGR, it is first necessary to discuss the limits inherent in FGR, particularly those that relate to its dominant constraint, its need to work within market frameworks.

2.2 The upper limits of FGR: overlap between radical innovation and SGR

There has historically been general agreement across the innovation literature that market-driven investments in R&D will typically not be sufficient to meet societal needs. The "level of investment in research and development is likely to be too low, from a social point of view, whether market structure is nearly atomistic, a highly concentrated oligopoly, or something in between" (Martin & Scott, 2000:438).

Hence, limited "appropriability, financial market failure, external benefits to the production of knowledge, and other factors suggest that strict reliance on a market system will result in underinvestment in innovation, relative to the social desirable level" (Martin & Scott, 2000:438). Given that constraints to first generation innovation exist, the issue then arises of whether first generation innovation in its most innovative form can solve societal problems. FGR, in its most effective form, can perhaps be taken to be radical, or breakthrough, innovation.

Whereas an organisation's competitive advantage is a function of its absorptive capacity (Zahra & George, 2002), its ability to innovate, particularly from both internal and open innovation, is also crucial (Enkel, Gassman & Chesbrough, 2009). However, innovation efforts also face innovation market failure (Martin & Scott, 2000), and radical innovations of firms need to conform to direct market needs.

Radical innovation can be applied to both FGR and SGR processes. An exploration of radical innovation can offer insights into the 'upper limits' faced by FGR. The implementation of radical innovation in firms has been well researched. Examples of this body of research include investigations into the integration of radical innovation units and business operations (Gassman, Widenmayer & Zeschky, 2012), how knowledge-based ecosystems can be used generate firm innovative capacity and fitness (van der Borgh, Cloodt and Romme, 2012), and how technology-based incubators can benefit from different forms of networks (Sa and Lee, 2012).

However, the shift from FGR to SGR is taken to be a function of the process innovations associated with radical innovation which can act as a necessary but not sufficient condition for the emergence of fully-fledged SGR capabilities such as crowdsourcing.

Radical innovation is important because "the contemporary competitive landscape has been and continues to be driven by technological revolution, globalisation, hypercompetition, and extreme emphasis on price, quality, and customer satisfaction, requiring an increased recognition and focus on innovation as strategic competence" (Leifer, O'Connor & Rice, 2001:102). However, what might be of increasing importance in R&D contexts is the role of radical innovation theory in its contribution to the 'paradigm shift' to include SGR as a dominant form of R&D.

The acceleration of innovation can be facilitated by radical, or breakthrough innovation (Leifer et al., 2001). A radical innovation "is a product, process, or service with either unprecedented performance features or familiar features that offer significant improvements in performance or cost that transform existing markets or create new ones" (Leifer et al., 2001:102).

Radical, or breakthrough, innovations "transform the relationship between customers and suppliers, restructure marketplace economics, displace current products, and create entirely new product categories", thereby providing "the engine for long term growth" (Leifer et al., 2001:102).

A radical innovation can also be defined according to its ability to meet one or more of the following criteria: "an entirely new set of performance features, at least a five-fold improvement in known performance features, and a significant (30-percent or greater) reduction in cost" (Leifer et al., 2001:102).

Strictly speaking, this definition locates radical innovation as any innovation process that provides improvements in performance. SGR therefore also falls within the scope of this definition. However, reliance on radical innovation to solve societal problems that are not profit-oriented without the probabilistic R&D mechanisms that associated with distributed knowledge systems may be problematic.

Constraints to problem-solving effectiveness therefore also exist for radical innovation. Certain of these can be overcome through the use of SGR. Others cannot. However, certain of these are now considered.

Radical innovation life cycles are typically "long term (often a decade or longer), unpredictable, sporadic (with stops and starts, deaths and revivals), non-linear, and stochastic (with unpredictable exogenous events)" (Leifer et al., 2001:103). Radical innovation projects are particularly susceptible to contextual influences and organisational culture (Leifer et al., 2001).

Organisational uncertainties around radical innovation projects can also include the need to consider different project sites and changing casts of "scientists, technicians, and project champions" and differing budget allocations over time (Leifer et al., 2001:104). These, and similar challenges, are expected to also be faced by SGR programmes.

The difference, however, is that the scale of knowledge creation under SGR programmes is significantly greater. This might necessitate different organisational forms, and new organisational cultures. However, lessons learned from FGR best-practice can be extended into SGR organisations or programmes.

The organisational structures associated with radical innovation might also be relatively well suited to SGR programmes. Certain best-practices associated with radical innovation are now outlined, in order to better understand the organisational contexts and processes potentially suited to SGR.

Certain organisational structures have shown themselves to be better suited to radical innovation. For Leifer et al. (2001), in order to facilitate radical innovation, an organisation should build a radical innovation hub, or a unit that oversees radical innovation projects without increasing bureaucracy; that can act as a repository for cumulative learning (Leifer et al., 2001). This unit should be used to support "idea hunters and gatherers, internal venture capitalists, members of evaluation and oversight boards, and corporate entrepreneurs experienced in the realm of high uncertainty" (Leifer et al., 2001:104/105).

Radical innovations should be incubated within the broader organisation, however, rather than within separate skunk-works projects, because of mutual learning potential and access to the greater pool of resources in the organisation; more opportunities might be recognised this way (Leifer et al., 2001). Frequent communication is also required, as internal influential advisors need to be developed in order to support the legitimacy of radical innovations (Leifer et al., 2001). A hub can act "as a conduit for money, human resources, advice, facilities, and legitimacy" (Leifer et al., 2001:108).

Radical innovations generally have a harder time getting "money, facilities, and people" because "an inordinate amount of time and energy chasing resources" is a typical aspect of the development of radical innovations; project champions are critically important (Leifer et al., 2001:108). Project transitions out of R&D require careful planning; projects need to be ready for transition, with clearly identified market opportunities, in order to reduce time to market and the realisation of revenues within shorter time-frames (Leifer et al., 2001).

Radical innovation is "such a long-term, chaotic, meandering, unpredictable process that promising radical innovation concepts are often never undertaken, to society's detriment" (Bers, Dismukes, Miller & Dubrovensky, 2009). Models of societal innovation based on SGR might offer stability to the radical innovation process, particularly in terms of societal innovations.

The high costs of developing innovations (Bers et al., 2009) make substantial advances in innovation problematic in general. It is possible that FGR is most effective for firms because they offer customers limited solutions rather than solving their problems outright (which can result in lost opportunities to provide continuous support). Given the difficulties faced by FGR, it is perhaps understandable that innovation, particularly in medical fields, has not provided curative solutions, but has been successful in providing 'chronicalised' solutions (e.g. HIV, diabetes, cancer, heart disease, arthritis and other fields of medicine). Chronicalised solutions allow for continuous revenue streams, whereas curative solutions have a one time payoff because they solve the problem itself. SGR can provide R&D improvements to either

approach. However, because of the high volume of knowledge inputs that it can harness, and the increased power of the R&D process it offers, widespread use of SGR might result in the dominance of curative approaches.

A further requirement of a radical innovation environment is person-job or person-organisational fit (Erdogan & Bauer, 2005). Individuals that "thrive in the radical-innovation environment of risk, uncertainty, and potentially high payout" need to be recruited and developed in this type of unit (Leifer et al., 2001:105).

Organisations should also encourage the presence of opportunity gatherers and hunters; gatherers "are alert and ready to react to radical ideas, while hunters taken responsibility for actively seeking out ideas with business potential" (Leifer et al., 2001:106). Such a hub then creates a space within the organisation in which different competencies can be developed. Uncertainties can be catalogued, which allows for choices to be made as to how, and when, different uncertainties will be managed (Leifer et al., 2001).

Transition teams might be needed, who have the skills and competencies required; notwithstanding the fact than extra handoffs may be required (Leifer et al., 2001). Deliberate attempts need to be made to recruit, develop and retain individuals that have the right characteristics for the development of radical innovations, "people with risk-taking propensity, drive, and out-of-the box thinking" (Leifer et al., 2001:110). At the heart of the success of radical innovations is the way culture is shaped by the executives of an organisation (Leifer et al., 2001). The radical innovation environment is perhaps best suited to organisations that can benefit from the new SGR paradigm.

Different ways of accounting for the progress of radical innovations also need to be considered. For instance, radical innovations can be assessed by the amount of learning needed, relative to the amount invested in the innovation (Leifer et al., 2001). A knowledge management system also needs to be assembled that can predict time frames for innovations or new market development to be aligned with budget planning (Leifer et al., 2001). The business case for new innovations can be assessed by this type of hub, or unit, and the implementation of radical innovations upon acceptance can also be undertaken by this unit (Leifer et al., 2001).

A state of radical-innovation maturity develops when, as a result of a systematic process, a set of competencies allows an organisation to be more effective at managing radical innovations (Leifer et al., 2001). Radical-innovation maturity may be a necessary state for SGR to be used by organisations. However, the same constraints faced by radical innovation might also be faced by attempts to implement SGR processes.

Whereas historical definitions of radical innovation stressed the technical uncertainties and market uncertainties associated with an innovation, Leifer et al. (2001) stresses the importance of addressing other constraints to the radical innovation process, such as organisational or resource uncertainties. Resource uncertainties relate to the conflict between radical innovation teams and the mainstream nature of their organisations (Leifer et al., 2001). These challenges might be intensified when an organisation incorporates SGR into its processes. Organisations may, however, resist the implementation of SGR the same way many have resisted radical innovation.

Firms have been found to resist innovation because of the "chaos and uncertainty that come with commercialising new technologies for markets that may not yet exist" or may "require vastly different competencies" (Leifer et al., 2001:102). The SGR paradigm offers organisations strategies and options that can be used either for the attainment of competitive advantage or for societal innovation. Radical innovation used in pursuit of competitive advantage, however, faces problem solving constraints associated with the market system it is inherently a part of. It is argued that R&D failure is an inherent feature of FGR, notwithstanding that radical innovation theory can be applied both to FGR and SGR paradigms.

2.3 R&D Failure to transcend profit incentives and FGR

Despite the potential of radical innovation to restructure market relationships, it cannot transcend the constraints of the market system itself. Radical innovation is still subject to market forces, which are fundamentally not necessarily anchored to real societal needs. This conceptualisation is not new. State support for innovation is therefore necessary when private payoffs are not present (Martin & Scott, 2000). If FGR, in the form of radical, or breakthrough innovation, cannot meet societal needs because of its dependence on the market mechanism, then what can state intervention (within the FGR paradigm) contribute to solving societal innovation needs?

Notwithstanding the typical state of underinvestment in socially beneficial innovation by both public and private sectors, certain policy instruments can stimulate private R&D investment (Martin & Scott, 2000). These include competition and tax policy, subsidies and the contribution of public research units (Martin & Scott, 2000). Consideration of synergies between market forces and government interventions can offer insights into how societally beneficial innovation can be stimulated. However, these measures are still located in the FGR paradigm.

Different prescriptions for increasing total societal R&D investments are offered by different industrial economic perspectives. According to the structure-conduct-performance paradigm, industry characteristics are used to predict performance that relates to R&D in general, such as tax breaks or extensions to patent protections (Martin & Scott, 2000).

For Martin and Scott (2000), however, in order to address market failure related to R&D, or R&D failure, specific types of R&D failure need to be identified, and specific policy remedies need to be applied. However, lacking in their typology is a consideration of the potential of probabilistic economies of scale to solve societal problems offered by SGR.

Markets differ "in terms of their mixture of basic and applied knowledge that contributes to their knowledge base, in the degree of appropriability of technology, in the extent to which commercially applicable knowledge is tacit, hence less likely to leak out, and in the importance of complementary assets to the commercialisation of knowledge" (Martin & Scott, 2000:440). Martin and Scott (2000) suggest that their typology of different forms of R&D failure and the policy measures to address these can offer a framework for what different types of R&D failure correspond to different policy prescriptions.

Their typology is shown in Table 1. However, in Table 1 a fifth category has been added to this table. This fifth category relates to the solving of R&D problems that might only be vulnerable to approaches based on SGR. This category is shown in the bottom row of the matrix in Figure 1. This 'fifth category' of R&D is associated with the forms of R&D failure associated with FGR. One dimension of this is the 'archipelago' forms of knowledge creation associated with FGR.

Table 3. Innovatoin modes, sources of innovation failure, and policy responses

Main mode of innovation	Sources of sectoral innovation failure	Typical sectors	Policy instrument
Development of inputs for using industries	Financial market transactions costs facing SMEs; risk associated with standards for new technology; limited appropriability of generic technologies.	Software, equipment, instruments	Support for venture capital markets; bridging institutions to facilitate standards adoption.
Application of inputs developed in supplying industries	Small firm size, large external benefits; limited appropriability	Agriculture, light industry	Low-tech bridging institutions (extension services) to facilitate technology transfer
Development of complex systems	High cost, risk, limited appropriability (particularly for infrastructure technology)	Aerospace, electrical and electronics technology, telecom/computer technologies, semiconductors.	R&D cooperation, subsidies; bridging institutions to facilitate development of infrastructure technology
Applications of high-science-content technology	Knowledge base originates outside commercial sector; creators may not recognise potential applications or effectively communicate new developments to potential users	Biotechnology, chemistry, materials science, pharmaceuticals	High-tech bridging institutions to facilitate diffusion of advances in big research
Applications of process innovation in the form of crowdsourcing or distributed knowledge systems: Second Generation R&D processes*	'Archipelago' forms of knowledge creation that do not attain 'critical mass'; incentives in market systems are not aligned to a large-scale and singular focus of resources targeting a problem; sheer lack of scale economies of knowledge*	Biotechnology, molecular medicine. Global health problems. Social innovation*	Large-scale resource allocation; an innovative approach to financing through state budgets*

Source: Adapted from Martin and Scott (2000:439). *Sections that have been added to the table that are not from the original source.

This archipelago reflects the iterative nature of FGR, lacking as it is in the connectivity that distributed problem solving systems are based on. The primary problem with FGR systems is their lack of scale economies of knowledge. The development of SGR should be complementary to FGR; not a replacement for it. In order to understand the potential contribution of SGR to societal problem solving, it is necessary to understand the limits of, or ultimate potential of, FGR to solve societal problems.

Academic research into R&D extends across industries and geographic regions globally and can offer insights into the ultimate potential of FGR. The tension, however, between firm R&D and university research output is reflected in the

different goals of these institutions. However, research suggests that academic researchers that engage in entrepreneurial spin-offs can be more, not less, productive in their academic productivity (Abramo, D'Angelo, Ferreti & Parmentola, 2012).

SGR is premised on the notion that stakeholder involvement in problem solving is maximised. Academic and entrepreneurial sources of input are therefore equally prized; R&D is taken to be associated with positive externalities, and by maximising inputs these externalities are strengthened.

Research indicates that spending on R&D contributes to technological advancement and technological progress (Anwar & Sun, 2013). Similarly, R&D spending also contributes to increased foreign direct investment (FDI), which can increase productivity-enhancing flows of knowledge, or spillovers, across the borders of countries (Anwar & Sun, 2013).

This literature is now explored further, in order to gain further insight into the problem of the transmission of market-generated R&D to the solving of societal problems. Challenges faced by FGR include constraints to innovation posed by national boundaries, or geographical constraints.

While national boundaries constrain global innovation, an increase in the presence of foreign firms within a country can improve the productivity of domestic firms through productivity spillovers that reduce the marginal cost of production of local firms and allow these firms to spend more on R&D (Anwar & Sun, 2013). One dimension of the global 'trade' in innovation that transcends national boundaries is the existence of patents as a class of asset.

Patents exist as a class of asset vital for the contribution of innovation to competitive advantage (Caviggioli & Ughetto, 2013). Patent portfolios generate income; corporate rivals can utilise consortia to purchase them (Caviggioli & Ughetto, 2013). Rival corporations can form dominant designs in certain industries (Suarez & Utterback, 1995). Patenting is increasing rapidly, but much market activity in patents is "veiled in secrecy", often entailing nondisclosure agreements (Caviggioli & Ughetto, 2013). This secrecy is a limitation of FGR, associated as it is with these closed models of innovation.

Furthermore, a great deal of patents are 'sleeping' or 'shelved' patents, that are not currently applied to innovative uses (Caviggioli & Ughetto, 2013). Despite the activities of patent intermediaries to develop trading platforms, and create markets, or exchanges, for trading patents (Caviggioli & Ughetto, 2013), the proprietary structure of innovation seems to be dominated by 'closed' models of innovation; which do not seem to easily result in a transparent internalisation of the externalities associated with breakthrough innovations. In contrast the open models of innovation offered by SGR can perhaps better share knowledge, resulting in fewer 'shelved' or 'sleeping' concepts.

The utilisation of patents by an organisation is also a function of the culture of the organisation, transaction costs related to patent transactions, the strategy of the organisation and the value of the patents themselves (Caviggioli & Ughetto, 2013). All these relationships, however, are tied to the dynamics of the market, which might put upper bounds on the maximum utilisation of this knowledge. The use of licencing has similar characteristics.

Licencing can be used as a tool to reduce the incentive for licensees to invest in R&D, and cross-licensing agreements can be used to defend market share and curtail market entry (Caviggioli & Ughetto, 2013). The strategic complexity inherent in these market relationships around innovation, as a feature of FGR, might militate against non-market related advances in socially-important innovation. Having provided a broad perspective of the R&D failures of FGR associated with market incentive constraints, the potentialities associated with SGR by virtue of its use of open innovation are now briefly considered.

2.4 Open innovation and Crowdsourcing within the SGR Paradigm

Open innovation falls within the SGR paradigm, and it is this property that differentiates SGR from FGR. As in the case of radical innovations, open innovation is not without its constraints to effectiveness and efficiency. A perspective of these constraints is now offered, in order to provide a more grounded conception of the potentialities of crowdsourcing as a form of open innovation.

Open innovation is innovation that sources inputs from any source, especially those outside of the boundaries of the firm; closed innovation models typically source inputs from within the boundaries of the firm (Xia, 2013). Open innovation is important for high-tech product development, yet small firms face a tension in that they need to manage the link between their internal capabilities and their external relationships (Xia, 2013). In the biopharmaceutical industry, which primarily comprises small firms, new product development is typically "long, resource intensive and risky" (Xie, 2013: 333).

Xia (2013) points to two overarching debates in the innovation literature that relate to open innnovation. For Xia (2013:334), the first of these relates to the need to combine both internal and external knowledge as part of an

organisation's innovation strategy, where:

> *open innovation may extend across a wide range of firms' activities requiring the firms: to search, capture and control new technological development through acquisition or joint venturing; to form relationships with different partners, and share risks and benefits in order to realize a technological opportunity; to engage with external partners to share ideas and objectives with them; or to make use of open source communities, often giving up some intellectual property (IP) in order to encourage further innovation.*

For Xia (2013;334), the second relates to issues around the "complementarities between firms' internal characteristics and external resources in open innovation", and the implications for the management of these firms based on their choice between conducting internal versus external R&D.

The tension between internal capabilities and the openness of firms has also been mooted as the reason why United States-based biopharmaceutical firms have outperformed European Union-based firms of late in innovation (Xia, 2013). The commercialisation of innovations, particularly, is a function of how orthogonal exploratory partnerships (which are primarily focused on basic R&D or activities 'upstream' on the firms value chain activities) and exploitative partnerships (which focus on 'downstream' activities such as manufacturing, marketing and sales) are managed within firms (Xia, 2013).

For Xia (2013), key to the management of these partnerships; both exploratory and exploitative, is the absorptive capacity of a firm. For Zahra and George (2002:185), absorptive capacity is "a dynamic capability pertaining to knowledge creation and utilisation that enhances a firm's ability to gain and sustain a competitive advantage". Absorptive capacity is embedded in organisational processes, and allows a firm to reconfigure its resource base to pursue competitive advantage (Cohen & Levinthal, 1990; Zahra & George, 2002). However, these innovative capacities are constrained by the need to achieve competitive advantage. Nontheless, the use of SGR might have the potential to exponentially increase the absorptive capacity of an organisation.

As indicated previously, the overview presented above is not intended to be comprehensive. It is intended to provide a basis for the arguments made here; that FGR represents a paradigm that needs to be superseded (yet not necessarily replaced) by SGR. Having provided an overview of the context of innovation (a context seemingly dominated by FGR in which it seems SGR implementation is not yet widespread), cases are now considered that provide broad evidence that supports the argument that SGR, in the form of crowdsourcing, has already demonstrated its effectiveness and efficiency as a new paradigm for R&D.

3. Proof of Concept: The Sucesses of Crowdsourcing as a Form of SGR

In the literature, a range of cases stemming from different fields and contexts seem to illustrate the emergent potential of distributed problem solving.

Under certain conditions, across different contexts, crowdsourcing has been found to improve the efficiency and effectiveness of problem solving (Afuah & Tucci, 2012). These conditions are typically related to the unique characteristics of the problem, the specific knowledge required, characteristics of the crowd and the solutions themselves (Afuah & Tucci, 2012).

According to Howe's (2006) definition, however, crowdsourcing exists only when a company commercialises what it has obtained from the crowd. In this paper, crowdsourcing is taken to refer to any part of the innovation process and commercialisation is not taken to be a requirement for the definition of crowdsourcing. Instead, crowdsourcing is taken to represent the use of distributed systems of communication that are targeted at the 'crowd', whether for information gathering or for any other part of the innovation process. Specific cases that illustrate the potential of crowdsourcing to solve problems are now discussed. As indicated above, the discussions are used as a platform for the argument made in this article; that social problems on a global scale might be able to be better addressed using this methodology.

3.1 The successes of InnoCentive and other organisations

Idea competitions, such as crowdsourcing are a form of open innovation which is premised on the idea that innovativeness can be increased through the incorporation of external ideas and knowledge (Stieger, Matzler, Chatterjee and Ladstaetter-Fussenegger, 2012). Despite current media reports which create the impression that crowdsourcing is an altogether new concept, the use of the general population to solve problems is not new (Brown, 2012).

The French government awarded the Alkali Prize in 1783 for the separation of salt from alkali, and in 1714, the

British government offered the Longitude Prize for a solution to navigation problems for ships (Brown, 2012).

However, it is the relatively recent development of the information technology that has led to a commensurate expansion in the use of crowdsourcing to solve problems, both in commercial and public sectors (Brown, 2012). The interactive capabilities and unique properties of digital media have opened up new potentialities in a postmodern society (Goneos-Malka, Grobler & Strasheim, 2013). Web 2.0 technologies and their social network capabilities have made collaboration across the crowd almost costless; cost, time and location are no longer constraints to the dissemination of knowledge (Stieger et al., 2012).

Statistics for 2010 and 2011 indicate that business-focused crowdsourcing revenues grew 74% over this period (Brown, 2012).

InnoCentive is an example of a successful organisation that specialises in solving problems using crowdsourcing. In 2001, InnoCentive was launched by the pharmaceutical firm Eli Lilly (Stieger et al., 2012). Its purpose was to provide an internet-based platform that could solicit input from scientists to solve problems, based on the payment of rewards for solutions (Stieger et al., 2012).

InnoCentive has referred to itself as the eBay of innovation (Lakhani, 2008). Problems are categorised into six Challenge domains: life sciences, chemistry, physical sciences, engineering/design, math/computer science, and business/entrepreneurship (Lakhani, 2008). A staff of about 30 runs these processes (Lakhani, 2008). By 2007, its success rate for problem solving was over 33% (Lakhani, 2008).

InnoCentive works as a broker; individuals sign up as problem solvers (Brown, 2012). To date, over 250000 scientists have been involved in crowdsourcing, across over 40 separate disciplines (Steiger et al., 2012).

Only 40% of problem solvers on the InnoCentive process typically have PhDs; problem solvers come from diverse fields, many unrelated to the field in which they contribute to the solving of problems (Lakhani, 2008). Solver inputs have come from over 175 different countries (Lakhani, 2008).

InnoCentive has been particularly successful in producing solutions to problems that could not be efficiently solved in-house (Stieger et al., 2012). Intellectual property rights are protected during the process; solvers sign agreements that cover the details of the reward, and the processes related to judging the contributions of solutions and the intellectual property stipulations; InnoCentive, by 2007, had a successful intellectual property transfer rate of 99% while operating across over 60 different countries (Lakhani, 2008). The following offers a sense of InnoCentive's vision, taken verbatim from their site (Lakhani, 2008:15):

Founded in 2001, InnoCentive is connecting industrial companies, academic institutions, and non-profit organizations with a global network of more than 135,000 of the world's brightest minds on the world's first Open Innovation Marketplace. InnoCentive believes that by exploring the power of open innovation and bringing together creative minds, it will deliver breakthrough solutions that touch every human life and change the way governments, business and the whole societies operate…InnoCentive wants to growth this community to include millions of the world's brightest minds. Moreover, InnoCentive wants all Solvers feel a sense of belonging to the same, exciting and unique, community.

The argument made in this article is that SGR has already achieved proof of concept status; and that it is only the scale of this relatively successful form of R&D that needs to be increased. There is a large, and growing, body of literature on the successes achieved by InnoCentive to date (Allio, 2004; Breen, 2002; Brown, 2012; Boswell, 2003; Lonstein and Lakhani, 2011).

Relevant to social R&D, InnoCentive has also been tasked with R&D related to social problems such those associated with the production of tuberculosis drugs (A.M.T., 2008), the reduction of environmental damage due to oil spills (Lakhani, 2008) and the solving of water issues worldwide (ITT, 2011),

On a global scale, if successful in accelerating problem solving, SGR might be able to contribute to a paradigm shift in the way we conceptualise large scale medical problems such as diabetes, cancer and others associated with aging.

Other organisations are increasingly developing their own crowdsourcing applications. The company, 'crowdSPRING' uses crowdsourced graphical and industrial designs together with writing input from the crowd (Brown, 2012). This firm is increasingly undertaking work for governmental units (Brown, 2012). These organisations are increasingly taking advantage of the new pool of diverse problem solving talent globally; people that provide crowdsourced inputs that are not necessarily motivated only by financial rewards, but by the opportunity to help others and to gain status and recognition (Brown, 2012).

Another attraction of crowdsourcing for organisations is that they can set their own price and schedules for inputs (Brown, 2012). A new set of economic relationships is therefore enabled, and organisations can take advantage of these,

with real implications for their cost structures.

The use of crowdsourcing has also spread to governments. In 2010, the Federal Office of Management and Budget in the United States commissioned the U.S. General Services Administration to select an online challenge platform for idea inputs (Brown, 2012). This is called 'ChallengePost' and is available at no cost to public agencies (Brown, 2012). By 2012 it had more than 200000 users and had run over 100 challenges (Brown, 2012). ChallengePost results in cost savings for government and offers a more efficient government services while providing exposure and recognition for problem solvers; it has been termed a "totally new paradigm for government" (Brown, 2012:21). As a new paradigm in knowledge management, SGR might offer a more extensive platform societal-level problem solving that can also enable more effective and efficient state service delivery.

Other examples of the rapidly increasing number of crowdsourcing sites that have emerged include 'Chaordix', used by major corporates for the management of market research, 'vWorker', which has about 400000 virtual technology workers that bid, globally, on projects, and 'IdeaScale', which focuses on obtaining knowledge of what people care most about (Brown, 2012).

Crowdsourcing can also be understood as a distributed labour network (Stieger et al., 2012). An example of this is the platform provided by Amazon's Mechanical Turk; for individuals from the crowd to undertake (and be paid for) tasks such as sorting images or other forms of work that computers cannot do well (Stieger et al., 2012).

Typically, a small number of requesters elicit responses from a large number of participants, and remuneration is low (Stieger et al., 2012).

Crowdsourcing, enabled by web-based features such as blogs, Wikis and RSS, has efficicency advantages over other techniques used to gather responses from individuals, as suggestion boxes, idea contests, interviews, surveys and many other collaborative data collection methods (Stieger et al., 2012). As indicated above, crowdsourcing also harnesses the intrinsic motivation of individuals (Lakhani, 2008), which is another potential dimension of the new paradigm offered by SGR. It can be used to leverage both a very large distribution of knowledge as well as varied motivations to contribute (Lakhani, 2008).

Networked marketing also uses crowdsourcing in the form of web-centred data gathering, where the collective intelligence of the crowd is used (Stieger et al., 2012).

3.2 SGR and Medical Research

Among the range of successful applications associated with crowdsourcing is its success in the field of medical research. Dissatisfaction with the slow progress of medical research is currently widespread (Saparito, 2013).

Commensurate with this dissatisfaction has been the rise of organisations such as 'Stand up to Cancer'; a form of citizen activism (Saparito, 2013), as community groups regard the status quo in medical research as unhelpful. It is in this context that crowdsourcing has offered new potentialities.

Crowdsourcing has to date already demonstrated success in gaining inputs to problems associated with protein folding, genomics data collection, AIDS research and other forms of drug R&D (Torr-Brown, 2013). The successes achieved by InnoCentive, with a staff of about thirty, offer a perspective of the potential of SGR when the scale of operation is ramped up on a global basis.

3.3 SGR Requirements

A new way of managing organisations might also be offered by crowdsourcing processes. Organisations such as Google use the collective 'crowd' comprised of their own employees to make decisions; for example, when demand needs to be predicted (Stieger et al., 2012). IBM hosts an 'Innovation Jam', where stakeholders, including employees, are all linked up to generate and commercialise new ideas, and new business units are launched (Stieger et al., 2012). Crowdsourcing can therefore be effectively used within an organisation to energise staff, to listen, to enable conversations, to support information sharing and support, and to surface innovative ideas and talent (Stieger et al., 2012). However, inasmuch as there are may positive outcomes associated with the application of SGR in the form of crowdsourcing, the application of effective crowdsourcing is not simple.

There are certain requirements for effective crowdsourcing. In order for crowdsourcing to be effective, certain pre-requisites need to exist: (i) participants need to be diverse, bringing into the process information that is new; (ii) information needs to be correctly summarised, as the average of many individual estimates is oftentimes surprisingly accurate; and (iii) participants need to be independent, or decentralised; conformity and peer pressures should not

confound the process (Stieger et al., 2012). Further, opportunities for self-organisation, through self-organisation mechanisms if necessary, should allow people to interact and to reinforce progress through working together (Stieger et al., 2012).

Although uniquely suited to societal problem solving, profit-seeking firms have further requirements for effective crowdsourcing. Whereas some (Bloodgood, 2013) stress that top managers of firms are tasked with a focus on profit, and not primarily on solving problems, Afuah and Tucci (2013) context this notion, and argue that solving problems is very much at the heart of business success. However, using crowdsourcing to solve problems precludes the use of concealment; concealment of the answers to problems, and, the problem itself, from competitors, according to Bloodgood (2013).

Capturing value is therefore a problem associated with crowdsourcing; the advantages associated with causal ambiguity are lost (Bloodgood, 2013). Afuah and Tucci (2013) also contest this, arguing that crowdsourced solutions, unlike in the case of open source software development, can be proprietary. Crowdsourcing organisations such as InnoCentive typically keep the identities of problem solvers and solution seekers disguised, and are generally successful at this (Afuah and Tucci, 2013). Further, Afuah and Tucci (2013) argue that internal problem solving itself is not risk free; knowledge can also leak through the mobility of employees and products can be reverse engineered by other firms.

Other concerns have also been raised with regard to the fairness of crowdsourcing as a "highly distributed microlabour online system" (Hyman, 2013:19). Tens of millions of people are now potentially exposed to how it influences human work systems (Hyman, 2013:19). Workers earn monies for tasks performed on online market and this is an exponentially increasing form of work (Hyman, 2013). Such concerns are perhaps to be expected on the advent of the emergence of another paradigm in working contexts. The exponential growth of SGR is expected to reshape many dimensions of working life. However, as with all large-scale process innovations that have increased the quality of human life in general, theorising and input from concerned stakeholders will always be necessary to bring awareness of both its negative and positive externalities.

As discussed above, the objectives of this paper were threefold; firstly, to provide an argument that FGR is associated with forms of innovation failure (that SGR, in certain cases, might be able to transcend), secondly, to argue that SGR has already demonstrated 'proof of concept' as a form of R&D that is more effective and efficient than FGR, and thirdly, to offer the example of a model of how SGR can be used right now to solve large-scale societal problems. Having discussed forms of innovation failure associated with FGR, and having considered different cases in which SGR has been successful, a brief example of a global societal problem solving model is now offered.

4. The Global Model

Within a new paradigm of SGR, many different models can perhaps be developed to solve problems which are beyond the scope of FGR. The following model of problem solving focuses on solving societal medical problems, and draws broadly from the SGR literature. Its particular focus is on diminishing the role of resource constraints to the R&D process.

If project success is typically a function of cost and time, then by 'crashing' the time dimension by using exponentially increasing volumes of R&D inputs it may be possible to reduce the resources needed for societal innovation. SGR offers this potentiality. The success of such a model is therefore primarily dependent upon its ability to provide sufficient knowledge inputs to reduce the time dimension of such projects to an absolute minimum.

An objective of the global model is to maximise the resources available to solve societal problems in a time-effective and efficient way. In the case of this model, a 'global' health problem is taken to represent (i) a challenge that costs national states a significant proportion of their yearly health budgets, and (ii) a problem that 'conventional' or market-system-related pharmaceutical R&D does not seem to be able to solve in the foreseeable future. Or that is associated with the 'golden goose' syndrome; where existing R&D generates constant income streams that would be destroyed by curative solutions.

This model follows the precedent of literature that seeks to radically accelerate innovation. Following Bers et al. (2009), it is possible to accelerate radical innovation. To this end the Accelerated Radical Innovation (ARI) project was initiated, and an ARI methodology was developed (Bers et al., 2009). Bers et al. (2009) found support for the ARI methodology; and example is the use of monochromatic X-rays in the diagnosis and treatment of cancer. SGR is perhaps the logical extension of this methodology of accelerated radical innovation.

Bers et al. (2009:165) recognise the definition of radical innovation as "innovation that creates and entirely new set of performance features; improvements in known performance features of five times or greater; or a significant (30% or greater) reduction in cost". No attempt is made here to delineate, or quantify the potential of SGR. However, a brief

discussion of the global model might offer a limited perspective of its potential.

In order to maximise the incentives available for a crowdsourced solution to a global problem, an appropriate funding structure needs to exist, which is underpinned by a convincing rationale.

National budgets are typically allocated according to the needs of citizens. The costs to a nation, as measured by their yearly health budgets, which relate a specific problem, can be calculated.

The cost of this problem for a time period, for example, five years ahead, can be quantified. This amount could be 'pledged' to a fund, administered by the World Health Organisation. There is no downside for such a country; if the problem is not solved, then no payment needs to be paid.

If enough of the over 170 countries globally were able to pledge a yearly expenditure budgeted amount to this fund, a relatively large amount of funding would be available for anyone that could solve the problem.

The problem could then be crowdsourced, in a similar manner to how InnoCentive has successfully solved similar problems. The scale of the successes of organisations like InnoCentive (with a staff of thirty) suggests that the scale of this problem solving exercise could work on a much larger scale. With a sufficiently large incentive, problem solving time-frames could be collapsed, and problems hitherto regarded as insoluble might be solved more rapidly.

There is no risk for the countries involved; if the problem is not solved, then they do not pay anything. The credibility of the process is ensured by having it managed by the United Nations Organisation. The technical details of the process would be developed in collaboration with all stakeholders. It is the objective of this section of the article merely to suggest a model based on the potentialities offered by SGR. It is beyond the scope of this exercise to go further than to suggest a broad model to solve large-scale societal problems. However, certain of these technical details are very briefly considered as follows.

A central information hub is at the heart of the processes of the global model. Information that arises from inputs received from the crowd or other sources is captured and recorded in real time as a stream of intellectual property. Itellectual property is incorporated into an asset base. Patenting and other forms of intellectual property ownership rights are formalised. Any person providing a knowledge input receives 'shares' in the outcomes of that problem solving process. The value of these 'shares' is dependent on the contribution of the input to the ultimate problem solving process. A parallel 'market' for these shares can also exist; they could be traded, or sold back to the organisation.

This flow of knowledge, in turn, forms the knowledge inputs into the commercialisation process. In the commercialisation process the knowledge flows form the basis for prototypes and pharmaceutical trials. This is an on-going process, which follows real time.

In the same way that a production process can run twenty-four hours a day, this process can also run continuously, with global inputs from different languages incorporated into the central problem solving hub. Problems can be visually represented with support information and knowledge provided on a large scale.

The shares or financial rewards allocated to individuals that provide inputs are ultimtely based on the success of the commercialisation process. However, governance of the process will include oversight from the WHO, or UN, in order to prioritise the integrity of the process.

The business models for the commercialised pharmaceutical products are based on the social entrepreneurial model and are therefore low-cost. All of the technical mechanisms involved in this process are based on the proven success of similar problem-solving used by crowdsourcing organisations. The precedent seems to already exist for this model to be implemented.

Information also flows back along these same linkages. Feedback from the commercialisation stage, together with problems with this commercialisation process, form knowledge inputs for the central information hub. These knowledge inputs are visually and textually represented; they form the 'front-line' of the problem-solving process. All knowledge is integrated and provided to problem solvers; visual representations and supplementary supporting knowledge is made available to individuals that log in to solve problems. In this way, knowledge is used to support the process until a critical mass is achieved, and spin-offs are increasaingly likely. A knowledge engine, on a global scale can result.

A virtuous circle of problem solving could be enabled; so that problem solvers are able to have available as much knowledge as possible. Knowledge resources from universities, governments and other stakeholders are also proactively integrated into the central information hub site. Partnerships are fundamental to this process. A simplified form of the global model is offered in Figure 1.

As stressed above, this example is presented in order for further researchers and policy makers to build on it. It is argued that building on these ideas might improve the lives of others, and articles similar to this one are important because they provide new ways of thinking about problem solving, particularly about problems experienced by us all as human beings.

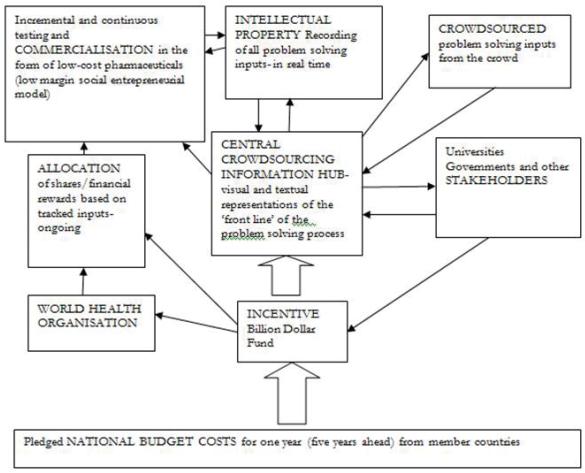

Figure 1. A global model of SGR/crowdsourcing for large-scale societal problem solving

Having offered a brief outline of a global model for societal problem solving that is based on SGR, the article is now concluded.

5. Concluding Remarks

The objectives of this paper were threefold.

Firstly, through a broad review of the literature, an argument was presented; that R&D failure is an inherent feature of FGR. FGR was defined as a generation of R&D that did not use economies of scale in the way that information and knowledge inputs are obtained in any stage of the innovation process.

Secondly, the argument was made that SGR (defined as R&D that uses large-scale economies of scale in obtaining knowledge inputs at any stage of the innovation process) can offer a new paradigm in problem solving, particularly with regard to societal problems that are outside the ambit of market incentives. Specific examples of the successes of SGR were considered in support of this argument.

Thirdly, a general, or global, model was offered of how SGR could be applied to solve societal problems on a world-wide basis. While this paper offered arguments, and was inherently normative in its approach, it is hoped that these ideas can provide some basis for further work in this area. It is argued that the incidence of the costs of any constraints to global innovation, pariticulalry as they relate to issues of disease, illness and human health, fall upon us all. It is hoped that the plight of millions in this world could be heeded by researchers that take up their responsibility to theorise more, and more effectively, about global problem solving process innovations.

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