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On

New innovation approaches to support the implementation of the Sustainable Development Goals

Advance Unedited Draft

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Prepared by the UNCTAD Secretariat[1]

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Introduction

During its 19th session held in May 2016, the Commission on Science and Technology for Development (CSTD) selected "New innovation approaches to support the implementation of the Sustainable Development Goals" as one of its priority themes for the 2016-2017 inter-sessional period. This Issues Paper has been prepared to assist the Commission in its deliberations. The paper responds to the call made by the ECOSOC to the Commission to raise awareness among policymakers about the process of innovation and to identify particular opportunities for developing countries to benefit from such innovation, with special attention being placed on new trends in innovation that can offer novel possibilities for developing countries.[2]

The paper has three chapters:

Chapter 1 introduces why new innovation approaches are needed for the Sustainable Development Goals (SDGs), highlighting innovation as a cross-cutting issue for the global goals, the range of challenges and constraints that make the achievement of the SDGs uncertain, and the new opportunities for innovation available at international, national, and local levels that contribute to sustainable development.

Chapter 2 discusses five innovation approaches: mission-oriented innovation, pro-poor/inclusive innovation, grassroots innovation, social innovation, and (digitally enabled) open and collaborative innovation. The chapter addresses the distinctive aspects of each innovation approach, how it can contribute to the achievement of the SDGs and promote inclusion and diversity, and how such approaches for innovation can provide opportunities to strengthen national innovation capabilities.

Chapter 3 proposes concrete policy considerations for governments and other stakeholders to strengthen capabilities for harnessing these new innovation approaches in sustainable development.

[2] E/RES/2016/23

Chapter 1. Why do we need new innovation approaches for the SDGs?

1.1. Innovation as a cross-cutting issue for the global goals

The 2030 Agenda for Sustainable Development (United Nations, 2015) puts forward a broad and ambitious agenda for global action on sustainable development. Innovation, understood as new forms of social practice and organization as well as new or improved technological products and processes, is not only an explicit focus of Goal 9 (Build resilient infrastructure, promote sustainable industrialization and foster innovation) but also a key enabler of most (if not all) the goals. Indeed, the ambitious nature of the 2030 Agenda – amongst other things, to end poverty and reduce inequality in all its forms everywhere, to promote inclusive and sustainable consumption and production systems, to provide full and productive employment and decent work for all – will require fundamental changes in the ways in which energy, food, water, housing, welfare, mobility and other goods and services are delivered, distributed and consumed.

Harnessing the positive potential for innovation to address the SDGs will also mean recognizing that some forms of contemporary innovation also contribute to environmental degradation, are disruptive of livelihoods, and exacerbate inequalities. The key questions are not about how to encourage more innovation in more places, but about which kinds of innovation need to be encouraged and how socially useful innovation can best be promoted and supported everywhere, whilst at the same time discouraging harmful innovation.

Until the late 1980s, innovation was widely conceived as the commercialization of scientific discovery, mainly by large corporations that had the capabilities to exploit new knowledge (Schot & Steinmueller 2016). This 'linear' conceptualisation of innovation (from science to R&D to commercialization) has since given way to a more sophisticated 'innovation systems' model, developed within a normative framework focused on supporting national or regional ´competitiveness´. Innovation is now recognised as mostly incremental – based on processes of adjustment to existing technologies – rather than about considerable novelty alone, and so it is recognised as involving practices and techniques that are new to a firm or to country as well as new to the world. More recent understandings of innovation also recognise that capabilities are important not only in formal R&D but also in design, engineering, management and entrepeneurship, and that innovation in forms of organization and social practice, as well as in technologies are relevant. Furthermore, innovation is seen as the outcome of a (difficult) process of learning and interaction between a diverse set of actors.

Public policy to support innovation has therefore broadened over the last thirty years (or at least attempts have been made to do so): from a focus on supporting centralised R&D programmes and the provision of incentives to large firms (e.g. in the form of R&D subsidies and strong intellectual property rules) to one that also encourages human capital formation and capability development across a very wide range of firms, and that faciliates interactions and linkages between firms, and across firms, science and technology institutions, users and other actors. The underlying normative framework remains, however, one of supporting

economic growth, with productivity increase at its core, and this is underpinned by the assumption that innovation-led growth is a key driver of social progress and the improvement of human welfare (Schot & Steinmueller 2016).

Viewed from a global development perspective, the central problem that has usually been highlighted in relation to contemporary innovation processes is that many developing countries have struggled to develop the firm-level and system wide innovation capabilities, and to create the appropriate forms of demand that enable a process of 'catching up' with the production or technological frontiers characteristic of advanced country economies. The result is low levels of productivity growth in many developing countries, and a failure to diversify the structure of their economies, with adverse consequences for employment generation and sustained economic growth.

In the context of the SDGs there are two additional problems. The first is that economic growth over the last two decades has occurred in many countries alongside significant increases in both absolute poverty and inequality (although inequality *between* countries has decreased over the last two decades, mainly due to rising middle class incomes in Asia) (Milanovic 2013; Chataway et al 2013; ISSC, IDS and UNESCO, 2016).

Some researchers argue that this phenomenon - an uncoupling of economic growth and social and economic development - is partly associated with the kinds of technological change that characterise contemporary innovation processes (Chataway et al 2013). The dominant innovation trajectory is one of the primary factors explaining why enhanced growth co-exists and, even in some increases, both absolute and relative poverty. Its capital-intensive nature, scale intensity, dependence on high-quality networked infrastructure, reliance on skilled labour, and product portfolio (producing products which meet the needs of the rich) have the effect of disadvantaging the poor, both as consumers and producers. It also excludes large segments of the population in many countries from productive employment (Chataway et al 2013). In short, dominant innovation trajectories fail to include very significant numbers of people (and these are disproportionately poorer and more socially disadvantaged groups including rural inhabitants and women) from the benefits of social and technical change.

The second problem is that some of the more dominant innovation processeshave been highly detrimental to critical environmental services, the adverse effects of which disproportionately affect poorer countries and communities. Furthermore, it is widely recognized that this problem is unlikely to be resolved by developing incrementally more efficient techniques alone. More fundamental changes to systems of production and consumption, in fields such as energy, transport, and food and agriculture, and in both their technological and social practice dimensions, are likely to be required to avoid catastrophic changes to climate, biodiversity and other critical environmental services.

These three core problems point not only to the long-standing need to continue to develop innovation capabilities in developing countries - across a wide range of firms and other actors - but also to reorientate and redirect innovation trajectories in ways that enable more inclusive,

socially just and environmentally benign patterns of socio-economic development. For the Global Goals to be achieved within 15 years, it is clear that new approaches to innovation will be required, that can experiment with different ways of solving problems, and that involve different actors, processes and governance, along with unprecedented forms of collaboration and cooperation across regions, sectors and stakeholders. These will need to recognize and overcome a number of challenges and constraints.

1.2 Challenges and constraints to achieve the SDGs

The achievement of the SDGs faces a range of resource constraints (including financial, technological, human skills and other dimensions). In particular, at national levels, similar financial constraints exist and are exacerbated by shortages of skills, human capital and poor infrastructure, especially in developing countries. Low income countries possess just 1.3% of the world's researchers (in comparison to 6.4% in lower-middle, 28.0% in upper-middle income and 64.4% in high income countries), and an average density of researchers 30 times lower than in high income countries (UNESCO, 2015, table 1.3).

Given these constraints at multiple levels, as well as the socially exclusive, and environmentally damaging nature of most contemporary innovation trajectories outlined earlier, what kinds of innovation approaches can help countries to achieve the SDGs? In recent years, a great deal of scholarly and policy attention has been given to a number of both novel and older - but hitherto relatively overlooked – approaches to guiding, organizing, thinking about and incentivizing innovation at international, national and local levels. Often falling under labels such as 'inclusive innovation', 'frugal innovation', or 'social innovation' many of these 'new' approaches involve different ways of doing and applying science, technology, and innovation (STI) to meet social needs. Some of these new approaches might be considered marginal, relative to the huge resources devoted to mainstream innovation processes.

They could be thought of as highly valuable innovation spaces, in which societal attempts are being made to imagine and practice novel and different ways of trying to reconcile and advance the ambitions of delivering both inclusive and greener forms of social and economic development. In doing so, the actors and institutions involved in the 'new' approaches often enjoy a degree of freedom to innovate that are simply not available to incumbents, locked in by prior investments, business models and other commercial and institutional commitments to existing, unsustainable, innovation trajectories.

The ambitious and progressive agenda of the SDGs is a huge opportunity to foster, support the emergence of and experiment with 'new' forms of innovation for sustainable development. There is considerable scope for recombining elements of the new approaches with those that are more mainstream to generate 'hybrid pathways to sustainability' (Ely *et al.*, 2013). Many of these processes are further facilitated by increasing digitization, providing important new opportunities for innovation.

1.3 Overview of the New Innovation Approaches

This paper highlights particular issues and considerations that need to be taken into account in the coming years to maximize the contribution of the approaches described below to sustainable forms of development. There is no consensus as to a typology of new models or approaches to innovation in the literature. Recognising the limitations and problems with categorization of distinct innovation approaches, and complications arising from ambiguous use of terms, emerging innovation approaches are discussed on the basis of broad themes, rather than compartmentalising them into falsely distinct 'models':

- **Mission-oriented innovation**: organizing networked research programmes at national or international levels, as well as the incentive structures that can direct innovation towards the achievement of specific technological, environmental or social goals.

- **Pro-poor and inclusive innovation**: extending the beneficiaries of innovation - building on ideas of innovation *for* the bottom of the pyramid (Prahalad 2004). This focuses on pro-poor innovation (primarily in the private sector) which, through new concepts, low-cost labour and materials and huge scales of production, can serve markets previously ignored by traditional innovation. It also includes innovations by marginalized groups, introduced under conditions of resource constraints.

- **Grassroots innovation**: broadening the range of actors in the innovation process to include grassroots innovation movements. The approach aims at practicing innovation, in both technology and service provision, in socially inclusive ways.

- **Social innovation**: shifting beyond technological to social innovation - this focuses on organizational innovations and new social practices designed to improve human well-being (e.g. in business models, production practices, finance, or public service delivery).

- **(Digitally enabled) open, collaborative innovation**: fostering open, digital collaboration - these innovation approaches draw on and recombine multiple sources and forms of knowledge, especially through open digital collaboration.

Chapter 2. Introducing the new and emerging approaches

2.1. Mission-Oriented Innovation: directing innovative activities

Mission-oriented innovation is concerned with directing innovation towards the achievement of specific technological or social goals, or to resolving social problems. It typically seeks solutions (or to address problems) that are considered to be under-supplied (or under-attended to) by markets. Mission-oriented innovation is by no means novel. The Manhattan and Apollo programmes - to build a nuclear weapon and land on the moon respectively - are examples of a much wider range of substantial post-war publicly funded 'mission-oriented research' programmes in the fields of defence/military, agriculture, energy and health in particular (Foray et al 2012). Historically, governments from the 13th century onwards have sponsored a wide range of initiatives to encourage innovations to address their most pressing needs, such as the early 18th century British ´Longitude Act´, an inducement to develop a practical method for determining a ship's longitude at sea (Murray et al 2012). A recent and successful example of a Grand Challenge is the one created in response to the 2014 Ebola outbreak in West Africa (Box 1).

Box 1: Fighting Ebola Grand Challenge (SDGs 3, 9 and 17)

As a response to the 2014 Ebola outbreak in West Africa, the U.S. Agency for International Development (USAID) launched the 'Fighting Ebola: A Grand Challenge for Development' to reach out for traditional and non-traditional partners around the world to come up with ideas to stop the disease. On the front lines of the Ebola epidemic, health care workers faced many obstacles in providing the timely care to patients that was required to prevent the virus from spreading. In just two months, innovators from around the world submitted over 1,500 ideas focused on helping frontline health care workers to provide better, more timely care and to contain the Ebola epidemic. 14 innovations were identified for their potential to reinforce the response to the West African and future Ebola outbreaks. The award nominees fell into six categories: (1) increasing the protection and comfort of health care workers and patients, (2) improved health care worker tools, (3) decontaminants, (4) rapidly deployable care settings, (5) behavior change, and (6) cutting-edge health information technology solutions that enhance the current response and provide a bridge toward longer-term recovery.

To make an innovative idea happen can be a time consuming and difficult process with plenty of uncertainties. But some of these 14 award-winning ideas are already making their ways to users on the field. A wearable patient sensor monitoring analytics platform went through user testing in Sierra Leone in the fall of 2015. A low-cost, battery-powered infusion monitor won approval from the US Food and Drug Administration. The personal protective equipment developed at the John Hopkins University started user testing in both Guinea and Liberia in January 2016 and will be commercially produced by DuPont. A barrier technology to prevent contamination is undergoing laboratory testing, while a decontamination chamber and a powdered bleach additive are undergoing user testing in Liberia. The dynamic, integrated health worker communication and coordination system called 'mHero' received additional

funding to expand their scope of work in Sierra Leone.

Source: http://www.ebolagrandchallenge.net/

The rationale for mission-oriented innovation fell somewhat out of favour during the 1980s and 1990s (although it has been consistently maintained in military R&D), reflecting concerns about the inability to 'pick winners' and an orthodoxy that government should only be responding to market failure (Mazzucato 2013). More recently, however, attention to, and a wide range of investments in, mission-oriented innovation reflect a weakening of market-oriented orthodoxies, and a focus on what have become known as 'grand societal challenges' (e.g. climate change, aging, inequality, or chronic and infectious diseases), recognition that some of those challenges require transformation of entire technological systems and the activities of foundations, in pushing for private sector-oriented ideas around innovation as a means of tackling social problems.

2.1.1 Potential contributions to the SDGs

Contemporary mission-oriented innovation programmes range from national, international, private foundation and public/private sponsored initiatives, of varying but often very substantial scales. Contemporary examples relevant to the SDGs range from initiatives that are directed at delivering specific medical solutions (e.g., malaria eradication techniques, vaccine delivery systems that do not require refrigeration (SDG 3), or green energy technologies (SDG 7)) (Varmus et al 2003; Bodnar and Turk 2015) to more general programmes (e.g., concerned with innovative responses to problems of access to safe water (SDG 6), food security (SDG 2), or climate change (SDG 13)) (EC 2013). Prominent examples include:

- State funded programmes such as USAID´s Grand Challenges for Development (with initiatives like Scaling Off-Grid Energy, Securing Water for Food, All Children Reading, etc.), Grand Challenge Canada[3] or the European Union´s large seven-year Horizon 2020 research programme. These programmes support innovators, largely through calls for international research collaboration, to solve challenges in sectors such as health, energy, water and food, governance and accountability, and education.
- Large multi-lateral initiatives such as 'Mission Innovation', a 2015 commitment amongst twenty countries to accelerate public and private global clean energy innovation.
- Initiatives led by philanthropic organizations, such as the Bill & Melinda Gates Foundation's 'Grand Challenges in Global Health', launched in 2003 (later renamed ´Grand Challenges´) encompass development as well as health objectives.
- State investment bank mission-oriented finance programmes creating demand (rather than supporting supply of new technologies), in countries like China, Germany and Brazil. In 2012

[3] See http://www.grandchallenges.ca/

alone, for example, state investment banks invested US$108.9 billion in clean energy projects (Mazzucato and Penna, 2014).

- Public-private initiatives such as the Global Alliance for Vaccines and Immunization (GAVI) which seeks to influence market mechanisms for vaccine development and procurement, and is an alliance between the Bill & Melinda Gates Foundation, WHO, UNICEF, World Bank, donor governments, international development and finance organisations, and the pharmaceutical industry.

Additional national and international cooperation efforts include:

- International cooperation initiatives such as Internet-of-Things Innovation Challenge in Indonesia 2016[4]
- Initiatives that promote innovation in specific sectors relevant for the achievement of the SDGs such as those aimed at exploiting the potential of waste and promoting the production of goods in a resource-efficient, socially and environmentally-friendly way in Switzerland[5]; programmes and centers created in Iran to solve challenges in areas such as energy, and water and urban issues (for instance, Tehran Urban Innovation Centers and Energy Saving through Mobile Applications)[6]; and measures aimed at the promotion of environmental protection, energy production, and energy efficiency in Bulgaria.[7]

Unlike traditional research programmes, many of these new mission-oriented initiatives seek to move well beyond R&D, to actively support prototyping, scaling up and the commercial or public diffusion of new technologies. The EU Horizon 2020 strategy, for example, will "…cover activities from research to market with a new focus on innovation-related activities, such as piloting, demonstration, test-beds, and support for public procurement and market uptake ."[8]

These new mission-oriented initiatives typically seek to involve - and provide incentives to - a more diverse range of innovators than researchers alone, across public, private and civil society sectors, and outside of the national borders in which funding programmes reside (e.g. including developing country-based researchers and innovators). A concern with attracting a more diverse range of innovators than procurement approaches typically can attract (and therefore, in principle, the identification of more novel technological solutions), and a concern with problems that do not promise market rewards (and for which patent availability is therefore of

[4] See https://smk.dicoding.com
[5] Contribution from the Government of Switzerland, see https://www.kti.admin.ch/kti/en/home.html
[6] Contribution from the Government of Iran
[7] Contributoin from the Government of Bulgaria
[8] See https://ec.europa.eu/programmes/horizon2020/en/h2020-section/societal-challenges

little attraction) has led to experimentation with innovation prizes and advance market commitments.

Innovation Prizes and Advance Market Commitments

Innovation prizes (large monetary awards to innovators who provide the first or best solution to a predefined technological challenge) are an inducement to private investment in areas where market opportunities are not visible. They have the advantage of not requiring monitoring of performance where contracts (e.g. procurement commitments) prevail, and of attracting wider participants. A recent example is the UK Longitude Prize, a £10m fund launched in 2014 that will reward an innovator that can develop a cost-effective, accurate, rapid and easy-to-use test for bacterial infections that will allow health professionals to administer the right kinds of antibiotics at the right time (thus helping to diminish antibiotic resistance). The 'mission' in this case was selected by the public, based on six possible missions that were identified through a mixture of consultation with experts and politicians and workshop-based public dialogue. The aim is that anyone, from amateur scientists to the professional scientific community, can try and solve it.[9]

Advance Market Commitments are a market-oriented mechanism to provide incentives for the private sector to invest, or to speed up investment, in areas that would normally be perceived as overly risky, such as the development and introduction of health technologies for developing countries. Unlike prizes, which reward the first supplier, advance market commitments can create a market of multiple manufacturers, with the advantage that this ensures both competition and sustainable production in the longer term. A well-known example is the Pneumococcal Advance Market Commitment, launched in 2009. In this initiative, a range of donors committed funds to guarantee the price of Pneumococcal vaccines once they had been developed, thus providing vaccine manufacturers with the incentive to invest in vaccine research and development and expand manufacturing capacity in circumstances where they would not otherwise have done so. In return, companies signed a binding commitment to provide the vaccines at affordable prices to developing countries. The programme has successfully accelerated the development and expanded the availability of pneumococcal vaccines for developing countries (Cernuschi et al 2011).

2.1.2 Policy implications

Much of the new wave of mission-oriented innovation, especially that part concerned with ´grand challenges´, seeks outcomes that are broader than a single, specific area of technological capability and addresses problems that are more complex and much less well-defined, compared to those associated with the ´old´ post war mission-oriented research programmes. Many if not most mission-oriented innovation programmes have been organized in ways that

[9] https://longitudeprize.org/

are not restricted to national or regional borders and thus enable multi-lateral collaboration. Typically, funding calls encourage researchers and innovators from anywhere in the world to apply for support, and many programmes take the form of collaboration between countries and institutions. Therefore, in principle, large international mission-oriented innovation programmes may be more likely than traditional national funding programmes to support innovation capabilities in developing country settings.

Despite the potential for supporting innovation capabilities, ´new´ mission-oriented innovation presents many challenges, including: identifying and defining appropriate missions; creating incentive structures; ensuring the long-term collaboration of many different actors and users (in both development and deployment of a range of technologies); coping with the fact that they are often common resource problems; extending beyond national boundaries; and the need to replace incumbent technological practices with new ones (Foray et al 2012). Amongst other things, this means that mission-oriented innovation to tackle ´grand challenges´ will require long-term commitments from a range of both public and private actors (Mazzucato and Penna, 2015).

An over-emphasis on technology solutions can potentially detract from other reasons for developmental challenges (e.g., poor health systems, poverty, lack of access to basic needs, poor infrastructure, political instability, etc.). There is concern about priority-setting and whether certain prizes or grand challenges are commensurate with the scale of the developmental challenges.[10] Furthermore, some researchers have argued that grand challenges could overlook the diversity and distributional concerns and potentially reduce space to deliberate issues of accountability and directionality.[11]

The governance mechanisms of the incentive structures associated with mission-oriented innovation are distinct as well, often involving a pooling of resources from multilateral, national and philanthropic organizations, and the creation of novel public/private institutions (such as the Gavi initiative in vaccine development and delivery). There are important questions about how the new governance arrangements define their missions, how the benefits arising from innovation are appropriated and distributed, and how governance processes cope with competing perspectives on what the problem is and what constitutes its resolution (Kremer and Glennerster 2004; Kuhlmann and Rip, 2014). There is a risk that the latter is done in ways that differ from, or that are less diverse than, the ways national-level public institutions have

[10] McCoy, David, Gayatri Kembhavi, Jinesh Patel, and Akish Luintel. "The Bill & Melinda Gates Foundation's Grant-Making Programme for Global Health." *The Lancet* 373, no. 9675 (9): 1645–53. doi:10.1016/S0140-6736(09)60571-7. Litzow, Jennifer M, and Howard Bauchner. "The Grand Challenges of the Gates Foundation: What Impact on Global Child Health?" *Journal of the Royal Society of Medicine* 99, no. 4 (April 1, 2006): 171–74. http://www.creativeworkslondon.org.uk/wp-content/uploads/2013/11/Digital-Innovation-The-Hackathon-Phenomenon1.pdf. LI, Li Min and JOHNSON, Sharon. Hackathon as a way to raise awareness and foster innovation for stroke. *Arq. Neuro-Psiquiatr.* [online]. 2015, vol.73, n.12 [cited 2016-06-10], pp.1002-1004.

[11] Brooks, S., Leach, M., Lucas, H. and Millstone, E. (2009) Silver Bullets, Grand Challenges and the New Philanthropy, STEPS Working Paper 24, Brighton: STEPS Centre

previously identified priorities and directions for mission-oriented research programmes (which include more horizontal or systemic interventions). For example, some of the philanthropic organizations have been criticized by public health scholars for an overly science and technology-focused definition of the impediments and solutions to improving health in developing countries (Birn 2005; Storeng 2014). Policy makers may find it beneficial to involve multiple stakeholders and make the framing of mission-oriented innovation programmes more participatory.

2.2. Pro-poor and inclusive innovation: extending beneficiaries

Approaches to innovation that are concerned with extending beneficiaries (also referred to as 'pro-poor' or 'inclusive' innovation) aim to actively include and involve poor people in mainstream processes of technology-related development, either as consumers in new product and service markets or, more ambitiously, as participants in the innovation process themselves. The former – innovation *for* marginalized groups - is most closely associated with the ideas about the 'Bottom of the Pyramid' (Prahalad 2004), originally a top-down management approach aimed at creating new markets for multinational companies amongst the poorest parts of the population. Here the focus is on innovating in low-cost products that can serve untapped markets with new commercialization and distribution strategies. The latter - innovation *by* marginalized groups and/or *with* mainstream actors such as firms, governments and R&D institutions - is often associated with ideas about 'Frugal Innovation', which focus on informal forms of innovation in contexts of scarcity, in either grassroots settings or companies. The work of UNCTAD on STI policies to promote inclusive development has shown that to increase the effectiveness of these policies, it is important that inclusive innovation programmes be designed using an integrated approach that includes not only the agents involved in the implementation of such programmes but also their beneficiaries.[12]

2.2.1 Contributions to the global goals

Both innovation for and innovation by and with marginalized people have the potential to address many of the SDGs. The former, by taking advantage of existing resources and capabilities within firms to develop simple, down-to-earth solutions, can make services and products available that would otherwise be unaffordable. A well-known example of this type of innovation is the GE ultrasound scanner case. As Box 2 shows, the development of new, cheaper devices based on existing technologies can create new markets and serve unmet needs among poorer populations, providing high-value products and services. Another example of initiative aimed at serving local needs of poor communities is the one currently implemented in India through a collaborative project between the Government of Germany and Bosch aimed at

[12] http://unctad.org/meetings/en/SessionalDocuments/ciid25_en.pdf

promoting locally technologically developed solutions to serve local needs (see **Error! Reference source not found.**).

Box 2: Examples of innovations *for* and *by* marginalized groups

The example of the GE low cost ultrasound scanner (relevant to SDG3)

General Electric's primary business in healthcare is high-end, expensive medical imaging technology. By the 1990s, GE's technology in ultrasound imaging had a strong position in the developed world market but struggled in developing countries for a number of reasons, including high cost, lack of portability and because the technology was complex to use. GE was simply unable to serve emerging markets with this technology, so in 2002 they developed a cheaper version (at US$30,000) of their ultrasound scanner that could be connected to a laptop computer. In 2007, they introduced a new, less expensive version that was sold at US$15,000, of which sales grew dramatically, gaining a market of around US$280 million. The portability, ease-of-use, and low cost also triggered new uses, allowing it to be fitted into ambulances, emergency rooms and operating rooms. The development was key for markets like China where most of the rural population did not have access to sophisticated medical services. However, it also allowed the company to develop new, premium versions of the scanner that were sold in the US and other developed markets. Thus, the capabilities accumulated for pro-poor innovation have subsequently led on to low-cost product development for richer markets (Immelt et al, 2009).

This case shows how a highly complex technology can be translated to different contexts using a "frugal" approach: a device originally designed for high end markets becomes adapted to infrastructurally-constrained situations in China and, as a result, helps to serve a market in other developing countries but also eventually in the global North. Another way in which this approach is being replicated across the global South is through the use and translation of its business models (see Box 4) to other similar contexts.

Promoting locally developed technological solutions in India

The German Development Cooperation in India is working with Bosch on providing affordable technology-based solutions in key areas of the SDG, supporting health suppliers in order to benefit low-income patients and expand access to better health services. One example is a locally-developed eye-care solution that screens and detects eye diseases. The system, composed of both hardware and software, is more affordable for individual practices and big health suppliers compared to competitors. In a country in which nearly one in every three citizens is visually-impaired, the provision of such a product can impact a significant number of lives – an estimated 80% of vision loss cases in India are preventable if they are detected early enough (source: Input from Government of Germany).

In order to create new markets where there is a lack of infrastructure or a lack of experience in logistics and distribution, this approach can take advantage of new methods, such as the use of online tools and social networks (see Prahalad, 2004). The mode of inclusion that this approach

favors is mainly focused on inclusion of the poor in consumption and in some cases impact. However, the provision of new products and technologies for marginalized groups can also be an important enabler, fostering familiarity with new technologies and allowing the development of new capabilities (see Hanlin & Kaplinsky, 2016).

There is perhaps greater potential to address SDGs with those initiatives that seek to involve and include poorer people in innovation processes themselves. Here the orientation is towards using existing resources and drawing on poor communities' knowledge, in order to foster creativity in conditions of scarcity, thus allowing the creation of potentially more resilient solutions to people's problems (See Box 3).

Box 3: The case of Mitticool (relevant to SDGs 1, 2, 7 & 9)

The Mitticool is a famous example of frugal innovation from India. Developed by Manksukh Prajapati, a trained potter, the Mitticool is a fridge that uses built-in clay and water evaporation as a coolant. The design works without electricity, uses sustainable materials, can keep food fresh for days, and can be easily and cheaply built at a cost of around US$30-50). As Prajapati continued to experiment with designs and improvements, the Mitticool also benefitted from interactions with the Grassroots Innovation Augmentation Network (GIAN) that supported its product development and helped to launch the Mitticool fridge in 2005. Prajapati was also awarded a National Award at the Fifth National Competition for Grassroots Innovations and Traditional Knowledge in 2009. The invention was granted an Indian patent and is currently on sale (NIF, 2013).

Different kinds and levels of inclusion are associated with these ideas. They range from (i) the inclusion of problems and issues from marginalized communities into R&D agendas, to (ii) enabling marginalized groups to participate in the process of innovation, to (iii) facilitating the adoption of innovations from marginalized groups, to (iv) creating innovations that have some measurable impact on the lives of marginalized actors (Foster and Heeks, 2013: 335).

2.2.2 Importance of capabilities

Instead of pursuing top-down strategies of technological development that generally disregard local idiosyncrasies and social asymmetries, pro-poor and inclusive innovation approaches (such as Unilever Shakti – see Box 4) often try to recognise and use local capabilities and existing informal networks with NGOs and other institutions. However, even when they recognise the role the poorest may have in the innovation process, in practice many of the programmes based on the pro-poor innovation are more focused on building capabilities in entrepreneurship than on knowledge or on creating bridges between local needs and conventional innovation (See UNCTAD, 2011).

Box 4: Unilever Shakti: inclusive innovatoin with NGO networks (relevant to SDGs 3 and 8)

Unilever Shakti is a good example of how inclusive innovation approaches can help setting up networks (shakti means strength in Sanskrit). The Unilever Shakti initiative is constituted by an alliance between Unilever and Care, an NGO with a long trajectory in capacity building and women's empowerment in poor communities. The aim for Unilever was to experiment with new distribution channels in order to reach poorer consumers in small communities in India with small, low-cost products such as shampoo or creams. Care provided the platform for women's training in the rural sector, while Unilever funded courses in health, sanitation, infant care and entrepreneurship. Additionally, Unilever provided micro-funding for business development. As a result, Unilever acquired a platform for selling its products in new markets in India (London and Davidson, 2011). In 2012, the project reached more than 3 million households with around 50 thousand "shakti women" that distribute their products (The Economist, 2012).

Furthermore, many of the innovations involved in this approach can be regarded as a simplification of already available products or process. Their translation into "frugal" products does not necessarily involve users, cutting short any possible participation, and missing the opportunity to develop local production capabilities. However, used appropriately (with a focus beyond the technology alone to include training and network-building), this approach could help to support the development of local capabilities amongst institutional actors (such as software development and technical maintenance) and to foster experimentation with new and unexpected forms of applications with users (see Chan, 2014). Thus, combining inclusive innovation approaches with other interventions like public procurement, extensive training, shared use of resources like blueprints and software and allowing the users to adapt and modify the innovation could help to devise more robust and sustainable innovation for social inclusion policies.

2.3. Grassroots innovation: broadening the innovation process to include grassroots actors

Grassroots innovation involves social movements and networks of academics, activists and practitioners experimenting with alternative forms of knowledge creation and innovation (Fressoli et al 2014). Such initiatives seek to practice innovation, in both technology and service provision, in ways that are socially inclusive towards local communities in terms of the knowledge, the processes and the outcomes involved. In contrast to mainstream innovation processes, which are led by firms operating in formal markets, grassroots initiatives operate in civil society arenas, typically within the social economy of community and voluntary activities and social enterprises, rather than the formal business sector. This type of innovation is often driven by social and environmental need rather than motives of competitiveness and profit in the market economy. It draws on resources such as grant funding, mutual exchange and voluntary inputs rather than commercial finance, and it relies more on local, situated forms of knowledge as compared to scientific and technological knowledge.

Table 1 below highlights some key stylized differences between grassroots innovation and more mainstream innovation processes, in terms of actors, values, incentives, knowledge, and sites of innovative activity. In practice, there is often more interdependence and interaction between the two sets of characteristics.

Table 1: Mainstream STI institutions and grassroots innovation movements' approaches to innovation

Characteristics	**Mainstream STI**	**Grassroots innovation movements**
Political dimensions		
Predominant actors	Universities, public labs, commercial firms, ministries and other public institutions, international funding agencies	Civil society, NGOs, social movements, cooperatives
Priority values	Scientific advance for profit and innovation / not necessarily focused on social inclusion	Social justice / not necessarily focused on for-profit innovation
Mechanisms		
Principal incentives / drivers	Market demand and regulation / scientific competence	Social needs / cooperation and community empowerment
Sources of investment	State / corporate funding, venture capital	Development aid, community finance, donations, State funding
Forms of appropriability	Intellectual property framework strongly biased towards patent-based innovation	Common goods
Knowledge dimensions		
Sites of innovation	Laboratories and R&D institutes, board rooms and ministries, market based firms	Community projects and participatory processes, social movements
Predominant forms of knowledge	Scientific and technical knowledge	Local, situated knowledge / indigenous knowledge
Emblematic technological fields	Biotechnology, ICTs, nanotechnology	Organic food, small scale renewable energies, water sanitation

Source: Fressoli et al 2014

Grassroots innovation movements can be understood as distinctive, relative to mainstream innovation processes, according to the ways in which activists and practitioners mobilize people around innovation and technological design. Three main features characterize grassroots innovation initiatives. First, they are based on collective action and solidarity, experimenting with different forms of bottom up organization that combine local spaces such as technology demonstration centres or makerspaces (see Box 5) with wider regional or international networks. Second, they encourage participation in technological development as a means of increasing democracy. In practice this means not only participating in developing solutions to local problems but ultimately in gaining a voice in larger debates about technology and the directions of development. Finally, by trying to encourage participation and solidarity, grassroots innovation movements have, over time, devised many mechanisms to foster collective sharing of, and collective learning about, technologies. From the use of Appropriate

Technology handbooks in the 1970s towards the contemporary prevalence of tutorials on Youtube, grassroots innovation movements are at foremost about supporting open ways of designing and producing technologies (see Smith et al 2016).

Box 5: The maker movement (relevant to SDGs 9, potentially 12)

A contemporary grassroots innovation movement that is creating a lot of interest is the Maker movement, which has become a global driver of informal experimentation with technologies as diverse as software, microelectronics, robotics and digital fabrication. This movement links traditional knowledge about carpentry, metallurgy and mechanics with new technologies such as software programming and basic electronics. It encompasses several global networks of practitioners such as hackerspaces, fablabs and makerspaces, and these include a wide variety of professions and craft skills, such as designers, architects, electronic artists and scientists. The main aim of the maker movement is to experiment with artefacts, modify them for novel purposes, and create unrestricted access to technology.

The internet has enabled the spread of maker movements by fostering practices of collaboration and learning, using tools such as online tutorials and the sharing of open designs that connect amateurs, practitioners and experts around the globe. The maker movement draws heavily on open source technologies such as open software (e.g. Linux and Python) and open hardware[13] tools such as the microcontroller Arduino or RepRap 3D printers.

Indeed, there is a whole ecosystem of knowledge interchange, learning and online collaboration around the maker movement based on the internet. Web sites such as Instructables, Thingiverse or Sourceforge allow practitioners to upload and share their own designs, software and tutorials in order to build anything from toys to mini-robots, create or modify a 3D printer, develop open software, or build a house. These repositories have grown sufficiently to start attracting serious interest from companies.

Learning how to create or use tools in the maker movement is part of a strong innovative ethos that is not shy of entrepreneurship, and sometimes fosters the creation of alternative business models, such as those based on providing services to free software users or tools for experimenting with open hardware. At the same time, the maker movement advocates free information, open source technologies, a new economy of sharing, and the search for more sustainable technologies. One of the strongest ideas of the maker movement is that anybody

[13] Open hardware, or open source hardware, refers to the design specifications of a physical object which are licensed in such a way that the object can be studied, modified, created, and distributed by anyone. Open hardware is a set of design principles and legal practices, not a specific type of object. The term can therefore refer to any number of objects (such as automobiles, chairs, computers, robots, or even houses). Source: https://opensource.com/resources/what-open-hardware.

with a technological query or problem can approach a fab lab, a hackerspace or a makerspace and try to develop their own solution or ask for help and create a new development in collaboration with others. As these practices foster a direct experimentation with technology, some authors even argue that the maker movement is creating a new form of citizenship (Ratto & Boler, 2014).

In 2012, Anderson estimated that there were about 1000 makerspaces world wide. Many of the projects created at makerspaces and fablabs seek to fulfill personal interest, whilst others seek to experiment with solutions for social inclusion, such as the creation of 3D printed prosthetics. There are also more ambitious projects that aim to challenge traditional technological practices, such as those of farming by developing open source, low cost tools that can enable sustainable farming, (notably the Open Source Ecology project – See Box 13).

New grassroots innovation networks have received considerable interest and have been replicated around the world. “Hackerspace”, “makerspace” and “fablab” are terms often used interchangeably to describe community-operated primarily non-profit workspaces where people with common interest in computers, technology, science or any other skills can meet to collaborate as well as to socialize (see Box 6). They are often located in social centers, education centers, public schools, libraries or universities and are very similar in the sense that they offer a public and shared access to high-end manufacturing equipment.

Given the long history of experimentation and design of solutions for environmental and social problems, grassroots innovation can be related to the majority of the SDGs. Beyond specific technologies, perhaps the areas where grassroots innovation movements can make unique contributions are in alternative forms of education, innovation, consumption and local and global partnerships for achieving these goals.

Box 6: Fablabs as an example of Makerspace

Fablabs evolved from an initiative at the Center for Bits and Atoms in MIT in 2002, but since then, have grown continuously. Fablabs provide computers and computer-controlled tools that allow community members to develop software code as well as technology-enabled products. They are considered as an MIT-franchise and have a very specific set of space requirements, required tools, and supporting software. They are required to be open to the public for little or no cost, and they also provide a platform for learning and innovation: a place to play, create, learn and invent. As with Appropriate Technology in the past, institutions such as universities, public R&D labs and even commercial companies like Airbus have adopted part of the Fablab

approach, creating their own digital fabrication labs.

According to Fab Foundation there are approximately 1050 fablabs around the world, in both developed and developing countries.[14] Brazil, for example, has 32 registered fablabs in different cities, some of them focusing on knowledge sharing and community building, while others provide more equipment and are hosted by universities. There are 7 fablabs in South Africa in different cities, several of them hosted at universities, and focusing on the youth and arts. Vietnam has 6 fablabs across the country with profiles varying from healthcare, agriculture, education to traditional crafting.

2.3.1 Contributions to the SDGs

Grassroots innovation occurs in sectors as diverse as water and sanitation (see Box 7), housing, food and agriculture, energy, mobility, manufacturing, health, and education. Examples include community-based renewable energy initiatives, low-cost and low impact self-housing developments, farmer-led irrigation systems, small-scale agricultural machinery development, urban food production schemes, community recycling, community sanitation and water projects, local remanufacturing, low cost refrigeration technologies, home-based nurse training schemes, farmers' markets, and open source energy monitors. They are supported by networks and social movements in both industrialized and developing countries. Traditional examples of this type of innovations include the Appropriate Technology movement, the People's Science Movement in India, the Social Technologies Network in Brazil, and more recent initiatives including the global Fablab and Makerspaces movements (Smith et al, 2016).

Box 7: The One Million Cisterns Project (P1MC) (relevant to SDGs 6 and 2)

The One Million Cisterns Project (or P1MC, as it became known) aimed at providing a significant number of water cisterns in a large semi-arid region in Northeast Brazil, which is characterized by low rainfall and scarce groundwater sources. The family-scale cisterns capture and store seasonal rainfall in sufficient quantities for both personal and productive needs (e.g. agriculture) throughout the dry season.

The project was originally devised by the Semi-Arid Association, a network of more than 700 institutions, social movements, NGOs and farmers' groups, which later become an important actor with Brazil's Social Technologies Network (STN). The Brazilian Ministry of Environment was also initially involved, and later the Ministry of Social Development. The main feature of the technology is that it is built by "users" (farmers/masons, a common archetype of Brazilian semi-arid areas). The self-build aspect of the cisterns is intended to

[14] For more information see: https://www.fablabs.io/map

foster relationship-building in the community through the process of learning to construct, use and modify the technology. This empowers local communities while also providing autonomy from local governments and water suppliers (see Fressoli and Dias 2014).

The project was adopted by the Ministry of Social Development in 2003. Since then, over 1 million water cisterns have been built by local inhabitants with the support of the STN and the Ministry of Social Development (MSD 2016).

2.3.2 Policy implications

From the high levels of institutional support for the Appropriate Technology movement during the 1970s and 1980s to contemporary interest in the maker movement, development agencies and mainstream science and technology institutions have historically shown interest in the alternative models of technological change and social development originating in grassroots innovation movements (see Fressoli et al, 2014; Ely et al, 2013). Policy initiatives to promote these movements include:

- creation of programmes that provide funding to acquire tools and to experiment with new technologies and capabilities;
- initiatives aimed at building bridges between the informal, heterogeneous nature of grassroots innovation and existing R&D capabilities;
- efforts to make networking infrastructure (such as funding regional hubs for technology demonstration and learning, open repositories for technological design, tutorials, etc.) and;
- initiatives aimed at fostering international networks that can help to foster grassroot movements at the local level and increase their visibility and legitimacy

It is nevertheless important to note that grassroots innovation often thrives because of its independence from bureaucratic procedures and institutional traditions. It is therefore important that mainstream institutions be careful not to impose their own objectives when providing support for grassroots innovation. Grassroots innovation efforts can thrive, for example, when due attention is given to process-based approaches instead of only outcome-based models of support (i.e. number of technologies built or participants). Furthmore, the desire to scale-up initiatives could potentially overlook the processes of empowerment and capacity building that are at the core of grassroots innovation movements.

2.3.3 Building capabilities

Grassroots innovation movements can generate valuable knowledge and experience that complement existing R&D capabilities in developing countries. This can occur via:

Advocating and experimenting with alternative pathways of social and technical change:

Over the last 50 years or so, grassroots innovation initiatives (and their predecessors) have created technologies and social practices that were once considered radical, fringe activities, but are now mainstream or almost mainstream, such as organic agriculture, wind energy, participatory design, and agro-ecology (Ely et al 2013).

Challenging conventional innovators and innovation policymakers to learn how to engage with diversity:

Grassroots innovation develops and uses knowledge and technology in ways that are often very different from formal institutions of science and technology. Such initiatives emphasise and foster the open character of knowledge production. They experiment, for example, with different ways in which citizens can help to define problems and issues requiring innovative solutions, and the underlying norms and rationales guiding the ways in which those solutions are defined.

Recognizing other forms of knowledge and building bridges between informal knowledge and practices and conventional innovation processes:

Grassroots innovation movements have been key in opening up new spaces for innovation and recognizing the role of marginalized groups in developing their own solutions. For instance, the Appropriate Technology movement in Latin America had an important role in retrieving and re-valuing indigenous knowledge. Much of this involved the collection and study of botanical and agricultural knowledge from indigenous communities (see Smith et al 2016).

Empowering civil society actors to engage with technology tinkering, technology design and ultimately questioning the established R&D agenda:

Grassroots innovation movements are ultimately aimed at opening up a discussion about the direction in which societies develop and change, and the roles of scientific research and technological change within those processes. As such, they raise questions about technological needs in societies, the appropriate directions of technological change, and who is enabled to design, own and access technology, and on what terms. These questions involve a politics of knowledge that seeks to modify the distribution of resources and power in knowledge production and technology development.

2.4. Social innovation: from technological to social innovation

This section reviews approaches to innovation that focus on the creation and diffusion of novel social practices and institutions, as opposed to technical novelty, and in particular to the idea of 'social innovation'. This term, which has received substantial policy and academic attention over the last 15 years, is generally held to refer to: a) innovations in social relationships, practices and structures that are b) primarily aimed at addressing social needs and at improving human well-being (van der Have & Rubalcaba 2016). The main driver for social innovation is

that of addressing unmet social needs. This distinguishes social innovation from non-technical innovations that take place within business and that are driven primarily by profit seeking, such as organizational innovation and innovation in services.

Understood in this way, most social innovations are initiated through entrepreneurial activities from the 'bottom up', by organizations and actors with roots in civil society and the third sector (e.g. co-operatives, associations, and foundations). Social innovation thus overlaps with grassroots innovation, but unlike the latter, it focuses only on innovations in social practices and organization. Although typically initiated from the bottom up, social innovation often involves the creation of hybrid combinations of civil society, private and public actors and their associated logics. The institutionalization of global fair-trade production models (a prominent example of a "social innovation" for instance, links social movements, producers and mainstreams firms and their associated norms in novel ways. Likewise, initiatives such as time banks (systems of reciprocal service exchange), or novel means of fundraising and finance provision, typically occupy a hybrid space between the private sector, the State and civil society linking social movements, producers and mainstream firms, and their associated norms, in novel ways (see Box 8). One interesting consequence of this hybridization is that it lends itself to experimentation with different organizational forms and practices (Pel et al 2015).

Box 8: Timebanks as an innovative way of exchange

Timebanks

Timebank is a form of social innovation where members of a community can come together and help support each other through online platforms. For every hour of help provided, members can deposit time credits in a timebank, and they are able to withdraw equivalent support in time when they themselves are in need of help by a fellow member. Because timebanks are just systems of exchange, they can be used in an almost endless variety of settings. It is a way of linking up people in a community and share their time and skill sets. It also enables members to tackle loneliness, and to improve their health and well-being. There are over 290 timebanks in the UK[15] and over 200 in the United States[16]

One notable example is the social enterprise Give&TakeCare[17] founded in the UK in early 2016. Give&TakeCare works together with a charity for the elderly to match the skills of caregivers with the needs of the elderly. Every hour of volunteer work can be logged in the timebank, and can be exchanged for care later in life. This intertemporal care-system, once it attracts a critical mass of members, could have a great potential to ease the healthcare and social pressure of

[15] See www.timebanking.org
[16] Se e www.timebanks.org
[17] See https://www.giveandtakecare.co.uk/

ageing societies. The UK government has recently awarded one million pounds for the organisation to support its activity.[18]

Recent examples of social innovation include energy cooperatives, forms of collaborative consumption such as car sharing clubs, alternative currencies, new models of investment and ownership, novel forms of drug rehabilitation, education and training, and new forms of organization such as social enterprises and co-operatives (Boelman et al 2014).

New and emerging social innovations

In recent years, substantial technological changes have reshaped the economy and the global financial system. Innovations in payments and credits are not only transforming the mechanisms of transactions and finance, but they also have the potential to reach and meet the needs of millions of people with no access to formal or capital (see examples for new forms of access to capital in Box 9). Furthermore, the technology behind digital money (blockchain, see Box 10) may revolutionize the way we manage everyday transactions of anything that presents value.

For instance, there is a wide array of emerging models for financial transactions. Digital money (Bitcoin) and digital currency exchange services (Remitly, TransferWise, Xoom), often used to make international payments such as remittances, are saving hidden costs for customers and dramatically decreasing the fees of transactions by eliminating financial intermediaries. Mobile payment systems (M-Pesa in Kenya, Smart in the Philippines, bKash in Bangladesh or EasyPaisa in Pakistan) are extending financial inclusion for millions of people in developing countries. Customers with mobile phones can receive money faster, more conveniently and at less cost while they make person-to-person payments, money deposits and withdrawals, remittance deliveries, bill payments, or microcredit transactions. Other financial services like digital wallets (such as Paypal, Paypass, Google Wallet or Apple Wallet) make payments faster and more secure. Customers can save time when filling out order forms online, make payments up to a limit instantly, and the benefit from encryption. While these technology-driven services were developed on a "for-profit" basis, they have very important social implications by providing financial inclusion for millions and decreasing financial transaction costs.

Box 9: Innovations to creatively provide access to financial capital

New approaches are also reshaping the traditional ways to access capital, creating alternative sources of finance and contributing to community and business initiatives that might not get funds through traditional credit markets. Some of the emerging fundraising models include

[18] Source: The Economist: A time-banking scheme aims to overcome Britain's crisis in care for the elderly. 17 December 2016. Available at: http://www.economist.com/news/britain/21711844-young-people-who-volunteer-now-could-bank-hours-credit-be-redeemed-kind-their-own.

among others crowdfunding, peer-to-peer lending, and social impact bonds:

- Online crowdfunding platforms (like Kickstarter, Indiegogo, Crowdfunder) propose two business models: either funders donate to members with business ideas in return for products, perks and rewards, or businesses seeking capital sell ownership stakes online in the form of equity or debt. Crowdfunding is currently predominantly a developed world phenomenon, but it could become an important tool for fundraising in the developing world as well. For instance, in Iran websites such as hamsaa.ir, iChallenge.ir, and genew.ir are platforms for crowdsourcing solutions for both public and private problems.[19]
- Peer-to-peer lending is the practice of lending money to consumers and businesses through online services (Zopa and Funding Circle in the UK, Prosper and Lending Club in the USA) that match lenders with borrowers. Platforms like Kiva for example allow people to lend money online to low-income entrepreneurs or students in developing countries.
- Social impact bond is an emerging financial mechanism for the public sector to improve public service delivery. Socially motivated private investors pay upfront for a set of interventions to improve a social outcome (housing, health, education, welfare, etc.) and they receive payments from the public commissioner based on the results achieved by the projects. Social impact bonds are in an early stage of exploration mainly in developed countries (Australia, UK, USA), but their 'pay for success' approach could be a model for projects in developing countries (e.g., South Africa where some initiatives have already been launched).

Box 10: Blockchain technology

Blockchain is a distributed digital ledger technology, where the information is recorded and shared by a peer-to-peer network using state-of-the-art cryptography. Each member has his or her own copy of the digital ledger (a database) and must validate updates collectively without a governing central authority. Blockchains not only have the potential to digitalize financial transactions in a decentralized and secure way, but they also may replace various traditional ledgers used in public administration or by businesses. Bitcoin is only one possible application of the blockchain technology that can be adapted to challenges in both developed and developing countries (especially in sending remittances at marginal costs). Blockchain is seen by some experts as a potentially transformative technology, with far-reaching iumpact including on the world's poorest people ,

Bitcoin and other blockchain services are still in early stages and a number of technological issues (e.g., security, achieving a critical mass of users, need for exponentially increasing computing power as the network grows, coding of traditional contracts into computer-based rules, etc.) can hinder their wide proliferation. The lack of regulatory oversight and the pseudo-anonymity of transactions may provide alternative mechanisms for terrorist financing and

[19] Contribution from the Goverment of Iran.

illegal transnational sales (see OECD 2016). Furthermore, currency volatility and cyber-hacking could invalidate the use of the blockchain platforms as credible, predictable, and reliable.

Innovations such as blockchain, crowdfunding, and peer-to-peer lending emerged as new solutions to minimize transaction costs and finance ideas which would not have been possible through traditional sources. These new platforms and approaches hold potential to addressing development challenges, for example in cutting transaction costs of remittances (SDG 10). The long-term effects of these innovative ideas are not yet known, and one also needs to consider the relative size of alternative finance compared to traditional finance in the long term. There are many open questions on how to create capabilities in developing countries to harness these new technologies. They have the potential to reduce the financial dimensions of the digital divide (e.g., mobile banking and remittances), but they may also reinforce or create new divides (i.e., where transactions becoming cheaper for those with access to innovative financial platforms and more expensive for those without such access).

2.4.1 Potential contributions to the SDGs

Given the explicit focus on addressing unmet human needs through new social practices and institutions, social innovation is likely to address aspects of the SDGs that stress *inclusion* and greater *equity*, especially in areas such as education, health, work and poverty reduction. Examples include:

- Education initiatives that cater to children who fail in mainstream institutions;
- Models of finance that provide credit to people not included in mainstream banking systems;
- Models of agricultural production and distribution that improve the incomes and working conditions of small scale producers and farm labourers;
- Initiatives that build capacity within communities to advocate for their needs; or
- Novel mechanisms for coping with conflict, displacement and corruption.

Since most social innovations seek to address problems and issues that both markets and states ignore, or fail to adequately cope with, they often constitute challenges to existing business models, existing systems of production and consumption, or incumbent models of social and welfare provision. As many commentators point out, they can therefore usefully be thought of as forms of experimentation with novel, potentially transformative, institutional and societal changes (Kemp et al 2015). This is highly relevant for the SDGs, since attaining many of the goals will arguably require transformative, rather than incremental, social and technological change (e.g. Schot & Steinmueller 2016). As such, many social innovations have substantial value as sites of experimentation with new ideas and practices, beyond their direct and immediate impact on beneficiaries.

It is important, however, not to exaggerate the potential of civil society-based social innovation. Many initiatives struggle to remain viable on limited resources (of time, staff and equipment as

well as funding), and are usually unable to do much about the wider structural causes of unjust and unsustainable social development that their interventions typically seek to remedy (Pel et al 2015).

2.4.2 Policy considerations and challenges

Over the last decade, policies to support and foster social innovations have been implemented in a number of countries. In part this reflects general interest in citizen engagement in innovation, but the main drivers are government retrenchment from the public sphere, budget constraints, a desire to support a more user-based, demand-pull approach to public services, recognition of a disconnect, in the high income countries, between economic growth and well-being and, in Europe especially, stagnant economic growth and poor employment generation since the 2008 financial crisis (Hubert 2010; OECD 2011; Bonifacio 2012; Totterdill et al 2015).

Policy attention is typically motivated by a desire to encourage social innovation, identify and foster innovations that appear promising, especially in areas of traditional public welfare and policy (e.g. youth development, employment training, and education), and to transfer, replicate and scale-up those that work. For instance, in the USA, the Social Innovation Fund provides both grants and managerial and technical support to community initiatives that "…displace stale, ineffective [public] programs", describing itself as concerned with "finding what works, and making it work for more people".[20] The European Commission also aims to encourage market uptake of social innovations, through funding mechanisms via its Employment and Social Innovation Programme; networking support; an annual social innovation competition[21]; and the financing of research about social innovation and the conditions under which it can best be supported.

Social innovation interventions face a number of challenges. First, given the *ad hoc* nature and community-based origins of many social innovations, the dynamism and nature of civic interest is central to enabling informal, 'solidarity-driven' entrepreneurial activity (rather than funding availability and governance arrangements more generally). This means the main drivers of social innovation are the ecosystem of networks and the groups and individual bound together by a shared vision of solidarity (Millard et al 2016). Yet this cultural context is difficult to affect through public policy, or at least through policies that are focused on innovation. Other policy areas such as education, culture, and other areas of public provision are more relevant given their primary focus on social infrastructure and the civic realm. Researchers suggest that funding and other support (such as network facilitation, advice and training) remain important, but amongst the most useful policy interventions to encourage social innovation are likely to be efforts to promote 'open policy-making'; that is, flexible modes of long-term collaboration

[20] http://www.nationalservice.gov/programs/social-innovation-fund/our-model

[21] In 2016 the social innovation competition involved a €150,000 prize shared by the three best ideas to support the reception and integration of refugees and migrants in Europe.Source: http://ec.europa.eu/growth/industry/innovation/policy/social_es

between public bodies, NGOs, users, and private actors, so that a range of voices, skills, competencies and resources are encouraged to, and can readily, come together around particular problems (Totterdill et al 2015; Millard et al 2016). However, such organizational culture changes can be difficult to foster.

Second, the desire on the part of policymakers to replicate, scale up and diffuse promising social innovations has to confront the diversity of local socio-political and cultural contexts and motivations in which social innovations occur, and this means that it is likely to be difficult to easily transfer innovations from one local context to another (Pel et al 2015; Millard et al 2016). There is also a danger, in seeking to scale up and diffuse exemplars of novel social practice, of losing sight of some of the underlying motivations that energise and prompt the innovations in the first place (which, for example, may be about fostering quite different social development pathways and social relationships to those championed by, or at least associated with, those mainstream institutions that are attempting to foster social innovation) (Smith et al 2016). There is also the risk of engendering scepticism that social innovators are being co-opted to substitute for effective public provision. Policy initiatives in support of social innovation are as experimental as the initiatives they seek to foster.

Finally, in terms of opportunities for international collaboration, most of the policy initiatives to support social innovation have so far had a national (or regional) focus. Nevertheless it is notable how many social innovations that have been successful, in terms of operating at scale (such as car clubs) have readily been implemented in many different jurisdictions.

2.5. Digitally enabled open and collaborative forms of innovation

Collaborative innovation enables knowledge and technologies to be produced across a multiplicity of actors and institutions, drawing from an immense pool of both formal and informal knowledge. There are two key requirements for enabling collaborative innovation: (a) open access to knowledge, and (b) wide participation in the process of developing ideas, products and technologies. Of course, collaboration and participation is nothing new, but what it is novel in collaborative innovation is the intense use of the internet, digital technologies and social networks in order to foster learning, enable the co-creation of (codified) knowledge, and to provide widespread access to tools, data and resources.

This combination of open access to resources with new modes of online engagement is allowing open digital collaboration to solve some kinds of problems at a much faster pace than within the more traditional, closed, institutional arrangements for organizing innovation (See Box 11). Some researchers have suggested that the mere fact of being able to share, validate or discuss different ideas, assumptions or avenues of inquiry, allows online communities with innovative purpose, such as open science or open software communities to amplify collective intelligence (Nielsen, 2012 and Benkler et al, 2015). Collective intelligence works by increasing efficiency through avoiding repetition and through maximizing the use of resources with openly

sharing ideas; and by allowing dynamic efficiencies by drawing ideas from a huge pool of collaborators from different institutions, locations and disciplines and other forms of expertise.

Box 11: Forms of collaborative production

Open innovation 1.0: It refers to new forms of collaboration between firms along value chains in order to enhance experimentation and R&D capabilities. The fundamental idea of open innovation 1.0 is the need for firms to connect their internal innovation with external ideas coming from other institutional actors, including suppliers, clients and public labs. The typical case of Open Innovation 1.0 documented by Chesbrough (2003) is the Xerox Palo Alto R&D Research Center (Xerox PARC). Xerox PARC developed many of the ideas and innovations of the information and communication technology revolution, but did not profit directly from those technologies. Those technologies included the Ethernet network protocol (3Com), publishing technology (that led to Adobe company), and the graphical user interface for PCs. Instead, Xerox licenced many of these innovations and allowed their employees to create their own companies.

Open innovation 2.0: It is based on the idea that innovation should involve not only large institutional players such as companies and R&D labs but also end users and other civic actors. Though this is an evolving term, the basis of open innovation 2.0 is the possibility of creating interdependence among different actors in order to foster innovation. Thus, open innovation 2.0 benefits from developments in social networks, internet resources and new tools such as the use of big data to foster more fluid forms of interaction. In practice, Open innovation 2.0 requires building connective infrastructure such as open data, web platforms, fab labs and/or civic labs in order to create knowledge interchanges between different forms of expertise and to seek cross pollination of ideas with a wider range of actors. Open innovation 1.0 and 2.0 differs from commons based peer production in that it retains its aim to capture value through private mechanisms (Chesbrough, 2006).

Key elements for widespread participation in open collaboration are the modularity of the objects (that allows them to be set as independent tasks), fine granularity of the modules (that allows small contributions from different participants) and availability of low cost integration mechanisms and quality control (including rules for social collaboration, open licences, etc) (Benkler & Nissenbaum, 2006). Heavily based in the organizational mode of operation of open software, a new mode of open collaboration is fostering a new way producing knowledge in science (open science) and technology (open hardware).

Open, collaborative innovation is often facilitated through digital online networks, but can benefit from spaces where face-to-face interactions, relationship and trust-building can take

place. These may take the form of hackathons or civic innovation labs (See Box 12). They may also take the form of more permanent structures. Funded by a range of donors, including foundations and private sector entities, the iHub complex in Nairobi[22] represents an example of this kind of co-working space, where entrepreneurs can gather, network and receive access to mentoring, infrastructure and other resources such as financing. Just one of a number of tech hubs across Africa, it differs from others such as CcHUBNigeria, which has since its establishment in 2011 focussed on social issues (Espinoza 2014).

Box 12: Spaces for open innovation

Hackathons

Hackathons are co-design marathons that originated in hacker culture to speed up the creation of solutions to certain problems. Typically, hackathons last from one to five days and are organized around specified challenges. People assisting hackathons usually coming from a variety of backgrounds and disciplines (from software, electronics, social sciences, etc.). There are different models for a hackathon, but usually people tend to self-organize in groups around a certain problem and compete to solve it using different approaches. Hackathons create bonds and community among developers, they let people experiment with different ideas and learn about new techniques, but they do not necessarily produce new products or polished solutions (Broussard, 2015). Public institutions and companies have started to use hackathons to kickstart new solutions to complex problems. For instance in 2015 USAID have organized a hackathon to design improved protective suits for medical professionals fighting the Ebola outbreak. That hackathon involved doctors, engineers, public health experts and fashion designers designing a prototype suit later chosen to be funded by USAID (PBS Newshour, 2015).

Civic Innovation labs

Civic innovation labs are spaces supported by local and/or national governments and focused on generating innovations to improve governance, public service management and citizen participation. Issues covered by Civic labs included, for example public transparency, transport efficiency, and urban planning. Civic innovation labs are usually based on participatory design techniques, are often open to the general public, and can be characterized by collaboration between citizens and public officials, sharing public knowledge and experimentation or prototyping new solutions to urban and regional problems. Examples of these labs include the Office of Social Innovation and Civic Participation founded by the USA in 2009 the with the aim of pursuing civic innovations in the public sector, and the Secretaría General Iberoamericana, which since 2014 has been organizing civic labs (called LABIC in Spanish) in different cities in the Latin American region[23].

[22] See http://ihub.co.ke/
[23] See: http://www.ciudadania20.org/#about.

Collaborative innovation combines participatory design techniques, as developed in grassroots innovation movements with the documentation and protocol practices found in science in order to create highly interactive forms of knowledge creation that are enhanced by the use of internet and social networks (see Box 13 for an example). Collaborative innovation can be regarded as a real change of paradigm in knowledge production that includes open science, open government, open software and open hardware and also new networks of collaboration and experimentation such as the maker movement, fablabs and hackerspaces. Interestingly, although these approaches and fields share a lot of characteristics and tools they are not necessarily connected with each other and their communities of practice are, to a large extent, independent of one another.

Box 13: Open Source Ecology (relevant to SDGs 2, 7 and 9)

Open Source Ecology: This initiative was created by a former PhD student in Nuclear fusion, Marcin Jakubowski, who started his own farm in Missouri. Unable to repair his own tractor, due to the cost of replacement parts, Jakubowski decided to create a ´Global Village Set´ following the philosophy of open source software. The Global Village Set is a challenge to create 50 tools that any farm will need in order to be sustainable and autonomous.[24] The philosophy of Open Source Ecology is that access to tools and machines is not a question of lack of resources but of their unfair distribution. By making available blueprints and instructions, Open Source Ecology seeks to make tools accessible to everyone, especially those in small communities, in order to create a sustainable society.

Open source ecology has been experimenting and building with the village set for the last 5 years and they already have about 20 prototypes. They offer blueprints and instructions (including tutorials on youtube.com) about how to make the tools and offer in-house workshops. By sharing their designs online, they have allowed a large network of people to collaborate in the design of the machines, and to improve and modify them to make them suitable for new uses. A survey in 2014 counted 110 replications of the designs from the Global Village Set in the USA, Chile, Nicaragua, Guatemala, China, India, Italy, and Turkey.[25]

Open Source Ecology is an obvious inspiration for other makers and entrepreneurs, but it can also provide lessons for existing R&D institutions. There are huge opportunities in opening up access to the technical blueprints of agriculture machinery, renewable energy and water/sanitation technologies that have already been developed by R&D institutions. Making those designs available could help local actors to gain new knowledge, develop their own tools and also help to improve available technologies.

[24] See http://opensourceecology.org/gvcs/.
[25] See http://opensourceecology.org/wiki/Replication.

2.5.1. Potential contributions to the SDGs and opportunities for international collaboration

Many forms of open and collaborative production have already been heralded as practices that can help to tackle SDG challenges. From the use of hackathons to find solutions to Ebola and the use of citizen driven data to monitor environmental and social phenomena (Fressoli, Arza & Castillo, 2016), to open science and data sharing schemes to solve neglected diseases (Masum & Harris, 2011), multiple initiatives are being pursued and tested (see Box 14). Given the intractability of many of the problems that need to be resolved in order to address the SDGs, a number of authors have argued that the use of open and collaborative practices are helpful because they can diminish barriers to innovation, accelerate the pace of innovation and help foster a more democratic approach to resolving complex and contested issues (Nielsen, 2012; Masum & Harris, 2011).

Free software projects provide a remarkable example of open collaborative innovation. For example, proprietary operating systems like Windows faced significant competition from open source alternatives like Linux which were developed through open and voluntary collaboration from software developers across the world.[26] Open source software is currently used by multinationals, governments and citizens around the world, allowing tools to be adapted by users and lowering the economic and technological barriers to the use of computers for almost any aspect of the digital world.

Although the practice of open and collaborative innovation has been quite successful in software, there are considerable challenges in trying to translate this approach to other areas like open hardware or open science. Maintaining open designs and code and avoiding restrictive forms of appropriation are key. So is the challenge of encouraging the development of wider capabilities, so everyone interested can become a maker of their own tools, and of creating viable business models through which open and collaborative innovation can flourish. Without significant empowerment of actors that are excluded from conventional innovation and development processes the notion of open and collaborative innovation might easily remain a practice that is exclusive to elites and those who already have access to advanced technology. At the same time, the practice of open software is not easily translated into other areas such as open hardware due to material and capital requirements, increasing tacit knowledge requirements, etc. In other forms of open and collaborative production such as open science, open access to papers and data helps to democratize the access to knowledge; however there are still questions of accessibility (who has the knowledge and skill to use available scientific data) and participation (how can citizens help to produce scientific data and being empowered at the same time) (see Arza & Fressoli, 2016)

[26] In fact, Microsoft has recently enabled open source development by adding the Linux command line to Windows 10.

Box 14: Other forms of collaborative production

Open science

Open science allows scientists to collaborate in different stages of the research process with scientists from other disciplines and other parts of the world. In some cases, open science also calls for the collaboration of the public in citizen science projects such as e-Bird (see Box 15), Galaxy Zoo and others. Open science practices are inspired and generally based on similar principles to the open source software movement. They seek to share data, outcomes, tools and problems and also the efforts of producing relevant knowledge. Web-based and electronic tools have created enormous opportunities to scale up and speed up openness and collaboration (see Box 12). Supporters of open science claim that these practices increase the efficiency of scientific production by fostering collective intelligence for the resolution of complex social problems, and that they empower local populations whose interests get to be better reflected in research agendas and allow better access to the latest scientific findings (see Woelfle 2011; EU Commision, 2016b). It should be noted, however, that open science may not be applicable for every context, and that quality control may be problematic in some setups.

Citizen driven data

Big data is sometimes regarded as the "new oil" of the 21st Century and companies, governments and civic organizations are paying increasing interest to the potential role of data in development. For instance, the United Nations Secretary-General's Independent Expert Advisory Group on a Data Revolution for Sustainable Development (IEAG) have argued that grassroots-based data production initiatives could have a relevant role in monitoring the SDGs. Citizen driven data is a practice that uses available data or produces new data in order to make visible hidden problems and processes and to create reliable information in relation to issues such as climate change, environmental pollution and inclusive development. Citizen driven data usually relies on cheap, flexible tools such as: participatory workshops, web forms, cell phone applications, low cost sensors, and social networks to collectively gather and distribute data with the help of engaged citizens. Since data activism usually crowdsources information through voluntary contributions from the public and uses open source tools, the practice can potentiality be replicated and adapted by small organizations at little cost. Examples of data activism include: the Ushahidi[27] app created in Kenya, and the project Territorio Indígena[28] by Amnesty International Argentina (see Fressoli, Arza and Castillo, 2016).

[27] Ushahidi, which translates to "testimony" in Swahili, is an open-source project which allows users to crowdsource crisis information to be sent via mobile phones. It was developed to map reports of violence in Kenya after the post-election violence in 2008 (https://www.ushahidi.com/).

[28] Territorio Indígena is a web platform that refers geographically to specific conflicts affecting indigenous communities. Over 180 conflicts have been included on the platform. The website invites visitors to produce information on conflicts not reported on the platform, using a specific form. Project organisers then move to validate data collected in this way (http://www.territorioindigena.com.ar/).

Opportunities for international collaboration

The methods of open, collaborative innovation are spreading to other areas such as open science and open hardware, with implications for North-South, South-South and multilateral collaboration. The combination of open hardware and open science is allowing scientists in developing countries to obtain access to tools and instruments that are either expensive or difficult to import in their own countries. This open labware phenomenon is not circumscribed to marginal actors. CERN (the European Organization for Nuclear Research) has been working on open hardware since at least 2013 and have recently launched a repository for open hardware and are promoting its own license to share designs and knowledge while assuring the proper documentation of modifications (Gibney, 2016).

In a similar vein, the Open labware initiative, organized by TReND (Teaching and Research in Natural Sciences for Development in Africa), the Open Neuroscience initiative and the Baaden Lab, are promoting the collaboration and construction of low cost, open scientific equipment for developing countries for educational and research purposes. The initiative includes designs and tutorials to 3D print tools such as optical fluorescence microscopes with optogenetics and temperature control, a motorized micromanipulator to handle very small biological samples (around 10 microns), and 3D printed micropipettes (see https://open-labware.net/). The consortium´s article explaining the methods and uses of open hardware in lab equipment published in Plos Biology, has been downloaded more than 50,000 times (Baden, Chagas, Gage, & Marzullo, 2015).

2.5.2 Capabilities and digitally enabled open and collaborative innovation

Collaborative innovation allows diverse participants to contribute, in their own time, from different locations and on the basis of heterogeneous forms of expertise and qualifications. For instance, open science projects such as e-BIRD (see Box 15), have more than 300 thousand contributors from very different backgrounds who share their time and expertise for scientific and recreational purposes. However, for these kinds of projects to thrive there are certain minimal conditions that need to be in place, namely:

- Basic literacy
- Internet connectivity and access to digital networks (without political, monetary or bureaucratic restrictions)
- Open access to existing scientific and technological information
- Flexible intellectual property rules that do not discourage users from contributing to project, and that allow fair use of their contribution

Other contributing elements include: physical space (e.g. as with makerspaces) that enable the use of online tools with hands-on learning, open repositories of scientific and technological knowledge. In the case of open science, there are also specific requirements for citizen

participation such as use of plain language, easy to use instruments, really simple protocols for data collection and visualization tools to understand complex data.

Box 15: e-Bird: from citizen science to open science collaboration (SDGs 13 and 15)

With more than 300 thousand online collaborators globally, e-Bird is one of the most successful cases of open, online collaboration based on citizen science ideas. The online platform was developed in the United States in 2002 by the Ornithology Laboratory at Cornell University and the National Audubon Society. It is a free access tool to manage and share online data of bird sightings by amateur and professional watchers, built on the simple concept that each time a watcher picks up their binoculars they have the chance to gather useful information about bird sightings. e-Bird makes use of free software tools and online collaboration to not only efficiently gather and archive but also distribute information about birds to a wide audience. The large amount of data collected by e-Bird, for example on the spatial distribution of species and on population trends, can help identify important areas for bird conservation and contribute to the design of better plans for managing threatened species. Given the sheer amount of data compiled by e-Bird scientists have also started to use machine learning techniques and machine visualization to model migration patterns in the US.[29]

There is substantial high level interest amongst scientific institutions, funding organizations and policy makers in open and collaborative practices in both open science and open innovation (Boulton et al 2012; RIN NESTA 2010; OECD 2015; Rossel 2016; Commission High Level Expert Group on the European Open Science Cloud 2016; EU Commision 2016). Policies to support open access and national public repositories for science have also being implemented in countries like Argentina, Peru, Mexico and South Africa[30].

Understandably, public policy and institutional recognition in areas like open science have focused on areas where there are existing capabilities or where it is easier to create them (such as requiring use of open digital repositories). However, other aspects of open and collaborative practice such as open hardware or citizen participation in data collection and analysis have received comparatively less attention. These are precisely the areas of collaboration where the production of knowledge faces higher barriers since they combine scientific expertise with other forms of informal expertise (such as community management, public communication of science, etc.) and/or because they require the use of novel participation techniques (see Mansell, 2013). To realize the potential of open and collaborative practices will require combining technical “hard” resources such as data repositories with more “soft” capabilities

[29] See http://ebird.org/content/ebird/occurrence/

[30] See the web site Melibea, available at: http://www.accesoabierto.net/politicas/default.php

such as organization skills, new communication tools (such as gaming, data visualization techniques, webinars, etc.).

2.5.3 Policy implications

Collaborative innovation projects like those in the field of open software and open hardware benefit from self-learning mechanisms such as online courses or online repositories and wikis that allow other users to follow protocol and learn in the process.[31] These kinds of practices, coupled with increasing participation in open knowledge production, can help foster the development of new capabilities in science, engineering, design, electronics and software. However, as previously noted, open and collaborative practices could be very disruptive for incumbent actors who are afraid to share their knowledge and resources (see for example Sheliga and Friesike, 2016).[32] Also, tacit knowledge and some engineering skills are not easily translated into digital collaboration and could require years of apprenticeship. In order to face these challenges, there is a need to develop new incentives, models, infrastructure and skills that could help realize the potential of open collaboration, especially in developing countries. Some of the issues that should be considered in the design of open digital collaboration policies are the following:

Developing new online infrastructure: Open collaboration platforms such as digital repositories for sharing data and technological designs, tutorials and massive online courses could help to democratize access to available knowledge and foster the creation of new communities of practice.

Building tools for open and collaborative practices: Although there is considerable interest in developing open access repositories for data produced by governmental institutions and scientists, there is much less interest in other services, such as public repositories for open hardware, platforms for citizen science and new communication tools. New infrastructure for open collaboration should strive to include as many participants from different backgrounds as possible, and to include them as active collaborators.

Building hybrid spaces of innovation: One of the most challenging aspects of open and collaborative production is how to manage the diversity of participants and expertise available, and how to provide spaces that allow experimentation with new technologies and ideas. Many conventional institutions are sometimes reluctant to host open innovation spaces, such as makerspaces or fab labs, often related to the lack of capabilities and resources to manage such

[31] For instance, massive online open courses (MOOCs) are creating a new platform of distributed learning. See http://unctad.org/meetings/en/SessionalDocuments/ecn162016d3_en.pdf.

[32] On the other hand, open source can be part of a competitive strategy for private firms. Some firms may create an open source platform to commoditize software tools that would alternatively be provided by market competition. Furthermore, contributions to an open source platform could help the firm benefit from contritbutions outside the firm as well as identify and recruit talent to the firm.

initiatives. Physical spaces are key to enabling meeting with other experts, learning by doing and for creating new projects.

Documentation and Inter-operability: Another important aspect of collaboration is the need to develop protocols for good documentation of the development and inter-operability of data. This is more easily said than done, since information can come from many different institutions and disciplines. Finding ways to make open data available and easily legible to different actors is an important challenge for public policies.

Developing new incentives: There is a need to develop new incentives for open collaboration and sharing data among R&D institutions and governmental offices. Such incentives will have to find a way to balance established policies for the commercialization of knowledge, but also to overcome cultural barriers to openness.

Chapter 3. Key policy considerations

The discussion presented in this document illustrates how new and emerging approaches to innovation can, and already are, contributing to the realization of the sustainable development goals. It provided an overview of different approaches, characterizing them on the basis of broad themes, rather than compartmentalising them into 'models'.

The characteristics of the new models of innovation can enable them to better address the needs, interests and perspectives of poorer, marginalized communities, and better serve non-market and environmental goals than traditional, linear models of innovation or conventional innovation systems approaches. This is particularly important given the resource constraints faced by many developing countries, the current levels of innovation capabilities and the transformative changes necessary to realise the SDGs.

Whilst each of the new and emerging approaches to innovation discussed above is potentially able to contribute to any of the SDGs, their utility was illustrated through case study examples. Table 2 gives a summary of the different approaches and examples.

Table 2: New and emerging approaches to innovation, with illustrative examples (and relevant SDGs)

Section/title	Other labels	Inclusion potential	Capabilities required	Illustrative examples (in boxes)	Relevant SDG(s)
2.1. Mission-oriented innovation	Grand challenges; Global challenges	Variable, depending on mission	Finance; agenda-setting and good governance; co-ordination; sophisticated research infrastructure	Fighting Ebola Grand Challenge	3, 9 & 17
2.2. Pro-poor and inclusive innovation	Bottom of the Pyramid; frugal; pro-poor; inclusive; jugaad	Inclusion of consumption/ impact	User's needs; scaling up; marketing; entrepreneurship	GE Low cost ultrasound scanner	3
				Mitticool fridge	1,2, 7 & 9
				Unilever Shakti	3 & 8
2.3. Grassroot innovation	Inclusive; grassroots; informal	Inclusion of process/ structure	User's needs; empowerment; mobilisation; internet connectivity (in some cases)	Maker movement	9, potentially 12
				One Million Cisterns Project	6 & 2
2.4. Social innovation	Social; organisational; supply-chain	Inclusion of impact/ process/ structure	Entrepreneurship; non-monetary incentives	Time banks	8 & 10
				Crowdfunding, peer-to-peer lending, social impact bonds	8, 9 & 10
				Blockchain	8, 9, 10, potentially

					16
2.5. Digitally enabled open, collaborative innovation	Open innovation; innovation ecosystems;	Inclusion of process	Basic literacy; internet connectivity and open access; flexible intellectual property rules; infrastructure	Open source ecology	2, 7 & 9
				Citizen driven data	13 & 15, potentially all

This chapter details various policy considerations that should be taken into account when examining new innovation approaches and their potential to contribute to the SDGs. The previous chapter illustrates a diversity of new and emerging innovation approaches, and the multiple objectives (beyond inclusion in its many forms) prioritized by different stakeholders. The analysis shows that rather than a limited number of 'models', diverse new organizational forms and policy mixes are required, suited to the different historical, environmental and cultural contexts seen in developing and least developed countries with varying levels of capabilities. At the same time, it also argues that the hybrids between these various approaches are often the most potent means for innovation to serve multiple SDGs. However, this creates challenges for policy and governance.

This chapter discusses general policy implications and recommendations and addresses considerations for strengthening capabilities in these new and emerging innovation approaches, with a specific focus on the role of digitization as an enabler of open collaboration. Furthermore, it considers the governance challenges associated with these new approaches, including considerations for priority-setting with multiple stakeholders. Finally, additional questions for policy and governance at national and international levels are considered.

3.1 Policies to facilitate new, emerging and hybrid innovation approaches

Each of the 'new approaches' described above can – as illustrated in the boxes provided - make important contributions to the SDGs. However, many of the most marked impacts will come from 'hybrids' between them, and with more conventional approaches (Ely *et al.*, 2013; Smith and Arora 2015). Hybridization can occur, for example, when initiatives created at the grassroots level, or through pro-poor innovation processes, for example, subsequently receive support (e.g. in the form of investment, joint R&D, and marketing) from more conventional science and technology institutions. The emergence of a large, successful commercial global wind energy industry, for example, has roots in the development of small-scale wind turbines and energy cooperatives in Denmark in the 1970s. At the same time, grassroots initiatives may adapt technologies that have emerged from conventional innovation processes, such as the digital design and fabrication equipment that makerspaces draw on to promote commons-based forms of production. This attention to hybrid innovation approaches involves widening the policy focus of innovation systems (Ely and Bell 2009), both in terms of the actors involved and their means of interaction and collaboration – a more general policy implication of this paper.

In a recent Fraunhofer ISI discussion paper, Warnke et al (2016) consider this broadening of the innovation system to include new actors and intermediaries, pointing to the "the need for a more radical revision of the innovation system analytical construct". The concrete implications of this new approach for policy are poorly understood and deserve further future research (see 'governance challenges' below), however the following are offered as general policy recommendations:

- Infrastructure and network facilitation;
- Financing and Incentives; and
- Regulation.

Infrastructure

Collaborative innovation involving commons-based peer-production requires both digital infrastructure (see below), as well as material infrastructure to permit face-to-face encounters (coordinated or fortuitous) between innovation actors such as through Hackathons or other spaces for open collaboration (see also Smith and Stirling, forthcoming). These forms of infrastructure can act in a similar way to traditional incubators (which provide services and resources to start-up firms, for example in specific sectors) but reach out to broader groups. Institutional support to build bridges between formal and grassroots innovation, other forms of infrastructure such as repositories and innovation platforms, and mechanisms for international network facilitation (see section 2.3.2) can further strengthen these kinds of hybrid activities.

Financing and incentives

Financing research and innovation around specific 'missions' can act as an important incentive for hybrid innovation and incentivize collaboration between different stakeholders (especially with the considerable large amount of financial resources outlined in section 2.1.2). Some researchers argue in favour of "redesigning the way society invests in innovation and looks at new ways of supporting a wider diversity of sites of innovation activity", pointing to both crowd-funding and public investment (Smith and Stirling, forthcoming).

At the same time, enablers and barriers to hybrid innovation are not necessarily financial but often linked to other motivations. Some scholars recognise multiple motivations (not just monetary, but also ideological or cooperative) in innovation (Warnke et al 2016, citing Rifkin 2014)) A similar insight has also been applied to grassroots innovations in India where intrinsic (e.g. duty or dharma) motivations often play an important role in driving local innovation but may be negatively affected by policies that focus on 'extrinsic' (monetary support, rewards, and patenting) motivations (Bhaduri and Kumar 2011). Under such circumstances, the generation of a vision and the formation of a community of actors committed to shared goals enhance the possibility of innovation. Beyond this, non-monetary benefits, such as recognition through awards (raising the innovators' profile, providing them with legitimacy or access to networks) can play a role.

Whilst governments are relatively new to some of the more novel financing approaches (however see section 2.4.2), organisations such as the World Economic Forum, Ashoka, and others have been using these approaches for many years. Key policy considerations, as far as financing are concerned include:

- the choice of economic instrument used (e.g. prizes, advance market commitments) and their design – as noted in section 2.1.2, this is a specialist task and bad design can lead to perverse incentives
- how to combine 'vertical' and 'horizontal' approaches to funding (Ooms et al 2008). In the area of global health funding, for example, vertical financing can be described as "aiming for disease-specific results" and horizontal financing as "aiming for improved health systems". A "diagonal" approach is defined as "aiming for disease-specific results through improved health systems."
- opportunities for combining financing at a national level with other actors (see section 2.1.1).
- the processes for identifying the 'mission' – ensuring that they are robust and respond to the priorities of multiple stakeholders – see also 3.3 below.

Regulation

Regulatory instruments can help to shift the direction of innovation towards SDG targets, support some of the emerging approaches or help to bring industrial activities that are inconsistent with the SDGs to a halt. Command and control policies (e.g. technology forcing standards on polluting industries to incentivize the diffusion of cleaner innovation), or economic instruments (e.g. pollution taxes, emissions trading) have long been used to induce innovation towards improved environmental performance (Porter and Van der Linde 1995; Berkhout and Gouldson 2003). These approaches have been practiced for many years alongside policies to support innovation systems. More recent work has shown how policy mixes, including economic instruments, regulations and information measures (which links to network facilitation) can combine to support innovation in the renewable energy industry (Rogge et al 2015).

The distributed, multi-stakeholder nature of many new and emerging approaches to innovation necessitates new, additional forms of regulation, providing the conditions that will enable them to flourish. Public procurement regulations that promote specific open (e.g. creative commons) or mission-oriented (e.g. linked to particular programmes) initiatives can act as demand-pull measures to support innovation for the SDGs.

In science systems, regulating for open access online publications (rather than researchers being assessed, for example, on their production of copyrighted material) can enhance collaboration. Regulating against appropriation of 'open' data or knowledge is much more difficult, but digital badging, for example, can offer a way for authors to mark their outputs (e.g. journal articles) as open (containing open data or materials) to signal the intent that it be available for unrestrained use.

At the same time as these new regulatory approaches can be beneficial, old, and outdated regulations, including inadequate intellectual property frameworks, must be reformed. As traditional innovation systems display path dependency based on their historical developments, institutions and interactions may be locked-in or overly bureaucratic, and act against the kind of fluid experimentation required for the new approaches described above. Public sector organisations must be willing to experiment with and directly involve beneficiaries (described as civic innovation above), requiring changes in organizational culture (Smith and Stirling forthcoming) as well as bureaucratic systems.

3.2 Strengthening innovation capabilities

The innovation approaches described in this paper are diverse. Whilst they largely rely on similar innovation capabilities to traditional forms of innovation, some – in particular with regards to open digital collaboration - require new skills and infrastructures and benefit from different governance arrangements. This section outlines related considerations for national governments.

Innovation capabilities involve not only scientific and technological capacity, but often more importantly in the context of developing countries basic education, engineering, design and management skills (Bell 2009). Research and development generates new knowledge that can be applied through innovation but does not drive it, and – as such – investment in research and development, is unlikely to build innovation capabilities on its own. Instead, innovation capabilities come about as a result of investments across a range of skills areas and by processes of learning and interaction between innovation actors and across national borders (Lundvall et al 2009). At the micro-level, entrepreneurship training can provide a valuable addition to the introduction of new products and services that aim to be pro-poor.

Open digital collaboration requires similar levels of basic education and scientific and technological literacy to more traditional forms of technological innovation. It is therefore difficult to imagine 'leapfrogging' directly to these emerging innovation approaches. As discussed earlier online training courses such as MOOCs can themselves contribute to these challenges.

Beyond this, ICTs are a cross-cutting area for policy support and ICT infrastructure is a key consideration for developing countries – with internet access and quality incorporated within the indicators for SDG17. Previous CSTD priority themes on internet broadband for an inclusive digital society (UNCTAD 2013) and digital development (UNCTAD 2014) cover these issues in detail. Beyond these, however, the increasing role of smartphones in online digital collaboration deserves further consideration. Recent research has shown vast differences across national contexts, as well as gender and age-related divides in ownership and use of smartphones (Pew 2016). Open connectivity beyond, as well as within, national boundaries is an additional requirement if a country's innovators are to effectively connect with collaborators and participate in North-South, South-South and South-North learning.

3.3 Priority-setting with multiple stakeholders

Prior to crafting the mix of policy instruments described above, a key governance challenge (returned to later) is agenda-setting and the identification of national priorities. Especially under circumstances of constrained resources, technically-informed and politically-robust methods of setting priorities across multiple stakeholders are a key requirement.

'Broadening out' the inputs to such priority-setting by including multiple actors in the appraisal of sustainability options can lead to more empowering and robust policy approaches (Stirling et al 2007). With regards to STI, technology assessment (Ely et al 2011) and technology foresight (Van Zwanenberg et al 2009) are among the tools that can be used to identify priorities, with more networked and open approaches (Ely et al 2014) providing opportunities to simultaneously link up actors in extended innovation systems, both at national or international levels.

Whilst mission-oriented approaches require a degree of top-down management, the new and emerging approaches to innovation described in this Issues paper, in particular when enabled through open digital collaboration, often require government to provide a platform through which other stakeholders can contribute. As an example, the Indian Open Source Drug Discovery (OSDD)[33] initiative is a platform provided by the publicly-funded Council for Scientific and Industrial Research (CSIR), but it has enabled an evolving R&D portfolio including TB, malaria, and involving a diverse range of national and international partners from the research, university and private sectors. Thus, whilst identifying shared priorities is important, flexibility that allows different stakeholders to co-produce knowledge and shape the direction of innovation is a characteristic of such platforms.

'Broadening out' can also be hard-wired into funding (e.g. crowd-funding) mechanisms. The UK government's 'Longitude Prize', for example, allowed the public to choose the projects to be funded, introducing a democratic component to prioritization and mission definition (see section 2.4.4). Providing funds through mission-oriented approaches, especially when it involves larger investments than usual, can come under additional scrutiny from users of social media and a more networked citizenry. The appropriate response is to embrace this openness (through 'open policy-making' – see Totterdill et al 2015) rather than attempting to constrain the flow of information or debate, however this raises serious political as well as technical challenges for many developing countries (see section 3.5).

3.4 Digitization as an enabler for new innovation approaches

Digitization of data is an enabler for new and emerging innovation approaches, but "digital development" is not enough. Seeking, adopting and using knowledge and innovations requires human capital, market and non-market linkages and the kinds of capacity identified in earlier

[33] See http://www.osdd.net/.

studies of technological accumulation in developing countries (Bell and Pavitt 1993). Thus, whilst increasing digitization is relevant to information flow and access, it is important not to lose sight of more traditional capabilities.

Digitization can be most powerful when it allows aggregation and disaggregation of data so that it can be applied by various stakeholders addressing various goals to ensure that no-one is left behind (Data Revolution Group 2014). But beyond raw data and access (as discussed in the previous section), this requires protocols for sharing, and arrangements through which ownership and openness are governed. This can include licenses (creative commons, copyleft) and other ways of ensuring that there are no free-riders that extract and appropriate the shared knowledge that is being generated. Whilst such systems are becoming more and more sophisticated, further innovation in blockchains or digital ledger technology (DLT), which can be used to track different contributions to shared knowledge, may further enhance the efficiency of sharing (Sierra, 2016). Others suggest that blockchains could be used as more efficient means to regulate intellectual property, facilitate the sharing economy or further open up manufacturing (Tapscott and Tapscott 2016).

Artificial intelligence and machine learning offer further opportunities for enhanced collaboration across databases. As shown in the e-bird example, artificial intelligence could potentially bring together diverse data sources to address complex problems that characterize certain aspects of the 2030 agenda. At the same time, emerging technologies such as DLT and AI themselves raise questions about the distribution of benefits, costs and risks of innovation, returned to in the next section.

Digital collaboration offers huge potential, but it also raises challenges. As discussed in 2.5.2, it is not always easy to translate open software processes to open science or open hardware. Also, considerations remain about who can be involved and who cannot; much of the knowledge that is most relevant to the SDGs' focus on basic needs (whether associated with food security, gender equality or peace) is tacit and cultural, not modular or granular (Benkler & Nissenbaum, 2006), and cannot be digitised. Active research and governance are required to ensure that these forms knowledge are not 'crowded out' by the increased attention and resources being allocated to digital approaches.

3.5 Governance challenges at national levels

Whilst the SDGs are universal, specific priorities will be set at regional, national and local levels through a combination of technical and democratic processes (Day et al 2013). Coordinating efforts across the SDGs, and recognizing the interactions between them is a key challenge (Stevens and Nilsson 2016). Some countries, such as Sweden or Colombia, have established cross-ministerial committees to map out a national strategy for the interacting SDGs (UN-DESA 2016) and scholars have written up a seven-point scale of interaction to aid this process (Nilsson et al 2016). Rather than agenda-setting in sectoral siloes, this requires interaction across 'nexus' issues such as energy, agriculture and water (Stirling 2015), a diversity of

innovation options (Stirling 2009), and policy mixes to foster multiple outcomes (Rogge et al 2016).

Skills for subsequent policy development and implementation (both specialist and non-specialist policy makers) are lacking in many developing countries. This is important as priorities and contexts differ from one country to another, so choice of policy instruments and their design cannot easily be transferred. At the level of innovation systems themselves, agenda-setting, financing, monitoring, evaluation and accountability will all be key considerations. Beyond innovation systems, complementary policies and regulations (see 3.1 above) are required to steer innovation in directions that serve environmental sustainability and other objectives. Beyond implementation, processes for monitoring progress and adapting policy based on emerging evidence require another set of skills.

Monitoring, evaluation and accountability within innovation systems is complex. Scholarship on inclusive innovation (Chataway et al 2014) and responsible research and innovation (Stilgoe et al., 2013) presents elements of a framework for guiding innovation systems towards societal goals, but more research and policy experimentation is required to understand how these might be applied in different contexts.

Within research systems, there are various approaches to changing incentives so that knowledge produced is both useful for other stakeholders and accessible for their use. One aim of collaborative innovation approaches is to maximize bi-directional linkages between researchers and research users. For example, various 'altmetrics' can allow digital tracing of interactions between researchers and other stakeholders, and potentially their impacts on SDGs. Whilst ways to measure the interaction between the research system and different users are emerging, the real challenge is influencing the quality (rather than just enhancing the quantity) of such interactions.

As mentioned in section 2.3, encounters between some of the new and emerging approaches (e.g. grassroots innovation) with formal research and innovation systems are difficult to govern, but policy should aim to enhance a synergistic dynamic of mutual mobilization, rather than focusing on insertion (and appropriation) of these new approaches into formal structures (Fressoli *et al.*, 2014). In many cases, this will require national governments or intergovernmental organisations to support more pro-poor, inclusive, collaborative components of hybrids, often against power gradients, if the SDGs are to be realised (Ely *et al.*, 2013). Guarding against free-riders and appropriation or de-skilling impacts of the innovation approaches (for example through displacing labour and productive employment) require clear but flexible approaches that are driven democratically, rather than purely by markets. During such processes, national governments and oppositions, citizens and other stakeholders all have a key role in holding those who have influence over innovation policies to account.

Digital technologies themselves are playing an increasing role in such democratic processes, and allowing diverse constituencies to form political alliances world wide. The pervasive nature and transformative potential of some of these digital technologies is sometimes seen to

threaten the stability of incumbent regimes and the sovereignty of nation-states. Whilst they may be viewed as a peril, governing within and across national boundaries to enable systemic transformations is the key to realizing the promise of these new and emerging approaches, and the route to achieving the SDGs. Research on these aspects of governing science, technology, innovation and the SDGs is required alongside the new wave of international initiatives if the 2030 agenda is to be realized.

3.6. Remaining challenges and focal areas for further research

It is evident that the implications for the new and emerging approaches detailed in this paper for STI policy are far from well-understood. As these approaches mature, a distributed but co-ordinated effort to improving the knowledge base to inform national and international policy is warranted. Internationally-linked research-based organisations such as the 'Pathways to Sustainability' global consortium and the 'Transforming Innovation Policy' consortium[34] are efforts in this direction.

Meeting the 2030 Agenda will require strong collaboration and partnerships amongst all stateholders at all levels. Organising innovation transnationally requires a move towards global sustainability-oriented innovation systems (Altenberg & Pegels 2012) and transformative change for the SDGs (Leach et al 2012). A range of international actors and UN initiatives including the CSTD and the Technology Facilitation Mechanism provide platforms to build such systems. A top-down approach is unrealistic and possibly undesirable. Therefore the role of national governments remains key. As they move from a focus on innovation systems for economic growth and productivity to one that aims to transform systems (through deep transitions) towards sustainable development (Schot and Steinmueller 2016), traditional approaches to 'benchmarking' innovation policies need updating. But rather than aspiring to a definition of the 'most innovative' country, the universal 2030 agenda requires an approach that recognizes the contributions that all states can make to the process of transforming innovation policy for sustainable development.

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References

Altenburg, T. & Pegels, A. (2012) Sustainability-oriented innovation systems – managing the green transformation. *Innovation and Development,* 2 (1)**,** 5-22.

Anderson, C. (2012) Makers : the new industrial revolution, New York : Crown Business

Arza, V. & M. Fressoli (2016), Benefits and obstacles of openness in science: evidence from four case-studies in Argentina, paper presented at SPRU 50th Anniversary Conference, University of Sussex, 7-9 September 2013

Baden, T., Chagas, A. M., Gage, G. J., Marzullo, T. C., Prieto-Godino, L. L., & T. Euler (2015) Open Labware: 3-D Printing Your Own Lab Equipment, Plos Biology, doi: info:doi/10.1371/journal.pbio.1002175

Bhaduri, S. & H. Kumar (2011) "Extrinsic and intrinsic motivations to innovate: tracing the motivation of 'grassroot' innovators in India" *Mind and Society* 10(1): 27–55

Bell, M. and K. Pavitt (1993) "Technological Accumulation and Industrial Growth: Contrasts Between Developed and Developing Countries" *Industrial and Corporate Change* 2(2): 157-210

Benkler, Y. & Nissenbaum, H. (2006) Commons-based peer production and virtue, *Journal of Political Philosophy*, 14(4), 394-419

Benkler, Y., Shaw, A, & Hill, B. (2015) Peer Production: A Modality of Collective Intelligence. In In Handbook of Collective Intelligence, edited by Thomas Malone and Michael Bernstein. MIT Press, Cambridge, Massachusetts., 1–27. Retrieved from http://mako.cc/academic/benkler_shaw_hill-peer_production_ci.pdf , 10th of November, 2016

Benkler, Y. (2016) Peer production, the commons, and the future of the firm, *Strategic Organization*, 1–11. http://doi.org/10.1177/1476127016652606

Berkhout, F. and A. Gouldson (2003) 'Inducing, shaping and modulating: perspectives on technology and environmental policy' in Berkhout, F., Leach, M. and I. Scoones (eds) Negotiating Environmental Change Edward Elgar, Cheltenham

Birn, A. E. (2005) Gates's grandest challenge: transcending technology as public health ideology. *Lancet,* British edition 366(9484): 514-519

Boelman, V., Kwan, A., Lauritzen, J.R.K., Millard, J. & R. Schon (2014) Growing Social Innovation: A Guide for Policy Makers. (TEPSIE), European Commission, DG Research. Available at: http://www.tepsie.eu/images/documents/policy_report_final_web.pdf (accessed 21/11/2016)

Bodnar, P. and Turk, D. (2015) Announcing: ´´Mission Innovation´´, The White House https://www.whitehouse.gov/blog/2015/11/29/announcing-mission-innovation

Bonifacio, M. (2012) Social Innovation: A Novel Policy Stream or a Policy Compromise? An EU Perspective. Technical Report # DISI-12-035

Borzaga, R., C., Bodini R. (2012) What to make of social innovation? Towards a framework for policy development, Euricse Working Paper, N.036 | 12

Boulton, G., Campbell, P., Collins, B., Elias, P., Hall, W., Graeme, L., O'Neill, O., Rawlins, M., Thornton, J., Vallance, P. & M. Walport (2012) Science as an open enterprise. The Royal Society,http://royalsociety.org/uploadedFiles/Royal_Society_Content/policy/projects/sape/2012-06-20-SAOE.pdf , accessed 10th October 2016.

Broussard, M. (2015) The Secret Lives of Hackathon Junkies, The Atlantic, retrieved from http://www.theatlantic.com/technology/archive/2015/07/the-secret-lives-of-hackathon-junkies/397895/ , 5th October 2016

Catlin-Groves, C. L. (2012) The citizen science landscape: From volunteers to citizen sensors and beyond, *International Journal of Zoology*, 2012, 12. http://doi.org/10.1155/2012/349630

Chan, A. (2012). Balancing Design: OLPC Engineers and ICT Translation: at the Periphery. In E. Medina, I. da Costa Marques, & C. Holmes (Eds.), Beyond imported magic: Essays on Science, Technology, and Society in Latin America (pp. 181–207). Cambridge, MA: The MIT Press.

Chataway, J., Hanlin, R. & Kaplinsky, R. (2014) 'Inclusive innovation: an architecture for policy development', *Innovation and Development* 4(1), 33-54

Cozzens, S.E. & Sutz, J., (2012) Innovation in Informal Settings: A Research Agenda. *Discussion paper for the GRIID Network*.

Cernuschi, Tania, Eliane Furrer, Nina Schwalbe, Andrew Jones, Ernst R Berndt, & Susan McAdams (2011) Advance market commitment for pneumococcal vaccines: putting theory into practice, *Bulletin of the World Health Organization* 89: 913-918

Chan, A. S. (2014) Balancing Design: OLPC Engineers and ICT Translations at the Periphery, Chapter 9 in Medina, Marques &Holmes (Eds), Beyond Imported Magic: Essays on Science, Technology, and Society in Latin America, Cambridge MA: MIT Press

Chesbrough, H. (2003) Open Innovation. The new imperative fro creating and profiting from technology. Boston, Massachusetts: Hardvard University Press.

Chesbrough, H. (2006) Open innovation: A new paradigm for understanding industrial innovation, in H. Chesbrough, J. West & H. Vanhaverbeke (Eds) Open Innovation - Researching a New Paradigm, Oxford: Oxford University Press

Data Revolution Group (2014) A World that Counts: Mobilising the Data Revolution for Sustainable Development, UN Independent Expert Advisory Group on a Data Revolution for Sustainable Development. Retrieved from http://www.undatarevolution.org/wp-content/uploads/2014/11/A-World-That-Counts.pdf , 5th October 2016

Day, J., Leach, M. and Ely, A. (2013) Engaging science and politics in a post-2015 framework, Brighton: IDS and The STEPS Centre

Doherty, B, Davies, I.A. % Tranchell (2013) Where now for fair trade, Business History, Vol. 55 (2). pp. 161-189

EC (2013) EU Research and Innovation: Tackling Societal Challenges, available at http://www.ncp-incontact.eu/nkswiki/images/7/73/H2020_societal_challenges.pdf

Ely, A. & Bell, M. (2009) The Original 'Sussex Manifesto': Its Past and Future Relevance, STEPS Working Paper 27, Brighton: STEPS Centre

Ely, A., Smith, A., Leach, M., Stirling, A. & Scoones, I. (2013) Innovation politics post-Rio+20: hybrid pathways to sustainability? *Environment and planning C,* 31 (6)**,** 1063-1081.

Ely, A., Van Zwanenberg, P. & Stirling, A., (2011) *New Models of Technology Assessment for Development, STEPS Working Paper 45.* Brighton

Ely, A., Van Zwanenberg, P. & Stirling, A. (2014) Broadening out and opening up technology assessment: Approaches to enhance international development, co-ordination and democratisation. *Research Policy,* 43**,** 505-518

Espinoza, J. (2014) African Tech Hubs and Funds Hope to Bridge the Digital Divide, http://blogs.wsj.com/frontiers/2014/04/29/african-tech-hubs-and-funds-hope-to-bridge-the-digital-divide/, accessed 1/9/2016

Etzkowitz, H. & Leydesdorff, L. (1995) The Triple Helix -- University-Industry-Government Relations: A Laboratory for Knowledge Based Economic Development. *EASST Review,* 14 (1)**,** 14-19

Etzkowitz, H. & Zhou, C. (2006) Triple Helix twins: innovation and sustainability. *Science and Public Policy,* 33 (1)**,** 77-83

European Commission (2016) Social innovation. Webpage (accessed August 2016) at https://ec.europa.eu/growth/industry/innovation/policy/social_en

European Commission (2016b) EU Open Innovation, Open Science, Open to the World. European Comission. http://doi.org/10.2777/061652

Ferguson, D. (2014) Introduction: A Grand Challenge for Next Generation Solutions, Frontlines: Grand Challenges for Development, July/August 2014, USAID

Foray, D., Mowery, D., and Nelson, R.R. (2012) Public R&D and Social Challenges: What Lessons from Mission R&D Programs? *Research Policy*, 41(10), 1697-1902

Foster, C. & Heeks, R. (2013) Conceptualising Inclusive Innovation: Modifying Systems of Innovation Frameworks to Understand Diffusion of New Technology to Low-Income Consumers. *European Journal of Development Research***,** 1-23

Freeman, C. (1995) The National System of Innovation in Historical Perspective. *Cambridge Journal of Economics,* 19**,** 5-24

Fressoli, M., Arond, E., Abrol, D., Smith, A., Ely, A. & Dias, R. (2014) When grassroots innovation movements encounter mainstream institutions: implications for models of inclusive innovation. *Innovation and Development,* 4 (2)**,** 277-292

Fressoli, M. and Dias, R. (2014) The Social Technology Network: A hybrid experiment in grassroots innovation, STEPS Working Paper 67, Brighton: STEPS Centre

Fressoli, M., Arza, V., & Castillo, M. Del. (2016) Argentina the Impact of Citizen-Generated Data Initiatives in Argentina, Civicus Datashift, Buenos Aires. Available at http://civicus.org/thedatashift/wp-content/uploads/2016/05/CGD-impact-report-Argentina.pdf (accessed 10th October 2016)

George, G., McGahan, A.M. & Prabhu, J. (2012) Innovation for inclusive growth: towards a theoretical framework and a research agenda. *Journal of Management Studies,* 49 (4)**,** 661-683

Gibney, E. (2016) “Open-hardware” pioneers push for low-cost lab kit, *Nature*, 531(7593), 147–148. http://doi.org/10.1038/531147a [doi]

Hanlin, R. and R. Kaplinsky (2016) South–South Trade in Capital Goods – The Market-Driven Diffusion of Appropriate Technology, *European Journal of Development Research*, 28, 361 -378

Heeks, R., Amalia, M., Kintu, R. & Shah, N. (2013) *Inclusive Innovation: Definition, Conceptualisation and Future Research Priorities, Development Informatics Working Paper No. 53.* Manchester

Heeks, R., Foster, C. & Nugroho, Y. (2014) New models of inclusive innovation for development. *Innovation and Development***,** 4 (2), 1-11

Wilsdon, J., et al. (2015) The Metric Tide: Report of the Independent Review of the Role of

Metrics in Research Assessment and Management. DOI: 10.13140/RG.2.1.4929.1363 http://www.hefce.ac.uk/media/HEFCE,2014/Content/Pubs/Independentresearch/2015/The,Metric,Tide/2015_metric_tide.pdf (accessed 21/11/2016)

Howaldt, J. & Schwarz, M. (2010) Social Innovation: Concepts, research fields, and international trends, IMA/ZLW & IfU, IMO International Monitoring (Vol 5)

Hubert, A. (Ed)(2010) Empowering people, driving change: social innovation in the European Union Publications Office of the European Union, Luxembourg

Immelt, J. R., Govindarajan, V., & Trimble, C. (2009) How GE is disrupting itself. *Harvard Business Review*, 87(10), 56-65

ISSC, IDS and UNESCO (2016) World Social Science Report 2016, Challenging Inequalities: Pathways to a Just World, UNESCO Publishing, Paris

Juma, C. & Yee-Cheong, L. (2005) *Innovation: Applying Knowledge to Development*. United Nations Millennium Project

Jéquier, N. (1982) The world of appropriate technology: A quantitative analysis. Paris: OECD

Kaplinsky, R. (2011) Schumacher meets Schumpeter: Appropriate technology below the radar, *Research Policy,* 40 (2)**,** 193-203

Karnani, Aneel (2009) The Bottom of the Pyramid Strategy for Reducing Poverty: A Failed Promise, DESA Working Paper No. 80, United Nations, accessed from http://www.un.org/esa/desa/papers/2009/wp80_2009.pdf , 21/11/2016

Kemp, R., Zuijderwijk, L., Weaver, P., Seyfang, G., Avelino, F., Strasser, T., Becerra, L., Backhaus, J. & S. Ruijsink (2015) Doing things differently: exploring Transformative Social innovation and its practical challenges (TRANSIT Brief ; 1), TRANSIT: EU SSH.2013.3.2-1

Kidwell, M. C., Lazarević, L. B., Baranski, E., Hardwicke, T. E., Piechowski, S., Falkenberg, L-S., Kennett, C., Slowik, A., Sonnleitner, C., Hess-Holden, C., Errington, T. M., Fiedler, S. & B. A. Nosek (2016) Badges to Acknowledge Open Practices: A Simple, Low-Cost, Effective Method for Increasing Transparency, *PLoS Biology* 14(5): e1002456. doi:10.1371/journal.pbio.1002456

Krishnan, R. T. (2010) From Jugaad to Systemic Innovation: The Challenge for India, Bangalore: The Utpreraka Foundation.

Kremer, M. & R. Glennerster (2004) Strong Medicine: Creating Incentives for Pharmaceutical Research on Neglected Diseases, Princeton, New Jersey: Princeton University Press

Leach, M., J. Rockström, P. Raskin, I. Scoones, A. C. Stirling, A. Smith, J. Thompson, E. Millstone, A. Ely, E. Arond, C. Folke, and P. Olsson (2012) Transforming Innovation for Sustainability, *Ecology and Society* 17(2): 11.

London, T. & W. Davidson (2011) Creating a fortune with the Base of the Pyramid, in T. London & S. Hart (Eds) Next Generation Business Strategies for the Base of the Pyramid. New approaches for building mutual value,, 1-18. New Jersey: Pearson Education

Lundvall, B.-A., Joseph, K. J., Chaminade, C. and Vang, J. (2009) Handbook of innovation systems and developing countries: building domestic capabilities in a global setting, Cheltenham: Edward Elgar

Mansell, R. (2013) Employing digital crowdsourced information resources: Managing the emerging information commons, *International Journal of the Commons*, 7(2), 255–277

MDS (Ministério do Desenvolmiento Social e Agrário - Brazil) (2016) A gente sabe que tem água, que a renda tá garantida, Available at: http://www.mds.gov.br/assuntos/seguranca-alimentar/201ca-gente-sabe-que-tem-agua-que-a-renda-ta-garantida201d (Retrieved the 10th October 2016)

Mason, P. (2015) Post-capitalism: a guide to our future, London: Allen Lane

Masum, H., & Harris, R. (2011) Open Source for Neglected Diseases : Challenges and Opportunities, 6–10. Retrieved from http://healthresearchpolicy.org/assessments/open-source-neglected-diseases-challenges-and-opportunities 15th September 2016.

Mazzucato, M. (2013) The Entrepreneurial State: debunking public vs. private sector myths, London: Anthem Press

Milanovic, B. (2013) Global Income Inequality in Numbers: in History and Now, *Global Policy* 4(2), 198–208

Millard, J., Weerakkody, V., Missi, F., Kapoor, K. & G. Fernando (2016 forthcoming) Social innovation for poverty reduction and sustainable development: some governance and policy perspectives, Published in the Proceedings of the 9th International Conference on the Theory and Practice of Electronic Governance (ICEGOV2015-16), Montevideo, Uruguay, 1 to 3 March 2016, the ACM Press

Moulaert, F. et al. (Eds) (2013) The International Handbook on Social Innovation; Collective Action, Social Learning and Transdisciplinary Research, Cheltenham: Edward Elgar

Mulgan, G. (2006) Social Innovation: what is it, why it matters, how it can be accelerated. Oxford: Skoll Center for Social Entrepreneurship and the Young Foundation

Murray, F., Stern, S., Campbell, G., & MacCormack, A. (2012) Grand Innovation Prizes: A theoretical, normative, and empirical evaluation, *Research Policy*, 41(10), 1779-1792

Nielsen, M. (2012) Reinventing Discovery: The New Era of Networked Science, Princeton: Princeton University Press

NIF website (National Innovation Foundation) 2013. Accessed 3th October, 2016, http://nif.org.in/innovation/mitti-cool-refrigerator/751

Nilsson, M., Griggs, D. & Visbeck, M. (2016) Map the interactions between Sustainable Development Goals, *Nature* 534, 320-322

Novy, A. & Leubolt, B. (2005) Participatory Budgeting in Porto Alegre: Social Innovation and the Dialectical Relationship of State and Civil Society, *Urban Studies*, 42(11) 2023-2036

OECD, (1996) *Shaping the 21st Century: The Contribution of Development Co-operation.* Paris.

OECD (2011) Fostering Innovation to Address Social Challenges, Workshop Proceedings. Available at https://www.oecd.org/sti/inno/47861327.pdf, accessed 21/11/2016

OECD (2015) Making Open Science a Reality. Retrieved from http://dx.doi.org/10.1787/5jrs2f963zs1-en

OECD (2016) OECD Science, Technology and Innovation Outlook 2016. Available at: http://www.oecd.org/industry/oecd-science-technology-and-innovation-outlook-25186167.htm, accessed 8/12/2016.

Ooms, G., Van Damme, W., Baker, B., Zeitz, P. & Schrecker, T. (2008) The 'diagonal' approach to Global Fund financing: a cure for the broader malaise of health systems? *Globalization and Health*, 4(6) doi:10.1186/1744-8603-4-6

Opensource.com (2016) Hacking the farm with low-cost, open source tool design. Interview with Marcin Jakubowski. Available in https://opensource.com/life/16/2/interview-marcin-jakubowski-open-source-ecology, accessed the 5th October 2016

Oxley, N. (2015) Float like a FabLab, Sting like a Honeybee, STEPS Centre, https://medium.com/hidden-sustainability/float-like-a-fab-lab-sting-like-a-honey-bee-4f9eab3b70c1, accessed 28/10/2016

Newshour, P. (2015) A hackathon to fashion a better Ebola suit, Retrieved from http://www.pbs.org/newshour/bb/fashioning-better-ebola-suit/ , accessed the 15th October 2016

Pel, B. & Bauler, T. (2014) The Institutionalization of Social Innovation: About the TRANSIT working papers series: between Transformation and Capture, TRANSIT working paper transitsocialinnovation.eu

Pel, B. Weaver, P. Strasser, T. Kemp, R. Avelino, F. and Becerra, L. (2015) Governance : co-productions challenges in Transformative Social Innovation (TRANSIT Brief 2), TRANSIT: EU SSH.2013.3.2-1 Grant agreement no: 613169

Pew (2016) Smartphone Ownership and Internet Usage Continues to Climb in Emerging Economies, http://www.pewglobal.org/2016/02/22/smartphone-ownership-rates-skyrocket-in-many-emerging-economies-but-digital-divide-remains/, accessed 3/9/2016

Pol, E. & Ville, S. (2009) Social Innovation: Buzz Word or Enduring Term. *The Journal of Socio-Economics* 38, 878–885

Porter, M. E. & C. van der Linde (1995) 'Green and competitive: ending the stalemate', *Harvard Business Review*, Sept/Oct 1995, Vol. 73 No 5, pp. 120-134

Prahalad, C.K. (2004) *The Fortune at the Bottom of the Pyramid: Eradicating Poverty through Profits.* Upper Saddle River, NJ: Wharton School Publishing

RIN NESTA. (2010) Open to All ? (Vol. 1). Retrieved the 15th October 2016 from http://www.rin.ac.uk/our-work/data-management-and-curation/open-science-case-studies

R&D Magazine, (2016) *2016 Global R&D Funding Forecast: Supplement Winter 2016*

Radjou, N., Prabhu, J. & Ahuja, S. (2012) *Jugaad Innovation: Think Frugal, Be Flexible, Generate Breakthrough Growth.* San Francisco, CA: Jossey-Bass

Ratto, M. & M. Boler (2014) Introduction, in M. Ratto & M. Boler (Eds) DIY Citizenship. Critical making and social media, Cambridge, The MIT Press, pp. 1-22

Raynolds, L.T. (2000) Re-embedding global agriculture , The international organic and fair trade movements, *Agriculture and Human Values* 17: 297–309

Rifkin, J. (2014) The zero marginal cost society: the internet of things, the collaborative commons, and the eclipse of capitalism. New York: Palgrave Macmillan

Rivoir, A. L. & Lamschtein S. (2012) Cinco años del Plan Ceibal: algo más que una computadora para cada niño, Montevideo: Unicef

Rodríguez, A & Alvarado, H. (2008). Claves de la Innovacion Social en America Latina y el Caribe. Santiago de Chile: United Nations and CEPAL

Rogge, K.S., Breitschopf, B., Mattes, K., Cantner, U., Graf, H., Herrmann, J., Kalthaus, M., Lutz, C. and Wiebe, K. (2015): Green change: renewable energies, policy mix and innovation. Karlsruhe: Fraunhofer ISI

Rossel, C. (2016). The World Bank Open Access policy, (c), 3–5. Retrieved 10th October 2016 from http://otwartanauka.pl/analysis/nauka-otwartosc-swiat/polityka-otwartosci-banku-swiatowego/the-world-bank-open-access-policy

Shaheen, S., Sperling, D., & C. Wagner (1999) A Short History of Carsharing in the 90's, *Journal of World Transport Policy & Practice* 5, pp. 18-40

Shaheen, S., Sperling, D & C. Wagner (2000) Carsharing and mobility services: An updated overview, available at: http://www.communauto.com/abonnes/SperlingShaheenW.html

Sierra, C. (2016) Report on 'Blockchains for Social Good', report of a policy workshop, Brussels June 21st, 2016, file:///C:/Users/user/Downloads/WorkshopReport.pdf, accessed 23/8/2016

Smith, A. & Arora, S., (2015) Mind your (innovation) language, STEPS Centre, http://steps-centre.org/2015/blog/mind-your-innovation-language/, accessed 1/9/2016

Smith, A., Fressoli, M., Abrol, D., Around, E. & Ely, A. (2016) Grassroots Innovation movements, London: Routledge

Smith, A. and Stirling, (forthcoming) Grassroots innovation and innovation democracy, STEPS Working Paper, Brighton: STEPS Centre

Stevens, A.-S. and Nilsson, M. (2016) Understanding how the SDGs interact with each other is key to their success, World Economic Forum Agenda blog, https://www.weforum.org/agenda/2016/07/understanding-interactions-is-key-to-making-the-sdgs-a-success, accessed 23/8/2016

Schot, J. & Steinmueller, W.E. (2016) Framing Innovation Policy For Transformative Change: Innovation Policy 3.0, SPRU Working Paper, University of Sussex

Stilgoe, J., Owen, R. & Macnaghten, P. (2013) Developing a framework for responsible innovation. *Research Policy,* 42 (9)**,** 1568-1580

Stirling, A. (2009) 'Direction, Distribution and Diversity! Pluralising Progress in Innovation, Sustainability and Development', STEPS Working Paper 32. Brighton, STEPS Centre

Sullivan, B. L. et al (2014) The eBird enterprise: An integrated approach to development and application of citizen science. *Biological Conservation*, 169, 31–40. http://doi.org/10.1016/j.biocon.2013.11.003

Tapscott, D. & Tapscott, A. (2016) The Impact of the Blockchain Goes Beyond Financial Services, Harvard Business Review https://hbr.org/2016/05/the-impact-of-the-blockchain-goes-beyond-financial-services, accessed 3/9/2016

The Economist (2012) Fighting for the next billion shoppers, Available at: http://www.economist.com/node/21557815 , Accessed 10th October 2016.

Times Higher Education (2015) Remove barriers to open science, says head of EU policy unit, June 28th. Available at: https://www.timeshighereducation.com/news/remove-barriers-open-science-says-head-eu-policy-unit

Totterdill, P., Cressey, P., Exton, R. & Terstriep, J. (2015) Simulating, Resourcing and Sustaining Social Innovation: Towards a New Mode of Public Policy Production and Implementation, *SIMPACT Working Paper*, 2015(3). Gelsenkirchen: Institute for Work and Technology.

Truffer, N. (2003) User-led innovation processes: the development of professional car sharing by environmentally concerned citizens. *Innovation*, 16(2), 139–154

UNCTAD (2011), Pro-poor technology, innovation and entrepreneurship policies, available at http://unctad.org/en/Docs/ciimem1d12corr1_en.pdf , Accessed 5th October 2016.

UNCTAD (2013) Issues Paper on Internet broadband for an inclusive digital society, prepared for Commission on Science and Technology for Development Inter-sessional Panel 7-9 January 2013, Lima, Peru http://unctad.org/meetings/en/SessionalDocuments/cstd2013_IssuesPaper2.pdf, accessed 3/9/2016

UNCTAD (2014) Issues Paper on Digital Development, prepared for Commission on Science and Technology for Development Inter-sessional Panel, 26-28 November, Geneva, Switzerland, http://unctad.org/meetings/en/SessionalDocuments/CSTD_2014_Issuespaper_Theme2_DigitalDev_en.pdf, accessed 3/9/2016

UN-DESA (2015) UN-DESA paper 141 http://www.un.org/esa/desa/papers/2015/wp141_2015.pdf, accessed 10th November 2016

UNDP (2008), Creating value for all: strategies for doing business with the poor, United Nations, Accessed May 10, 2012, http://web.undp.org/

UNESCO, (2015) *World Science Report: Towards 2030.* Paris: United Nations Educational, Scientific and Cultural Organisation

United Nations, (2015) *Transforming our world: the 2030 Agenda for Sustainable Development, A/RES/70/1.* New York: United Nations

Unwin, T. (2009) *ICT4D: Information and Communication Technology for Development.* Cambridge: Cambridge University Press

Vachelard, J., Gambarra-Soares, T., Augustini, G., Riul, P. & V. Maracaja-Coutinho(2016) A Guide to Scientific Crowdfunding. *PLoS Biology* 14(2): e1002373. doi:10.1371/journal.pbio.1002373

Van Zwanenberg, P., Ely, A. & Stirling, A., (2009) *Emerging Technologies and Opportunities for International Science and Technology Foresight, STEPS Working Paper 30.* Brighton

van der Have, R. P. & Rubalcaba, L. (2016) Social innovation research: An emerging area of innovation studies?, *Research Policy* in print, doi:10.1016/j.respol.2016.06.010

Varmus, H. R. Klausner, E. Zerhouni, T. Acharya, A. S. Daar, P. A. Singer, (2003) Grand Challenges in Global Health, *Science*, 302 (5644), 398-399

Wagner, C. (2008) *The New Invisible College: Science for Development* Washington DC: Brookings Institution Press

Warnke, P. Koschatzky, K., Dönitz, E., Zenker, A., Stahlecker, T., Som, O., Cuhls, K. & Güth, S. Opening up the innovation system framework towards new actors and institutions', Fraunhofer ISI Discussion Papers Innovation Systems and Policy Analysis No. 49, http://www.isi.fraunhofer.de/isi-wAssets/docs/p/de/diskpap_innosysteme_policyanalyse/discussionpaper_49_2016.pdf, accessed 23/8/2016

Warschauer, M. and M. Ames (2010), Can One Laptop per Child save the world's poor, *Journal of International Affairs*, Vol. 64, No. 1, pp. 33-51

Woelfle, M., Olliaro, P., & Todd, M. H. (2011) Open science is a research accelerator, *Nature Chemistry*, 3(10), 745–748. http://doi.org/10.1038/nchem.1149

Young Foundation (2012) Social Innovation Overview: A deliverable of the project: "The theoretical, empirical and policy foundations for building social innovation in Europe" (TEPSIE), Framework Programme, Brussels: European Commission, DG Research