Towards Inclusive and Responsible Technological Innovation Systems

By Tania S. Douglas

Thesis presented in partial fulfilment of the requirements for the degree of Master of Philosophy (Applied Ethics) at Stellenbosch University

Supervisor: Dr Minka Woermann

April 2019

Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

April 2019

Tania Douglas

Abstract

Innovation has gained prominence as a key ingredient to economic success. As a consequence, policy makers and researchers have paid increasing attention to the factors that enhance innovation. In addition, recent innovation policy directions globally reflect a desire for social justice. This study, focussing specifically on technological innovation, contributes to the set of tools available for gaining an understanding of the societal implications of innovation. It draws on three sperate but related innovation concepts: inclusive innovation, which refers to innovation activities that are intended to benefit the marginalised and enhance their social and economic well-being; responsible innovation, an approach that recognises and aims to moderate the hazards of technological innovation to humanity and the planet; and technological innovation systems, a framework for analysing the status and trajectory of technologies and technological fields. Inclusive innovation, responsible innovation, and technological innovation systems fulfil different roles in the assessment of technologies and their evolution. They are however potentially complementary and reciprocally beneficial . The study considers the expansion of the technological innovation systems framework with the aid of concepts derived from inclusive innovation and responsible innovation. It aims to extend the technological innovation systems formulation to strengthen a normative element that addresses benefit to society as well as the potential long-term harms of innovation. Particular consideration is given to the ethical foundations of responsible innovation and inclusive innovation. The expanded formulation presents an analytical tool for assessing technological innovation systems, particularly in developing countries, where inclusion of the marginalised as beneficiaries of, and participants in, innovation is an imperative. Such a broadening of the technological innovation systems approach provides for richer and more nuanced analyses, increasing the utility of the approach and its potential to influence innovation policy towards societal benefit, also in the long term, particularly in developing countries.

Opsomming

Innovasie word beskou as 'n belangrike komponent van 'n land of gebied se ekonomiese sukses. As gevolg hiervan gee beleidmakers en navorsers toenemende aandag aan die faktore wat innovasie bevorder. Daarbenewens weerspieël onlangse innovasiebeleide wêreldwyd 'n begeerte vir sosiale geregtigheid. Hierdie studie, wat spesifiek fokus op tegnologiese innovasie, dra by tot die stel analitiese instrumente wat beskikbaar is om begrip van die sosiale implikasies van innovasie te bevorder. Dit behels drie aparte maar verwante innovasiekonsepte: inklusiewe innovasie, wat verwys na innovasie-aktiwiteite wat bedoel is om gemarginaliseerde belanghebbendes te bevoordeel en hul sosiale en ekonomiese welsyn te verbeter; verantwoordelike innovasie, 'n benadering wat die gevare van tegnologiese innovasie erken en die doel het om hierdie gevare te modereer; en tegnologiese innovasiestelsels, 'n raamwerk vir die ontleding van die status en die trajek van tegnologieë en tegnologiese velde. Inklusiewe innovasie, verantwoordelike innovasie en tegnologiese innovasiestelsels vervul verskillende rolle in die evaluering van tegnologieë en hul evolusie. Hulle is egter potensieel komplementêr en wederkerig voordelig. Die studie oorweeg die uitbreiding van die raamwerk vir tegnologiese innovasiestelsels met behulp van konsepte verkry uit inklusiewe innovasie en verantwoordelike innovasie. Dit is daarop gemik om 'n normatiewe element in die formulering van tegnologiese innovasiestelsels te versterk, sodat voordeel vir die samelewing sowel as die potensiële langtermyn nadele van innovasie aangespreek word. Die etiese grondslae van verantwoordelike innovasie en inklusiewe innovasie word spesifiek ondersoek. Die uitgebreide formulering bied 'n analitiese instrument vir die evaluasie van tegnologiese innovasiestelsels, veral in ontwikkelende lande, waar die insluiting van gemarginaliseerde groepe as begunstigdes van en deelnemers aan innovasie 'n noodsaaklikheid is. Hierdie verbreding van die tegnologiese innovasiestelselbenadering maak voorsiening vir ryker en meer genuanseerde ontledings. Dit verhoog die nuttigheid van die benadering en sy potensiaal om innovasiebeleide in die rigting sosiale voordeel te beïnvloed, ook op die langtermyn, en veral in ontwikkelende lande.

Acknowledgements

To Minka Woermann, the Business Ethics lecturing team and my classmates, thank you for creating a stimulating learning environment. Thanks also to Minka for her support and supervision.

I am grateful to my employer, the University of Cape Town, for the flexibility that has enabled me to pursue this programme; to my Health Innovation group at UCT for interesting discussions on innovation; and to Carsten Dreher from the Freie Universität Berlin for introducing me to the discourse on context in technological innovation systems.

Table of Contents

1 Introduction

1.1 Background

Innovation is regarded as a key determinant of a nation's prosperity. Innovation may be defined as the introduction and implementation of new, or the adaptation of existing, products, equipment, forms of organisation, or organisational procedures (Cozzens & Kaplinsky, 2009). Innovation has also been defined as "the creation of value from knowledge" (Gault, 2010, p. 4). Innovation has gained prominence as a key contributor to economic well-being. Consequently, policy makers and researchers have increasingly made efforts to understand the factors that promote innovation (Schroeder, et al., 2016). In addition, recent innovation policy directions globally reflect a desire for social justice. This study, focussing specifically on technological innovation, makes a contribution towards the tools employed in gaining an understanding of the societal implications of innovation.

The traditional view of technological innovation is that it is inherently good, a driver of economic growth, and therefore a catalyst for prosperity. However, growth, innovation and inequality have a context-dependent relationship that is mediated by a variety of social, economic and political processes, with innovation and growth not necessarily associated with a reduction in inequality (Cozzens & Kaplinsky, 2009). For example, innovation may reinforce inequality by conferring benefits preferentially to those who already have the easiest access to the products of innovation through their resources and social capital. In recognition of the existing and potential biases inherent in innovation, entities like the World Health Organization (WHO) and the Organization for Economic Cooperation and Development (OECD) emphasise innovation that serves the interests of marginalised groups (WHO, 2010; OECD, 2015).

The beneficial intentions of innovation for the marginalised do not always come to fruition. The PlayPump serves as an example of such a failed attempt (Kimmitt & Munoz, 2015). The PlayPump is playground equipment that was installed at schools in Africa to harness children's play on a merry-go-round, pumping water from the ground for storage. It was intended to

address water shortages and provide fresh water to millions of people. However, it failed due to high costs, complexity of operation and maintenance, risk of injury, and inaccurate water demand estimations. Failures such as this speak to the need for more deliberative interventions in marginalised communities and greater attention to the needs of the intended beneficiaries in the innovation process.

The view of innovation as inevitably beneficial also finds a counterargument in the unpredictability of the long-term consequences of technological innovation. It is almost impossible to foresee the use pathways that may result from the adaptation and repurposing of an original technology, often facilitated by complementary technological advances. Von Schomberg (2013) cites as an example the Microsoft Kinect device, initially intended for interactive games on personal computers, which was appropriated for medical benefit, namely to aid visualisation in surgical procedures. Although the Kinect is no longer manufactured by Microsoft, it spawned a range of applications including three-dimensional scanning and robot vision, and some of the underlying technology has been incorporated into other devices, including mobile phones (Heater, 2017). The long-term impacts of technology may also be negative. An example of undesirable impacts on the environment is the electronic waste generated as a result of consumers regularly upgrading their mobile phones and other devices.

Responsible innovation is a framework that recognises and aims to moderate the hazards of technological innovation to humanity and the planet. It considers innovation as beneficial only if it addresses society's needs and thereby contributes to economic, social and environmental sustainability. While responsible innovation aims to foresee and guide the consequences of technological innovation, the technological innovation systems (TIS) approach analyses the status and trajectory of technologies. In particular, TIS studies examine the processes and structures that support or impede the establishment and the development of technologies or technological fields. The social benefit and the inclusive nature of the technologies in question are not explicitly considered in this conceptual framework. Inclusive innovation is a term applied to innovation activities that are intended to benefit the marginalised and enhance their social and economic well-being.

The TIS approach has been applied primarily in industrialised countries. TIS scholars are in agreement that the research focus of this field should shift from the developed world to include studies in the Global South (Bergek, et al., 2015; Blum, et al., 2015; Murphy, 2015; Tigabu, et al., 2015). It is acknowledged that TIS research in emerging and developing economies would lead to new knowledge on technological change in different contexts and may also inspire new conceptual approaches (Bergek, et al., 2015).

1.2 Problem statement

Inclusive innovation, responsible innovation and TIS fulfil different roles in the assessment of technologies and their trajectories. They do overlap and are potentially complementary and reciprocally beneficial . Consideration of social benefit as a motivator and a consequence of innovation within the TIS framework would advance the goals of inclusive innovation. Deliberation on the unintended consequences and potential harms of innovation in TIS analyses would advance the goals of responsible innovation. Consideration of both responsible innovation and inclusive innovation would enrich the TIS framework.

In addition, the TIS framework currently lacks adequate consideration of the specificities of developing countries, and the suitability of its current formulation in the developing world has thus far been considered in only a few studies. A TIS framework enriched by inclusive innovation and responsible innovation would further enhance the scope and utility of the TIS approach, particularly for application in developing contexts.

1.3 Aim and approach of the study

This study aims to extend the technological innovation systems formulation to strengthen a normative element that addresses benefit to society as well as the potential long-term harms of innovation. It does so by drawing on concepts from the inclusive innovation and responsible innovation frameworks. The study reviews the literature on these approaches. It identifies gaps in the technological innovation systems formulation, particularly with regard to its consideration of the societal impacts of innovation. It considers the ethical foundations

of inclusive innovation and responsible innovation with reference to the stated goals of these innovation formulations. Based on these considerations, the study then reconceptualises the technological innovation system functions and indicators. The implications of this extended TIS framework for developing countries are considered. Such a broadening of the TIS approach is expected to increase its utility and its potential to influence innovation policy towards social benefit, particularly in developing countries.

1.4 Overview of conceptual frameworks

This section provides an overview of the three conceptual approaches that the project aims to integrate, namely technological innovation systems, inclusive innovation, and responsible innovation.

1.4.1 Technological innovation systems

The concept of an innovation system has been used extensively to analyse the manner in which innovations are developed and propagated and to understand how innovation is supported within the environment in which it takes place (Lundvall, 2007). Such processes might take different forms in different contexts. Different conceptual approaches have been developed for the examination of innovation systems, including national, regional, sectoral and technological innovation systems.

The technological innovation systems framework is commonly used to study the development, growth and performance of new technologies, technological fields, and industries, identify limitations, and make policy recommendations (Markard, et al., 2015). TISs are a "network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure or set of infrastructures and involved in the generation, diffusion, and utilization of technology" (Carlsson & Stankiewicz, 1991). Innovation is conceptualised as interactive and recursive, and enacted in a network of co-evolving actors and institutions (Binz, et al., 2014). The structures of a TIS include actors, institutions and networks that play a role in the generation, diffusion and utilisation of a technology. The TIS

functions include entrepreneurial activities; knowledge development; knowledge diffusion through networks; guidance of the search (for the direction of technological development); market formation; resource mobilisation; and creation of legitimacy (Hekkert, et al., 2007).

The TIS framework and its functions have started to be applied in developing countries and emerging economies, and their suitability for these contexts have started to be assessed. Gosens et al. (2015) found that the existing TIS functions sufficiently capture the transnational dimensions of clean technologies in emerging economies. Similarly, Tigabu et al. (2015) deem the TIS approach to be a promising tool for analysis of renewable energy technology innovation in developing countries. Some variations have however been found in the expression and scope of the TIS functions when applied to developing settings, as compared to their application in industrialised countries (Bento & Fontes, 2015; Gosens, et al., 2015; Blum, et al., 2015; Tigabu, et al., 2015; Kebede & Mitsufuji, 2017). The TIS functions lack explicit reference to societal benefit and the inclusion of marginalised groups, both of which are imperatives for developing countries. The TIS approach is also largely silent on the possible adverse consequences of innovation.

1.4.2 Responsible innovation and inclusive innovation

Responsible innovation (also referred to as responsible research and innovation) has emerged as a policy framework aimed at directing technological innovation towards ensuring benefit for society (de Saille, 2015). The debates that surround responsible innovation emphasise the social, political and normative choices that inform knowledge generation and adoption; they also focus on the democratic participation of a variety of actors in technological innovation (Ribeiro, et al., 2017).

Responsible innovation has been discussed primarily in the policy context, with a focus on regulation and governance, and mainly in the European policy arena. However, it reflects global concerns about the societal role and impact of science and about scientists' engagement with communities, governments and industry. The normative dimension of responsible innovation holds promise for directing technological innovation pathways towards long-term social good. While Organization for Economic Cooperation and

Development and World Health Organization documents contain practical guidelines for socially beneficial technological innovation (WHO, 2010; OECD, 2015), responsible innovation may provide the foundation for an ethical framework within which such activities might take place.

Inclusive innovation is concerned with innovation that benefits marginalised communities. It aims to enhance social cohesion, promote equitable development, and reduce economic disparities. Different conceptualisations of inclusive innovation include reducing income inequality, enabling excluded groups to participate in the process of innovation, and ensuring that the outcomes of innovation are beneficial to the marginalised. Interest in inclusive innovation as a social and political agenda has been prompted by the dominant model of global growth, which has seen GDP growth accompanied by a persistence of poverty and inequality in many countries (Chataway, et al., 2014). Inclusive innovation recognises the inequalities that may result from the development, implementation and distribution of innovations (George, et al., 2012), and aims to mitigate these by the deliberate and active consideration of the marginalised.

The consequences of technological innovation are integrally linked to the pathways of technological development, which are the subject of technological innovation system analysis. Responsible innovation and inclusive innovation are both concerned with the impacts and consequences of innovation, and both emphasise stakeholder participation in innovation. Inclusive innovation may be considered a special case of responsible innovation, in that it focuses particularly on marginalised stakeholders. Thus responsible innovation, inclusive innovation and TIS have inherent commonalities, which are explored in this study.

1.5 Overview of chapters

Chapter 2 discusses the technological innovation systems framework and its current formulation. TIS functions and their use to examine technological innovation are covered, as are applications of TIS in developing countries.

Chapter 3 examines responsible innovation and inclusive innovation and their relationship to innovation policy. The ethical grounding of responsible innovation and inclusive innovation is discussed, and the ethics of a representative inclusive innovation formulation is considered.

Chapter 4 considers the conceptualisation of inclusive innovation within the technological innovation systems approach. It discusses a reconceptualization of the technological innovation systems functions, particularly with regard to their indicators, with reference to the ethical foundations of inclusive innovation and responsible innovation. Implications for TIS analyses in developing countries are considered.

Chapter 5 concludes the study.

2 Technological Innovation Systems

This chapter discusses the concept of innovation, and provides an overview on the systems of innovation approach, of which technological innovation systems (TIS) is one example. The TIS framework and its functions are reviewed, as are recent discussions in the literature on the role of context in TIS analyses. The application to developing country settings of innovation systems broadly, and of technological innovation systems specifically, is considered.

2.1 Innovation

The term innovation generally refers to the development and implementation of new ideas, or to the adaptation and application of existing solutions to new problems. Dosi (1988, p. 222) has described innovation as the "search for, and the discovery, experimentation, development, imitation, and adoption of new products, new production processes and new organizational set-ups". Dosi further views innovation as being characterised by certain "stylised facts":

- uncertainty about the unexploited opportunities presented by innovative activity, specifically in the form of unknown solutions to techno-economic problems and an inability to foresee the consequences of actions;
- technological opportunities increasingly being reliant on advances in scientific knowledge;
- increasing complexity of research and development resulting in their formal organisation and in less emphasis on individual entrepreneurs;
- increasing importance of experimentation through learning, in the form of both "learning by doing" and "learning by using", as part of firms' informal activities; and
- innovation having a cumulative character, with technological advances relying on existing technology.

These characteristics render innovation an interactive process, which is influenced by the surrounding organisational and institutional structures (Carlsson & Stankiewicz, 1991). Thus

innovation is considered a learning process in which an array of actors, including a variety of organisations, businesses, governments and research institutes, participate, and in so doing exchange and recombine knowledge (Suurs, 2009, p. 36). This insight, namely that innovation is a collective activity that takes place in the context of a broader innovation system, has dominated studies on innovation in recent decades (Hekkert, et al., 2011).

2.2 Innovation systems

The technological innovation systems approach forms part of the innovation systems (IS) framework, which views innovation as a collective activity, taking place within a broader system. The view holds that technological change is not determined solely by individual companies or research institutes, but also by the broader societal context in which these types of organisations are embedded (Suurs, 2009, p. 35). Thus systems of innovation include "all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovation" (Edquist, 1997). The notion of the innovation system emphasises the flow of technology and knowledge among actors, and the interaction between actors, as key to innovation (Hekkert, et al., 2011).

The IS approach also stresses the role played by institutions, which are defined as the routines, norms, habits and established practices that delineate the interactions between actors, or the "rules of the game" (Edquist, 2013). The IS concept has been used extensively to analyse the evolution of knowledge through learning and innovation and to understand how innovation is supported within the environment in which it takes place (Lundvall, 2007).

The IS approach derives from evolutionary economics, which places technological innovation in a central position (Suurs, 2009, p. 19), based on the ideas of Schumpeter (1934). Schumpeter considered innovation as a driver of the evolutionary change that takes place in the capitalist economy, through "the new consumers' goods, the new methods of production or transportation, the new markets, [and] the new forms of industrial organization" which results in the economic structure continually being destroyed and created from within, in a "perennial gale of creative destruction" (pp. 83-84).

Multiple IS approaches are in use. The oldest one, and that which has been applied most often, is the national system of innovation (NSI) approach (Suurs, 2009, p. 37). An NSI is "the network of institutions in the public and private sectors whose activities and interactions initiate, import, and diffuse new technologies" (Freeman, 1987, p. 1). The NSI approach inspired innovation system analysis at different levels of aggregation, namely regional, sectoral, technological, and corporate (Lundvall, et al., 2009). Regional (Asheim & Gertler, 2005) system of innovation approaches are used to examine the innovative performance of geographic regions, emphasising the importance of space and proximity (Weber & Truffer, 2017). Sectoral (Malerba, 2005) system of innovation approaches examine industrial sectors, emphasizing the importance of production systems (Weber & Truffer, 2017).

2.2.1 Innovation systems in developing countries

Innovation pathways in developing countries are expected to differ from those in industrialised countries. The development, diffusion and adoption of innovations are shaped by socio-economic and institutional context; innovation is therefore determined by the particular features of countries and regions (Cozzens & Kaplinsky, 2009). Altenburg (2009) draws attention to the particularities of innovation systems in developing countries, which, he argues, are recognised in the literature in principle, but are not specifically and systematically addressed. Altenburg particularly points out the need for innovation in developing countries to protect the interests of the poor and to be targeted at reducing poverty and promoting social inclusion. Cozzens & Kaplinsky (2009) add an imperative for innovation to address inequality, cautioning that innovation systems might serve either to reduce or to increase poverty and inequality, based on a complex interaction mediated by a variety of social, economic and political processes. Innovation may, for example, reinforce inequality by preferentially bringing benefit to those who already have the resources and the social capital to gain easy access to the products of innovation. Thus innovation may exacerbate inequality by reinforcing existing, or resulting in altered, patterns of capabilities and income distribution. In turn, inequalities may shape innovation, with innovation employed by the economically more powerful to limit the developmental capacity of the less powerful. Alternatively, while innovation may reflect existing unequal income and power

relations, it may also undermine them. Thus technology may have a democratising effect, for example by providing mobile phone connectivity as a means of communication to communities in which fixed line communication infrastructure has been absent.

The research community has expressed conflicting views on the suitability of the IS framework for developing countries. The reason for this ambivalence, is that such countries typically do not have a full-blown IS (Lundvall, et al., 2009). Some have argued that the reliance of developing countries on technology importation from technologically advanced countries, precludes the use of the term IS in these countries (Viotti, 2002). However, Lundvall, et al. (2009) point out that national governments in developing countries do refer to innovation systems as a framework for their development strategies, and in addition, that the original broad conceptualisation of innovation systems does indeed accommodate the activities of less developed countries. This may span incremental innovation, diffusion and learning, but not necessarily the introduction of radically new world-leading technologies. Foster & Heeks (2013) conclude that systems of innovation models have been shown to be superior to previous approaches at explaining innovation in late-industrialising countries; such innovation has taken place through the combination of research and development policy, alignment and integration of different parts of the economy, guidance of iterative innovation, and technological learning.

Johnson & Lundvall (2003) proposed a set of requirements for the application of the national system of innovation concept in Africa. All sectors should be included in the analysis, as should all aspects of innovation, including “diffusion, imitation, and the use of new technologies” and all forms of training and building of capacity and competence. In addition, the construction of the innovation system should be emphasised, and the wider context and its impact on learning and innovation should be considered. Thus an IS conceptualised sufficiently broadly, is a legitimate analytical tool for developing countries.

The national IS, despite its inherent boundary, does not exist in isolation. Arin & Arza (2009) argue that it is necessary for innovation systems in developing countries to maintain a capacity for international involvement, for two reasons: to gain access to complementary capital to aid them along the path towards technological knowledge production in a complex

global technological landscape; and to keep pace with high rates of technological change globally. These authors define international involvement of such countries as the existence of mechanisms both to ensure access to technology or knowledge and to enable participation in international knowledge creation and diffusion activities. Gosens, et al. (2015) summarise several studies that have attributed the technological "catch-up" of Japan and other Asian countries in part to strong reliance on foreign technologies, and others that have pointed to the potential for innovation in emerging economies to be stimulated through increased involvement with the state-of-the-art globally. Arin & Arza (2009) cite mobility of qualified workers, researchers and/or graduate students, knowledge interaction with expatriates, joint technological ventures or projects, inter-governmental cooperation, and the presence of multinational subsidiaries, as examples of international involvement.

2.3 Technological innovation systems

Technological innovation system (TIS) analysis typically has, as its starting point, a technology, a technological field, or an industry. The purpose of TIS analysis is usually the evaluation of the development, growth and performance of new technologies, technological fields, and industries, with regard to the structures and processes that support or impede them, the identification of limitations, and the making of policy recommendations for technology development and diffusion (Suurs, 2009, p. 38; Gosens, et al., 2015; Markard, et al., 2015). The TIS framework enables understanding of the emergence and growth of the innovation system surrounding a new technology, but the focus can also be on mature technological fields (Bergek, et al., 2015).

The TIS approach has been applied extensively in studies of sustainability transitions, addressing large-scale transformation of established sectors towards production and consumption that are more sustainable (Markard, et al., 2012). Thus clean technologies, namely those with a reduced environmental impact compared with conventional alternatives, as a result of lower environmental emissions or reduced use of natural resources, have been focal areas of TIS analysis (Gosens, et al., 2015). Examples include technologies for efficient and sustainable energy generation and storage, solid waste

management, water management, and transport (DCTI, 2013). Empirical TIS analyses have focused on advanced economies (Gosens, et al., 2015).

The TIS approach emphasises not only the flow of knowledge, but also its exploitation, to create business opportunities (Carlsson & Stankiewicz, 1991; Suurs, 2009, p.38). Analysis of technological change starts at the "micro" level, which may mean actors such as the individual, the unit within a firm or organisation, the organisation, or even a cluster of organisations, which interact within the technological system (Carlsson & Stankiewicz, 1991). This systems view recognises the importance of interactions between organisations, innovations and institutions in effecting economic change.

The structure and functions of the TIS are the keys features of TIS analysis. The structure comprises the actors and rules that form the system. TIS functions have been defined and associated with indicators. In addition to an analysis of TIS functions, their interactions are also analysed to establish the development status of the TIS and the barriers to its functioning (Hekkert, et al., 2011). The TIS functions are discussed below.

2.3.1 Functions of technological innovation systems

Bergek, et al. (2008) synthesised the TIS functions that had been identified by several scholars as required for the evolution and performance of innovation systems. These have been used extensively in the analysis of TISs to examine their historical progression, current status and contributions to technology development, diffusion and utilisation. A number of indicators by which the status of the TIS can be measured are associated with each of the functions. The consolidated TIS function formulations and indicators of Bergek, et al., along with definitions extracted from Bergek, et al. and Hekkert, et al. (2007), are captured below.

Knowledge development and diffusion considers the "breadth and depth of the current knowledge base of the TIS, and how that changes over time, including how that knowledge is diffused and combined in the system" (Bergek, et al., 2008, p. 414). Indicators associated with this function include bibliometric analyses, numbers of R&D projects, researchers and patents, and increases in technological performance.

Guidance of the search represents the combined strength of the factors that serve to incentivise and/or exert pressure on organisations to enter the TIS and enable its development. It also includes the factors that influence the selection, from a variety of competing options, of technologies, applications, markets and business models. Indicators include expectations of the potential for growth and future opportunities in the TIS; regulatory and policy pressures and incentivisation; and expressions of interest and demand from leading customers.

Entrepreneurial experimentation entails exploration of new technologies and applications in a learning process to reduce uncertainty, and prevents stagnation of the TIS. This function may be assessed by the number of new entrants and diversification of existing actors; and by the variety of technologies and their applications and of the use of complementary technologies.

Market formation entails creating "protected space for new technologies" such as the introduction of niche markets, favourable tax regimes, and new environmental standards. Indicators include market phase and size; customer bases, their articulation of demand and their purchasing processes; actors' strategies; and the impact of standards.

Creation of legitimacy enables the establishment of a new technology as socially acceptable, appropriate and desirable to relevant actors, as well as institutionally compliant, in order to ensure resource mobilisation, creation of demand, and political strengthening of the TIS. Indicators include the strength of TIS legitimacy and its alignment with current legislation and industry and societal values; the influence of legitimacy on demand, legislation and company behaviour; and the factors and actors that influence legitimacy, as well as the mechanisms of influence.

Resource mobilisation makes available financial and human resources and other assets such as products, services and infrastructure, required for the continued development of the TIS. This function can be assessed by the changes in the volume of capital as well as seed funding

and venture capital; changes in the volume and quality of human capital; and changes in other, complementary, assets.

Development of positive externalities may be regarded as an indicator of the overall dynamics of the system, and refers to the strengthening of the other system functions through the entry of new actors into, and their contribution to, the TIS. Indicators include the resolution of uncertainties related to technologies and markets; political power and advocacy; reorganisation and combination amongst the pool of actors; the pooling of labour markets; the emergence of specialised intermediate providers of goods and services; and information and knowledge flows.

Recent literature has stressed the importance of context with regard to the functional dynamics of a TIS. An overview of such context considerations is provided below.

2.3.2 The role of context

It has traditionally been assumed that innovation starts in industrialised countries and is transferred to developed countries. In addition, TIS research has mainly been framed within national boundaries, particularly of developed countries. These mind sets have been criticised (Coenen et al., 2012), and in response several studies have in recent years emphasised the importance of the geographical dimension of technological innovation systems e.g. Binz ,et al. (2014), Wieczorek, et al. (2015) and Murphy (2015). Binz et al. (2014) ascribe the neglect of geographical context to the original conceptualisation of the TIS framework (Carlsson, 1997), which assumed a homogenous and unlimited set of global resources and opportunities in existence outside the TIS under examination, and the consequent use of territorial or national boundaries to delineate the system. Coenen (2015), on the other hand, argues that early work in the area acknowledged context and favoured a network-based, relational notion of TISs, whereas later empirical work may have succumbed to “methodological nationalism”. Gosens et al. (2015) argue that transnational processes have limited influence on TIS at the very early stages of system development in industrialised countries.

A more sophisticated consideration of space in TIS research has emerged (Binz, et al., 2014). This has been prompted by an awareness that innovative activity is geographically varied (Asheim & Gertler, 2005), and by the need for better understanding of the relationships between technological innovation systems and other innovation system types, so as to properly contextualise TIS analyses (Jacobsson & Bergek, 2011). Increased participation of emerging economies such as India and China in the clean energy sector and increasing global diffusion of clean technologies have further contributed to this shift towards the consideration of geographical context (Coenen, 2015), bearing in mind that the energy sector predominates in TIS studies.

Hansen & Coenen (2015) have reviewed the literature on the geography of sustainability transitions, a field in which the TIS approach has been applied extensively. In assessing the theoretical and empirical insights gained, they found a lack of generalizable knowledge on the impact of geographical specificity on the development of TISs. Thus a need has been expressed in the literature for research to explain why and how geographical contexts matter in TIS, beyond empirical mapping of TIS geographies. This deficit has been identified specifically for sustainability transitions and clean technology industries, their spatial distribution, and the effect of the latter on the formation and functioning of TISs (Coenen, 2015) (Hansen & Coenen, 2015). It would, however, also be relevant to the understanding of other industries and sectors in applications of TIS analysis.

Along a different analytical axis, additional arguments for spatial context to be considered in TIS studies include the appreciation that TISs might develop differently in economies at different stages of industrialisation, and that the supportive conditions for TIS development might differ in different national contexts (Blum, et al., 2015; Gosens, et al., 2015; Markard, et al., 2015). Variation in geographical context has implications for the generalisation of the results of TIS analyses, and also for the suitability of applying the TIS framework in contexts other than those in which it was initially developed (Markard, et al., 2015).

Scholars have recently advocated a network approach for TIS analysis to aid the understanding of geographical impact (Binz, et al., 2014; Blum, et al., 2015; Walrave & Raven, 2016). A network approach enables analysis across different geographical levels of

aggregation and enables distinctions to be drawn for example between local and international TIS activity. Coenen (2015) advocates for TIS research to engage with both local and distant spatial contexts, as networks may be locally concentrated. Binz, et al. (2014) applied such a network perspective to the knowledge creation function in a membrane bioreactor TIS, with the aid of social network analysis as an analytical tool and journal co-publications as a source of data, for the delineation of actors in the knowledge creation network. The approach enabled a study of the spatial characteristics of knowledge creation.

Bergek, et al. (2015) extended the TIS framework towards considering the contextual embedding of TIS beyond the geographical. They articulated four types of contextual structures, namely the technological, the sectoral, the geographical and the political. The technological context includes TISs that surround and are related to the one in question; these may be competitive and complementary, coevolving with and influencing the system in focus. The sectoral context structure includes existing institutions and infrastructures spanning several related TISs and is concerned with "the production, distribution and use of technologies and products needed to serve a certain function for prospective users" (p. 56). Geographical context structures include historically established "industrial sectors, cultural norms, formal regulations, educational systems, labour markets, political systems" and "natural context conditions" which may "host distinctive cultural communities with specific institutional arrangements" (p. 58) and result in geographical differentiation in the embedding of TISs. The political context refers to supporting institutions providing resources (e.g. policy-making, educational and financial) that are critical to the development of the TIS.

Developing country contexts have been discussed in Section 2.2.1 with regard to the application of the broader innovation system concept. The next section considers the application of the TIS approach to developing countries.

2.3.3 Technological innovation systems in developing countries

While the literature on innovation systems has been applied to developing country contexts, empirical TIS studies have primarily focused on high-income countries (Blum, et al., 2015). Gosens, et al. (2015) suggest that late-comer countries tend to enter new technological fields

when the global TIS has reached a certain level of maturation, and that this global maturity may promote innovation in the late-comer countries; thus, they argue for an analysis of transnational influence on early TIS development in emerging economies.

The suitability of the TIS approach and its functions for the study of emerging economies has been examined. Gosens, et al. (2015) identified a set of transnational dimensions of the TIS for clean technologies in emerging economies, and found that the existing TIS functions sufficiently captured these; however, they caution that the expression of the TIS functions in emerging economies has not been empirically tested for comparability with that of technologically advanced countries. Tigabu, et al. (2015) deemed the TIS approach to be a promising tool for analysis of renewable energy technology innovation in developing countries. They found variable expression of the TIS functions in the emerging biogas TIS in Rwanda, and attributed missed biogas implementation targets, in part, to functional weaknesses in the TIS. Blum, et al. (2015), on the other hand, found that the scope of the knowledge diffusion function was inadequate in a TIS analysis of remote electric mini-grids in Laos. They recommend that the knowledge diffusion definition be extended to account for bottlenecks in the local transfer, retention, and exploitation of knowledge in this developing setting. In addition, Blum, et al. identified culture as an informal institutional aspect, which emerged from their analysis but has been neglected in TIS studies, and which may be relevant in technology innovation and diffusion in some contexts. Bento & Fontes (2015) showed the TIS functions to be relevant to the establishment of a wind energy system in Portugal as a follower, rather than a pioneer, country, although the types of resources and the nature of activities required for adoption might differ from those in pioneer countries.

Schmidt & Dabur (2014) separated national and international TIS components in a study of biogas diffusion in India, defining a national TIS existing within the focal country and an international TIS existing outside it. They found that the international TIS had contributed to a small number of TIS functions that were in fact the most developed within the national TIS, and concluded that the international TIS had made an important contribution to the national one through technology transfer.

In a study on the diffusion of renewable energy technology in Ethiopia, Kebede & Mitsufuji (2017) categorised the broader TIS into two components. They distinguished between the research and development (R&D)-based TIS and the diffusion-based TIS, focusing on the latter. The distinction is motivated by the reality that, rather than developing new technologies, least developed countries often introduce technologies imported from industrialised countries. In such a context, the TIS emphasis in "technology-receiving" countries is on the introduction, diffusion and use of imported technologies, and on the building of local innovative capacity. The authors propose a role for academic and research institutions in the building of skills and absorptive capacity to support the transition from a diffusion-based to an R&D-based TIS.

2.4 Conclusion

Some limitations have been identified in the scope of the TIS functions in their application to developing countries (Blum, et al., 2015), while the expression of the functions has been found to vary, or has been thought to have the potential to vary, between developing or emerging and industrialised countries (Bento & Fontes, 2015; Gosens, et al., 2015; Kebede & Mitsufuji, 2017; Tigabu, et al., 2015). Culture has been identified as a pertinent but neglected institutional factor impacting on a TIS in a developing country (Blum, et al., 2015).

The literature suggests that the successful diffusion and adoption a new technology, requires the presence of a well-functioning TIS (Tigabu, et al., 2015). The literature does not, however, address the social and environmental consequences of TISs that might be considered successful by the current standard. The long-term social and environmental consequences are not assessed explicitly in the TIS functions, nor are indicators devoted to them. TIS studies, also those in and on developing countries, focus on technology development and implementation or adoption, rather than the long-term consequences of the technology and the management of such consequences. Because the TIS framework has been used primarily to examine sustainability transitions towards clean technology, which is meant particularly to benefit the environment, there is an implicit assumption that evolution of the TIS would bring long-term benefit. But if the TIS framework is to be used more broadly, also for technologies

and technological fields that cannot be assumed to be inherently beneficial, its focus on sustainability should include an element of social benefit and environmental sustainability.

3 The Ethics of Responsible Innovation and Inclusive Innovation

Responsible innovation (RR) and inclusive innovation (II) are concepts that may be useful in the analysis of technological innovation systems, by adding considerations of societal benefit. This chapter starts by placing responsible innovation and inclusive innovation in the context of science, technology and innovation policy. It then examines RI and II and their ethical underpinnings, and considers the ethics of a representative II formulation.

3.1 Innovation policy

Science, technology, and innovation policy direct scientific activities toward serving public needs. Lundvall & Borrás (2005) present science policy, technology policy and innovation policy as "ideal types", as a means of illustrating their distinctions and overlaps. These characterisations are discussed below.

The main concerns of science policy are the allocation of sufficient resources to science, their distribution between scientific activities, their efficient use, and their contribution to society. Science policy focuses on universities, research institutes, technological institutes, and research and development laboratories. The internal regulation of these organisations and their relationship to their environment, particularly government and industry, are considered. In applying science policy, governments pursue objectives that may include social and economic progress and national security, but also cultural values and national prestige.

Technology policy is concerned with technologies and considers science-based technologies as key to economic growth. The policy goals and organisations in focus are similar to those of science policy, but with an emphasis on linkages with industry. Relevant activities include the identification of technology trends and future strategic technologies.

Innovation policy has economic growth and international competitiveness as its main objectives. It may also be directed toward social and environmental benefit. The mechanisms of innovation policy include the regulation of intellectual property rights, the development of

skills and capabilities at the individual and organisational levels, improving access to information, supporting social capital development, and regulation to prevent harm from technological development.

The outcomes of innovation policy may be analysed using the systems of innovation framework discussed in the previous chapter. RI and II on the other hand, may be regarded as policy tools or drivers, providing normative pressure. However, they also provide normative criteria against which innovation systems may be evaluated.

RI and II have served as components of innovation policy in different settings. RI is primarily used as a policy tool and a governance framework to drive innovation towards societal benefit, particularly, and prominently, in Europe (Schroeder, et al., 2016). II has, similarly, entered the policy arena, but mainly in the developing world, and with the aim of advancing the interests of the poor. Governments in low-and-middle-income countries, such as India and Thailand, have introduced policies to promote inclusive innovation, while other countries, such as China, have expressed a commitment to inclusive innovation (Heeks, et al., 2013). RI and II on the surface appear to share overlapping goals. Both are underpinned by an appreciation that technology and innovation are not neutral. This lack of neutrality is the result of the role played by the context of innovations (Lorentzen & Mohamed, 2010), as well as their interrelationships and their relationships with people (Balabanian, 2006). Context and relationships influence the deployment of innovations, and therefore the benefits they confer. Given the differential uptake of RI and II as policy tools in different settings, deeper examination of their motivations and ethical underpinnings is warranted.

3.2 Responsible innovation

RI has emerged as a response to the traditional view of innovation as being inherently good and automatically giving rise to societal benefit, employment and prosperity (Von Schomberg, 2013). This view is now contested. While RI is concerned with implications for, and benefits to, society, it does not disregard the economic benefits of innovation. RI is considered a route

to increased economic competitiveness, through increased research quality and more successful products of innovation (Schroeder, et al., 2016).

RI is also a consequence of the recognition of innovation as a complex process, which relies on the interaction of a variety of "actors, considerations, demands, expectations and values" that exist within an innovation ecosystem (Eizagirre, et al., 2017). This same recognition gave rise to the innovation systems framework. Thus, while RI may be considered as having appeared on the political stage fairly recently, it can also be interpreted as part of a sequence of debates on the interrelationship between science and society; these debates consider how research agendas are shaped and reflect on the governance of new knowledge and new technologies (Ribeiro et al., 2017).

A prominent consideration in this interrelationship between science and society, is the difficulty in predicting the impact of innovation on society. Technological innovation is motivated by a desire for novelty and improvement. Traditionally, however, the normative dimension of what constitutes improvement, is determined by market mechanisms, with the benefits of technology regarded as equating to market success and the impact of innovation justified only in economic terms (Von Schomberg, 2013). The recent recognition of RI is that the trajectories of innovations are unpredictable, with the potential for unforeseeable negative implications and unintended consequences (Owen, et al., 2012). RI calls for an effort to extend the normative dimension and to anticipate and mitigate such adverse impacts.

The RI discourse highlights the democratic governance of research and innovation, with the goal of achieving desired impact. It requires that research and innovation be responsive to the needs of society. However, innovation can only be responsive if it integrates, accommodates and institutionalises the diversity, in terms of values, interests and knowledge, that informs and motivates it (Eizagirre, et al., 2017). RI therefore proposes the crafting of a collective responsibility for technological innovation in the face of its uncertain outcomes (Von Schomberg, 2013). These considerations demand broad engagement involving the public and various stakeholders including policy-makers and other decision-makers. Furthermore, they require an understanding of innovation that extends beyond the technological; this necessitates an appreciation of the value of knowledge transfer across the

boundaries that exist between the humanities and social sciences, and science and engineering (Burget et al., 2017).

RI can be characterised as responding to and reflecting a growing interest in foreseeing the consequences of technology, considering its ethical and social dimensions, and recognising the values and concerns of a variety of stakeholders (Ribeiro, et al., 2017). The definition of RI by Von Schomberg (2013, p. 19) has been endorsed widely and is often cited:

> *Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society).*

Expansions of this definition include an emphasis on shared responsibility amongst actors for the consequences of innovation (Ribeiro, et al., 2017), i.e. "a collective duty of care" in framing the desired outputs of innovation and guiding innovation in the face of uncertainty (Owen, et al., 2012) and "collective stewardship" to safeguard the future (Stilgoe, et al., 2013).

3.3 Inclusive innovation

Inclusive innovation is concerned with innovation that benefits the marginalised. It refers to "the development and implementation of new ideas which aspire to create opportunities that enhance social and economic well-being for disenfranchised members of society" (George, et al., 2012, p. 663). While the social groups of concern that are potential beneficiaries of inclusive innovation have included women, youth, the disabled and ethnic minorities, the poor have received most attention (Heeks, et al., 2013). Inclusive innovation is also referred to as "innovation for inclusive development" (van der Merwe & Grobbelaar, 2018).

Interest in an inclusive innovation agenda has been prompted by the dominant global growth model, which has excluded a large proportion of the population from the benefits of economic growth; this model has resulted in a persistence of poverty and inequality in many

countries, despite growth in their GDP (Chataway, et al., 2014). Inclusive innovation recognises the inequalities that may result from the development, implementation and distribution of innovations (George, et al., 2012). Certain features of the dominant innovation trajectory contribute to such inequalities (Chataway, et al., 2014): it is capital-intensive and scale-intensive, it depends on networked infrastructure, it relies on skilled labour, it tends to focus on products that meet the needs of the rich, and it often has harmful environmental consequences. All of this disadvantages the poor, both as producers and as consumers of innovation. Inclusive innovation, in response, mandates innovation to address the problems of the marginalised while also requiring engagement with such communities in the development and implementation of solutions for their problems. Although the phenomenon now referred to as inclusive innovation may not be new, recent new features are notable (Heeks, et al., 2013): a broader range of actors, activity locations and contexts, and modes of implementation for inclusive innovation; increased markets created among excluded groups; and new technologies able to support inclusive innovation.

Views differ on the nature of the inclusivity or the aspects of innovation that should demonstrate an inclusion of otherwise excluded groups (Heeks, et al., 2013). Johnson & Anderson (2012, p. 8) distinguish between passive and active inclusion, which are about "reducing income inequality and bringing the poor out of poverty through raising their income", and "giving rights, voice, capabilities and incentives for the excluded to become active participants in processes of development and innovation", respectively. George et al. (2012) refer to innovation for inclusive growth, which they believe can be viewed as a desired outcome of innovation activities and simultaneously as a feature of the processes by which innovation occurs. Cozzens & Sutz (2012, p. 12) similarly require inclusive innovation to be inclusive in terms of both "the process by which it is achieved" and "the problems and the solutions" to which it is linked. Thus inclusive innovation serves as a normative construct for guiding innovation efforts for the specific benefit of the marginalised.

Despite these prescriptions, inclusive innovation has thus far received limited attention as an area of scholarly inquiry. Donors, governments, industry, academics and others require knowledge and evidence on the topic (Heeks, et al., 2013). Several scholars have highlighted topics for empirical research and theorisation. George et al. (2012) have suggested

opportunities for empirical research related to entrepreneurship, strategy, and marketing as well as for the development of research tools to examine the impact and consequences of inclusive innovation on, and for, the poor. Chataway et al. (2014) have argued for inclusive innovation to be studied and developed holistically, with reference to the innovation cycle, the distinction between the processes and products of innovation, and the role of the poor as both consumers and producers of the products of innovation. These suggested areas of research address the processes, the outputs and the participants of inclusive innovation. Calls for an examination of the normative basis of inclusive innovation are less prevalent.

3.4 Ethical frameworks for responsible innovation and inclusive innovation

Despite the "inclusive" intentions of inclusive innovation, and the "responsible" orientation of responsible innovation, these approaches are not inevitably beneficial in practice. Kimmit & Munoz (2015) argue that inclusive innovation cannot be assumed to be morally and ethically neutral – unforeseen or poorly considered consequences of the processes and products of innovation may cause harm to intended beneficiaries. Avoiding such unintended consequences and harms is an explicit goal of responsible innovation, but not clearly articulated in formulations of inclusive innovation. Practice guidance is required towards ensuring that these policy tools are implemented in ways that secure the desired outcomes. An examination of the ethical underpinnings of both responsible innovation and inclusive innovation may provide such guidance.

3.4.1 Ethics of responsible innovation

Some consideration has been given in the literature to the ethical frameworks that do, or should, underpin responsible innovation. These discussions mainly cite deontological ethics, teleological or consequentialist ethics, virtue ethics, and the ethics of care (Grinbaum & Groves, 2013; Groves, 2015; Pandza & Ellwood, 2013).

Consequentialist, or teleological, ethics carries out moral assessments of acts, choices and intentions based on their consequences, or the states of affairs in which they result, rather

than by their intrinsic nature, their antecedents, or their circumstances (Alexander & Moore, 2016; Sinnott-Armstrong, 2015). Deontology is a normative theory that stands in contrast to teleology. Deontology, in its most familiar forms, asserts that some choices are morally unacceptable, irrespective of the moral goodness of their consequences, and cannot be justified by their effects (Alexander & Moore, 2016). Deontological ethics focuses on duties, rights, permissions and rules. It guides moral choices by emphasising that which ought to be done. Thus deontology defines virtues as characteristics that are expressed by those who perform their duties reliably, while consequentialism defines virtues as characteristics that produce good consequences.

Virtue ethics regards virtues in a different way. Virtue ethics can be distinguished in its consideration of virtues as foundational. Deontological and consequentialist ethics, in contrast, define virtues in terms of another concept that is considered more fundamental; they hold duties and good consequences, respectively, as fundamental concepts (Hursthouse & Pettigrove, 2016). Virtue ethics is grounded in character (Bertland, 2009). It considers a moral virtue to be a valued character trait of a morally good person; moral virtues are expressed in habitual behaviour and have been acquired with some effort (Velasquez, 2006, p. 110). Virtues are enacted with resolve, and with the purpose of achieving good. In the sense that virtue ethics is poised towards the purpose of doing good, it is teleological (Weaver, 2006). However, virtue ethics does not find expression only in action; it cultivates a particular disposition from which action may result (MacIntyre, 1981, p. 140) and is therefore motivational (Weaver, 2006). Virtue ethics is characterised by social interrelationships, which, with the desired disposition of actors, form the basis of practice, which in turn gives rise to the production of internal goods. Practice in this sense is defined as follows (MacIntyre, 1981, p. 187):

> *… a coherent and complex form of socially established cooperative human activity through which goods internal to that form of activity are realized in the course of trying to achieve those standards of excellence which are appropriate to, and partially definitive of, that form of activity, with the result that human powers to achieve excellence, and human conceptions of the ends and goods involved, are systematically extended.*

The internal goods are recognised by practitioners as having value (Opderbeck, 2007), while

practice and internal goods appear to be reciprocally dependent.

The ethics of care has its origins in the emergence of feminist thinking, which challenged the presuppositions of traditional ethics, in which the self was separated from others; such a traditional ethics saw reality expressed in abstract, impartial, rational and universal knowledge (Tong & Williams, 2016). An ethics of care is manifested in concern and compassion and has two moral demands (Velasquez, 2006, p. 102): we should nurture and preserve our close and valuable relationships with specific individuals; and we should attend and respond to the needs, desires, values and well-being of those with whom we share such relationships, especially if such individuals are vulnerable and depend on our care.

Pandza and Ellwood (2013) view studies of responsible innovation as predominantly building on deontological and teleological ethics, both of which they consider insufficient. They regard these as unable to address the uncertainty that is inherent in technological innovation and the difficulty of predicting the outcomes of technological innovation. One response to the inability of teleological ethics to account for the delayed and unexpected consequences of innovation, has been regulation; duty-based deontological ethics, requiring the observation of norms, rules and principles, is often relied on to ensure that science-driven innovation has a responsible orientation (Pandza & Ellwood, 2013; Groves, 2015). Preston & Wick (2016) interpret the duty-based view as often taking the form of risk assessment. Risk assessment is a dominant tool used to aid decision-making in the governance of innovation, especially when the products of innovation are new and emerging technologies, with the risks that generate concern typically being related to human health and/or the environment (Preston & Wick, 2016). Groves (2015) argues that rights are often used as a defence against uncertainty about the outcomes of innovation, and that the guidance provided by legislation is used to confer legitimacy to decisions about innovation; these are examples of deontological ethics. Groves, however, points out three limitations in using a rights-based ethics to guide responsible innovation. First, a rights-based approach doesn't address the uncertainty about the potential negative impacts that particular innovation trajectories might have on human rights. Second, in different contexts, cultural and developmental imperatives would affect the socially sanctioned balance between social priorities and rights; for example, views may differ in developing and industrialised countries. Third, the equilibrium between competing priorities,

which is interpreted in the definition of rights, may shift in time; for example, the balance between growth and sustainability may change in the long term.

Pandza & Ellwood (2013) advocate for the emphasis on rules that guide ethical behaviour in RI, to be shifted to an innate and virtuous desire to benefit society. Thus they promote an ethics of virtue, which, they hold, through its demand for deliberate agency to achieve good, is highly relevant to responsible innovation. Pandza & Ellwood argue that the social obligations and interrelationships that underscore virtue ethics and its outcome of doing good, resonate with the requirement for social interaction among stakeholders in responsible innovation.

Groves (2015) expresses a perspective of RI as "taking care of the future". This term was coined by Stilgoe et al. (2013) to draw attention to the importance of collective and responsible effort in the present to engender benefit in the future. Groves argues for a virtue-based ethical perspective for RI; the required virtues, namely anticipation, inclusion, reflexivity and responsiveness, enable the desired responsible orientation towards the future. These virtues form the basis of an ethics of care that recognises, attends to, and provides for, needs that are defined in an ongoing process of social learning which is possible through connectedness to others (stakeholders). While both Pandza and Ellwood (2013) and Groves (2015) draw on virtues as a route to achieving social good in RI, the virtues are foundational for Pandza & Ellwood, but instrumental for Groves.

Preston & Wick (2016) recognise feminist themes in the ethics of care that they deem to be useful in the assessment of new technologies:

- a relational ontology to shift the focus from the individual and instead emphasise relationships that have personal, social and cultural importance;
- an appreciation of cultural specificities, which can be achieved through a focus on particularity and context, and through paying attention to individuals and their contexts rather than treating individuals in abstraction;
- recognition of dependence and asymmetries in relationships as well as the vulnerability of relational networks to disruption;

- awareness of power and vulnerability, for sensitisation both to the way in which power is wielded in relationships, and to the needs of the most vulnerable;
- a recognition that moral decision-making has an emotional dimension; and
- the use of storytelling or narrative as a device for explaining moral situations.

With the aid of these lenses, Preston & Wick advocate that technology be examined "as a transformative practice that dramatically restructures relationships" and that technology be conceptualised as "a system embodied in a set of practices that both reflects the world from which it arose and in turn reconstitutes the world into which it is introduced" (p. 50).

These care themes are discussed by Preston and Wick in the context of an aspect of RI, namely technology assessment, yet they are in alignment with principles of care that have been hailed by other authors as suitable for RI more broadly. Groves (2015) cites the innovator's virtues put forward by Stilgoe et al. (2013) as an appropriate basis for an ethics of care: anticipation, namely the capacity for foresight into, and adaptation to, potential but uncertain negative consequences of innovation; reflexivity, namely the capacity for reflection on the purposes of innovation and on the limits of anticipation; inclusion, namely an active engagement with stakeholders; and responsiveness, namely a capacity for social learning and for responding to stakeholders. Groves also proposes that humility be added to the virtues that underpin an ethics of care for responsible innovation; humility in this context entails awareness of, and reflection on, the potential dangers and limitations inherent in using technology to achieve certain goals (Grinbaum & Groves, 2013).

Groves (2015) argues that the care approach should be applied sufficiently early to aid in identifying social priorities and shaping the priorities of innovation. Such a care approach should also accompany innovation, influence design, and guide risk identification, assessment and management. This approach would not depend on principles or rules to form the basis for regulatory decisions, but would create practices and institutions to enable innovation to be embedded in society. In advancing innovation, the approach would recognise the knowledge held by society as well as society's competence in understanding its own needs.

3.4.2 Ethics of inclusive innovation

The ethics of inclusive innovation has received limited attention in the literature. II has been linked to Rawls's theory of justice (Schroeder, et al., 2016) and to the capabilities approach (Kimmitt & Munoz, 2015). Through a view of virtue ethics as a foundation for the latter (Bertland, 2009), inclusive innovation may also be linked to the ethics of virtue.

Questions of justice and fairness may be considered in three categories (Velasquez, 2006, p. 88): distributive justice, which focuses on the "just distribution of benefits and burdens"; retributive justice, which is concerned with the imposition of penalties and punishments; and compensatory justice, which atones for injuries or wrongs. Distributive justice is pertinent to inclusive innovation, which is concerned with a distribution of the benefits of innovation. Rawls (1971) presented a theory of distributive justice, "justice as fairness", in which a just distribution of benefits and burdens is based on two principles. The first affords all persons equal rights to basic liberties, consistent with similar liberties for all.

The second principle of Rawls's theory of distributive justice has two parts; the first calls for equality of opportunity so that those with the same abilities and industriousness have the same opportunities regardless of their circumstances, while the second, the difference principle, allows for wealth and income inequalities if they are to the benefit of all, but especially those who are the least advantaged (Wenar, 2017). The difference principle might be invoked in inclusive innovation, given the focus of the latter on benefits particularly for the poor (Schroeder, et al., 2016).

Rawls's approach is concerned with the distribution of primary goods (Rawls, 2001): rights and liberties; powers (including powers of office and the responsibilities accompanying authority) and opportunities; income and wealth; and the social foundations of self-worth and confidence. All citizens are assumed to have a fundamental interest in these primary goods, which enable them to pursue a good life (Wenar, 2017). Critique of Rawls's approach, particularly by capabilities scholars like Amartya Sen, suggests that the notion of primary goods does not sufficiently deal with human diversity. This is because people have varying

needs, while an index of primary goods assumes that these goods are assigned similar value by all (Sen, 1980).

Kimmitt & Munoz (2015) suggest that Sen's capabilities approach (Sen, 1999) provides an important lens through which to evaluate inclusive innovation, by assigning the ownership of social problems to disadvantaged communities. Sen asserts that development requires that such communities be viewed as agents and that the expansion of their capabilities to address problems is both an end and a means of development. The capabilities approach has two fundamental normative claims (Robeyns, 2016): the first assigns primary moral importance to the freedom to achieve well-being; the second understands the freedom to achieve well-being in terms of people's opportunities to do and be that which they have reason to value, and considers it a matter of the kind of life that they are able to lead. The emphasis of inclusive innovation on participation by marginalised communities, expands the capabilities of such communities in the sense of creating opportunities to guide innovation towards outcomes that are valued in these communities.

Bertland (2009) recognises an ethics of virtue in the capabilities approach, based on the notion of human dignity. From Bertrand's perspective, the virtue by which a character should be measured in this context, is the ability to foster a community that maintains human dignity and supports the development of human capabilities. In this way the virtuous character contributes to the creation of an environment in which stakeholders are able to flourish.

RI is more mature than II as a topic of scholarly investigation, and may therefore provide some insights that are of value to II. Given the shared goals of RI and II, the ethics discussions related to RI are also relevant to II. Section 3.4.1 has shown that virtue ethics and the ethics of care are supportive of RI. Bertland brings focus to the support expressed by Pandza & Ellwood (2013) for an ethics of virtue for RI. While Pandza & Ellwood rely on social interaction with stakeholders in RI to give expression to the expectations of virtue ethics, Bertland's focus on a respect for human dignity provides a normative guideline that defines the nature of the interaction.

The ethics of care themes that have been highlighted above as important for RI, are relevant to the inclusive goals of II. The feminist care themes delineated by Preston & Wick (2016) and the innovator's virtues listed by Stilgoe et al. (2013), demand active inclusion of stakeholders and attention to their needs, as well as sensitivity to power dynamics. These attributes, accompanied by the humility required by Groves (2015), mitigate against the unforeseen harms and consequences of II about which Kimmitt & Munoz (2015) have expressed concern. Despite the broader range of intended beneficiaries of RI compared with those of II, namely all of society vs the poor and marginalised, an analysis of the ethical foundations of RI is able to provide insight into the ethics of II.

3.5 An ethical lens applied to the ladder of inclusive innovation

The ethics themes that may be applied to inclusive innovation as identified in Section 3.4, provide a lens through which to consider structured conceptualisations of inclusive innovation. Heeks et al. (2013) suggest a "ladder of inclusive innovation" comprising a set of steps pertaining to innovation and representing increased levels of inclusivity. In formulating the ladder, these authors have taken into account a variety of perspectives on inclusive innovation. They identify three key features of inclusive innovation that should be considered in defining the concept: which group is to be included, for example the poor; which members of the target group are to be included, for example those consuming the intended product or their representatives in the community; and which aspects of innovation are to be considered, for example the process of innovation or the outcome of innovation.

The levels of the ladder are described below. The ethics themes identified above are then applied the inclusive innovation ladder, which is treated here as an exemplar formulation of inclusive innovation.

3.5.1 Levels of inclusion

Level 1 – Intention

At this level, an innovation has the intention to address the wants, needs or problems of the excluded group, without the need for any concrete activity. Interaction with stakeholders is thus absent.

Level 2 – Consumption

Here, the good intentions of Level 1 are implemented: an innovation is developed into concrete goods or services that can be accessed and afforded by the excluded group, which the excluded group has the desire and capability to adopt, and which are used by the group.

Level 3 – Impact

At this level, innovation has a positive impact for the excluded group, in terms of a broad range of development indicators, including well-being and economic prosperity.

Level 4 – Process

At the process level, members of the excluded group are involved in the innovation activity, including invention, design, development, production, or dissemination. Participation is key, although it may vary in degree.

Level 5 – Structure

At this level, innovations are created using an inclusive structure, including institutions, organisations and relations that form part of an innovation system; this ensures depth and sustainability of the innovation.

Level 6 – Post-structure

At this level, the innovation is created within an inclusive "frame of knowledge and discourse". For innovation to be truly inclusive, the key actors participating in the innovation must have a world view that accommodates (and, one could argue, demands) inclusion.

With reference to the Heeks et al. ladder, Saha (2016) discusses four key themes underlying inclusive innovation. States, markets and society are critical actors in the process of innovation; at the lowest level of the ladder, they guide the "intention" of innovation. The importance of building capacity for technology transfer, adoption and diffusion for the "consumption" and "impact" levels is noted. At the "process" and "structure" levels, participation from local stakeholders who understand local needs, including entrepreneurs, research organisations and communities, enables knowledge creation to address these needs. The need is stressed for framing innovations in the social context at the highest level of the ladder, in recognition that technological trajectories are shaped by social forces.

Each step of the ladder suggests a broadening and/or deepening of the extent to which the target group is included. Heeks et el. confirm that an observer located at one level would not consider a lower level of the ladder as representing inclusive innovation, and that the ladder represents a progression from the "positive towards the normative" (p. 7). The key to the progression is the level of inclusion of marginalised groups. One may therefore assume that each successive level incorporates the stakeholder inclusivity of the former. The authors acknowledge that inclusivity at the level of structure and knowledge frames (Levels 5 and 6) may be uncommon and aspirational.

3.5.2 The ladder through an ethics lens

An ethics of care is evident in the attention to the needs of marginalised stakeholders throughout the six levels of the ladder of inclusive innovation, mainly through the innovator's virtue of responsiveness (Stilgoe, et al., 2013). The levels of the ladder respond to different extents to the needs of the marginalised. An ethics of virtue in the form of a virtuous wish to make valuable contribution to society is also present throughout the levels, while the nature and extent of the expression of this wish differs.

The promotion of human dignity that resides in responding to the consumption needs of the marginalised group at Level 2, also suggests Bertland's (2009) notion of an ethics of virtue. Bertland, however, recognised an ethics of virtue in the capabilities approach. At the

consumption level, the targeted communities are passive recipients of innovation rather than being agents in the innovation process, and the capabilities approach does not apply.

The ethics of virtue takes a more concrete shape from Level 2, where it becomes evident not only in virtuous intentions, but also in the production activities of (non-marginalised) innovators, and from Level 4, in their social interactions. Weaver (2006) refers to moral identity as a basis for the moral agency in which virtue ethics is embedded. At Level 1, the inclusive intention of the Foster & Heeks ladder represents moral identity, which gives rise to moral agency that produces tangible innovation from Level 2 and higher.

While the tangible products of innovation may be regarded as external goods that are not solely dependent on practice, the inclusive intentions of inclusive innovation must be practiced at all levels of the ladder if they are to be apparent in the ladder; this, as suggested above, requires an ethics of virtue. However, at Levels 1 to 3, the scope of participating innovators remains limited, and excludes marginalised stakeholders and intended beneficiaries. The respect for human dignity that is evident at these early levels is not sufficient evidence for the capabilities approach. Level 3 recalls a teleological ethics, in that the process of innovation is judged by its outcomes. The targeted communities remain passive recipients of innovation; while innovation is meant to uphold the dignity of the marginalised, recalling the ethics of virtue as suggested by Bertland. Community members are not yet agents; thus the capabilities approach does not apply.

Only at Level 4, are the previously excluded groups given the opportunity to be practitioners of innovation. The innovator's virtue of inclusion, though active involvement of stakeholders (Stilgoe, et al., 2013), becomes evident. Thus interaction of other innovators with marginalised stakeholders becomes necessary at this level, recalling MacIntyre's (1981) view of practice as a complex and coherent type of human activity that gives rise to internal goods. The broad interaction of all stakeholders also recalls the restructuring of relationships based on an ethics of care, that is advocated by Preston & Wick (2016) for the examination of technology.

Participation of the marginalised suggests agency and even ownership of the innovation activity. It is therefore only at Level 4 where the ethics of virtue gives rise to the capabilities approach, in support of Bertland's link between virtue and human capabilities.

The marginalised may also become enactors of an ethics of virtue. The "doing good" of inclusive innovation at Levels 1 to 3 is from the viewpoint of benefiting the marginalised as passive beneficiaries. Even at Level 4, their agency might be conferred through inclusion by others, with limited application of the capabilities approach. However, true inclusion and true agency would mean that the marginalised become able to convert into practice their virtuous intentions towards each other and towards other stakeholders of the present and of the future.

Levels 5 and 6 may be more aspirational than what is found in practice (Heeks, et al., 2013). It is at these levels that a longer-term view becomes apparent. Level 5 seeks sustainability of innovations, while the inclusive knowledge discourses of Level 6 suggest a codification, and therefore embedding, of inclusive innovation. However, neither of these levels explicitly addresses the potential harms of innovation as anticipated in responsible innovation. A "responsible" orientation to inclusive innovation would include in the structures of Level 5, elements that anticipate and mitigate the uncertain consequences of the innovations being developed. Similarly, the knowledge framework of level 6 would include knowledge generation on the potential harms of innovation. These additions would strengthen the ethics of care and extend its scope to the stakeholders of the future. It would reflect the anticipation and reflexivity (Stilgoe, et al., 2013) that contribute to an ethics of care as proposed for responsible innovation by Groves (2015). The additions would also bring Groves's (2015) virtue of humility to the higher levels of inclusivity, in that humility is required for the admission of uncertainty about the future. The additions would serve the capabilities approach by increasing the agency of future generations and their ability to define and lead the lives of their choosing.

3.6 Conclusion

Responsible innovation is an emerging concept, and as such, some of its dimensions are poorly specified and ambiguous. These include its theoretical conceptualisations, motivations, and translations into practice (Ribeiro et al., 2017). Despite this lack of clarity, RI is being used as a policy tool to guide innovation towards benefit for society. Examination of its ethical foundations suggests a basis in the ethics of virtue and the ethics of care.

RI already includes inclusive innovation as a special case. II also has the goal of societal benefit, but with greater focus on benefit to the poor and the marginalized, but II does not look far as far into the future as RI does. II, too, suffers from limitations in the scholarly attention it has received. II would benefit from studies of its impacts and consequences (George, et al., 2012). While its ethical roots have received less attention in the literature than those of RI, the latter are informative for II.

Exploration of the normative dimensions of inclusive innovation has highlighted some shortcomings of II, particularly with regard to a responsible orientation that considers future impacts of innovation. A formulation of inclusive innovation as a ladder of inclusivity (Heeks, et al., 2013), which captures the essence of the inclusive innovation literature, displays an ethics of care and an ethics of virtue. At greater levels of stakeholder inclusivity, the capabilities approach becomes apparent. The longer-term goals of responsible innovation, namely guarding against the potential harms and unintended consequences of innovation, are not clearly evident in inclusive innovation conceptualisations. II is not explicit about ensuring a sustainable future. Guarding against the consequences of innovation is however as important for II as it is for RI. Both the ethics of virtue and the ethics of care demand it.

The capabilities approach has been proposed as a suitable lens for the evaluation of inclusive innovation (Kimmitt & Munoz, 2015), while Bertrand (2009) has described an ethics of virtue that maintains human dignity and enables stakeholders to flourish, for the capabilities approach. This ethics of virtue should not only apply during the innovation process and in the immediate application of innovation products. Rather, human dignity and thriving should be

a long-term goal, and the virtuous character should endeavour to minimise unfavourable long-term consequences of innovation.

Thus ethics of care themes recognised in the literature for RI and identified in II, should also be applied to II with foresight and care for the future. Stilgoe's (2013) innovator's virtues, namely anticipation, reflexivity, inclusion, and responsiveness, and Groves's (2015) humility, have been proposed by Groves as the basis for an ethics of care in RI. Among these, inclusion, responsiveness and humility are clearly articulated in the II formulation: inclusion of the marginalised, responsiveness to their needs, and humility in recognising the limitations of technology. Clear attention to anticipation of, and responding reflexively to, the long-term consequences of innovation, would render II more comprehensive in its concern for marginalised stakeholders. As with RI, a capacity to anticipate and adapt to uncertain negative consequences should be present in II. The RI prescription for reflection on the purposes of innovation would also serve an anticipatory role in II. In addition, II should share the prescription of RI for reflection on the limits of anticipation, which requires humility.

Considerations of the ethical underpinnings of inclusive innovation may complement the set of analytical tools available for assessing innovation systems, especially in developing countries, where inclusion of the marginalised is an imperative.

4 Indicators for Inclusive and Responsible Technological Innovation Systems

Both responsible innovation and inclusive innovation have emerged in the context of recent innovation policy directions worldwide that reflect a desire simultaneously for economic competitiveness and growth, and for social and environmental justice. Both aim to benefit society. Inclusive innovation has its focus specifically on the poor and marginalised, as beneficiaries as well as co-producers of innovation, while responsible innovation embraces a universal set of stakeholders.

Responsible innovation and inclusive innovation are concerned with interrelationships among a variety of stakeholders in the context of innovation and its consequences; this is a feature shared with the systems of innovation framework. Consideration of the ethics of responsible innovation and inclusive innovation provides both guidance for innovation policy and criteria against which to assess innovation policy. Such guidance may augment analytical applications of the systems of innovation approach.

The literature on both responsible innovation and inclusive innovation is mainly descriptive rather than analytical, suffering from limited formulation of analytical frameworks to examine their implementation. Schroeder et al. (2016) advocate for the use of both responsible innovation and inclusive innovation in a complementary manner with innovation systems approaches, as the descriptive and analytical focus of the latter would enable assessment of the success of responsible innovation and inclusive innovation and of the validity of their claims. The emphasis of the innovation system approach on learning, institutions and interaction is important for the understanding and promotion of inclusive innovation (Johnson & Andersen, 2012). Analytical integration of inclusive innovation and responsible innovation with innovation systems, would however require a sensitivity of innovation systems analysis to the stakeholder focus of responsible innovation and inclusive innovation.

There is a recognition that innovation systems research is being redirected from an initial focus on competitiveness, towards addressing concerns regarding the impact of innovation

activities on major societal, developmental, and environmental challenges (Weber & Truffer, 2017). This redirection is informed by a reconceptualisation of the role of science, technology and innovation in society, reflected in an expectation that public investment in innovation activities should result in socio-economic benefit. The inclusive innovation prescription with regard to inclusion of otherwise excluded stakeholders is pertinent in the interactive learning that is a key feature of innovation systems. Such stakeholders serve both as providers of contextual knowledge for innovation and as learners of innovation. The call made by Weber & Truffer for innovation systems research that is suitable for guiding research and innovation policy that is responsive to society's needs, presents an opportunity for the consideration of inclusive innovation and responsible innovation against a systems of innovation background. Their call recognises the need for innovation policies that place a greater emphasis on the role of demand-side innovation actors and the participation of society in innovation activities. Ribeiro, et al. (2018) suggest that system of innovation frameworks may be helpful in exploring policy options towards achieving inclusive and responsible innovation. They refer in particular to removing the divisions between consumers, private firms, and public organisations as participants in innovation activities. Inclusive and responsible innovation would require all these stakeholders to be recognised in the innovation system. Weber & Truffer (2017) and Ribeiro, et al. (2018) reveal an opportunity for responsible innovation and inclusive innovation to enhance innovation systems concepts. This can be achieved by incorporating into innovation systems analyses, a focus on the participation of societal stakeholders in innovation activities, as well as the recognition of the value of their contributions.

While the literature has given some attention to placing inclusive innovation in the systems of innovation framework, less has been written about responsible innovation in this regard. As seen in the previous chapter, however, the ethical underpinnings of responsible innovation have been discussed more extensively in the literature than has the ethics of inclusive innovation. The ethics of responsible innovation provides some guidance towards an examination of the ethics of inclusive innovation. This chapter examines the conceptualisations of inclusive innovation within the innovation systems approach (inclusive innovation systems). It reviews the reconceptualisation of the technological innovation system functions towards inclusive innovation, and extends this reconceptualisation with

reference to the ethical foundations of inclusive innovation and responsible innovation. Finally, it considers the implications of the expanded indicators for TIS analyses in developing countries.

4.1 Responsible innovation systems

The literature shows limited discussion of responsible innovation within a systems of innovation framework. Wickson & Forsberg (2015) find an absence of attention to the concept of responsible innovation as a system. They suggest that a systems-based approach to responsible innovation would support analytical understanding of the complex interactions that responsible innovation demands and would enable more proactive policy-making. These authors anticipate three "learning points" for responsible innovation to be derived from innovation system analysis. First, the diversity of agents involved in the production and diffusion of innovation would be acknowledged. This would enable recognition of new modes of interaction in what Wickson & Forsberg refer to as "interstitial spaces", and the contribution of these spaces to responsible innovation. Second, it would be recognised that these spaces and the interactions that occur in them differ across sectors and technologies, providing specific targets for policy intervention. Third, the roles and interrelationships of actors and organisations, as well as the influence of institutional practices and culture, would be illuminated. The call by Wickson & Forsberg suggests that analysis of responsible innovation using innovation system approaches, would enable interrogation of the responsible innovation focus on the inclusion of multiple stakeholder perspectives. Schroeder, et al. (2016) similarly hold that innovation system analysis of successful responsible innovation, would reveal diverse networks of actors.

Schroeder, et al. (2016) argue that innovation system analysis enables an examination of the validity of policy claims made for responsible innovation: for example, the sectors and regions for which responsible innovation might enhance economic competitiveness could be identified, and the role played by actors with regard to responsible innovation within the innovation system could be explored. Ultimately, system of innovation analysis could be used

to determine whether the components of responsible innovation enhance economic competitiveness and are able to combine the latter with improved social justice.

4.2 Inclusive innovation systems

Schroeder, et al. (2016) propose that innovation system analysis could be used to provide evidence for the normative aims of inclusive innovation. Foster & Heeks (2013) suggest that the core components and focus of the systems of innovation approach are well suited to the study of inclusive innovation. They do, however, caution that certain features of inclusive innovation are underemphasised in the systems of innovation conceptualisation. These inadequately developed features would promote inclusivity and technology adoption in developing markets; they include technology diffusion mechanisms, demand-side actors and intermediaries, and the role played by informal and localised institutions. Foster & Heeks describe the distinctive features of inclusive innovations systems in terms of the nature of innovation, actors, learning, relations, and institutions, as discussed below.

Inclusive innovation is more incremental in nature and focuses on diffusion processes, rather than on steps that lead to and follow production. The innovation is directed at local needs and local context, and takes the shape of "appropriation, configuration, use variation [and] domestication" (p. 351). It is often non-technical, focusing on social systems for sales and support.

With regard to actors, the focus is on low-income consumers. In contrast to the formal supply-side industrial actors found in conventional systems of innovation formulations, inclusive innovation systems have non-traditional innovators working directly for or with end users, for example micro-enterprise phone repairers or sellers of mobile phone sim cards, air-time and accessories. In addition, intermediaries, such as wholesalers, who operate between suppliers and end users, effect small adaptive innovations to link supply and demand.

Learning in inclusive innovation systems is highly contextualised, and focuses on diffusion and the broader social processes that inform the distribution and adoption of new goods and

services; this is in contrast to traditional systems of innovation, where learning is about production, implementation and technology. Learning by interacting with other actors is key to serving low-income markets. Learning in inclusive innovation systems is guided by survival and the maximisation of utility, rather than the maximisation of profit. The maximisation of utility as described by Foster & Heeks (2013) could be interpreted as a maximisation of capabilities, towards enabling end users to live the lives of their choosing.

Informal and loose yet socialised relations are necessary in inclusive innovation systems but are also limiting, whereas tradition systems of innovation have a preference for more formal and close relations. Inclusive innovation systems encompass a complex landscape of formal institutions, which have indirect impact, and informal institutions, including local customs and markets. Informal institutions at the local level in the form of behavioural norms and social expectations may be barriers to innovation.

This section has described inclusive innovation systems, as envisioned by Foster & Heeks (2013). Their formulation departs from the conventional system of innovation approach in many respects. Inclusive innovation may present challenges in the inclusion of a broader range of stakeholders whose norms and expectations may be at odds with those of traditional innovation processes; yet it is the consideration of these norms and behaviours that defines inclusion. The Foster & Heeks conceptualisation of inclusive innovation is for low-income communities with a suggested absence of capacity for technology development, production and implementation. This neglects the reality in middle-income countries, where high technology exists alongside significant poverty, and social and economic inequality is prevalent, and in some cases, widening. As argued by Cozzens & Kaplinsky (2009), the complex interactions that characterise innovation systems, might serve either to reduce or to increase poverty and inequality. It is therefore imperative that analyses of inclusive innovation systems in developing countries address the spectrum of innovation, rather than being limited to the diffusion of innovation and neglecting the development of technology. The distinctions between the inclusive innovation system depiction above and the traditional innovation system conceptualisation, may be used to expand the latter. Inclusive innovation should enhance the innovation system conceptualisation, and conversely, the latter should provide a framework for analysis of inclusive innovation. Inclusive innovation systems need

not be regarded as a limited form of innovation system for application to developing countries.

The following section specifically addresses technological innovation systems as an analytical framework for inclusive innovation. It employs an ethics lens to evaluate and enhance indicators of inclusive innovation that have been proposed in the literature, and draws on responsible innovation to expand these indicators.

4.3 Revisiting the TIS functions

Section 4.1 has shown an acceptance in the literature, albeit in limited literature and at levels lacking in detail, that responsible innovation is compatible with analysis from a system of innovation perspective. Section 4.2 contains a more detailed contrasting of inclusive innovation with the current systems of innovation conceptualisation, but has argued that the distinctions should be accommodated in the application of innovation system analysis to inclusive innovation. This section focuses on technological innovation systems as an analytical framework for inclusive innovation and responsible innovation, particularly with reference to the TIS functions.

Much of the inclusive innovation literature focuses on activities that promote development, with less attention to technologies, technological fields, and industries. However, the latter are not absent from developing contexts. The specific role of technology in inclusive innovation deserves attention in a world in which technology has the potential to exacerbate inequality by preferentially serving the rich. Expanding the technological innovation systems approach to include principles of inclusive innovation, has utility for the examination of the inclusiveness of technological innovation.

The same holds for responsible innovation: consideration of the long-term focus of responsible innovation on securing the future would benefit TIS analysis. It might reveal whether technological innovation is sufficiently directed at sustainability and at avoiding potential harms. TIS analyses are concerned with examining the development of

technologies, rather than their possible societal and environmental consequences. Although, and perhaps because, the TIS approach has mainly been applied to sustainability transitions in fields such as renewable energy, there has been an implicit assumption in the technological systems studies, that the technologies in question are beneficial in the long term. TIS studies have therefore been agnostic to the long-term consequences on society of the technologies or technological systems examined. This agnosticism of TIS analyses could be countered by assessing TISs against indicators of inclusive innovation and responsible innovation.

Van der Merwe & Grobbelaar (2018) propose a framework for systemic policy intervention guided by the technological innovation systems approach, towards establishing more inclusive innovation systems. Their framework is aided by a case study of a large-scale mobile health project in South Africa, which assesses the technological innovation in question with respect to its inclusivity. Included in the systemic policy intervention framework, is a discussion of the TIS functions and associated indicators of inclusive innovation. Still absent in the literature, however, is a discussion of TIS indicators in the context of responsible innovation. Van der Merwe & Grobbelaar derive indicators for the TIS functions that may be used to analyse the systemic elements surrounding technology implementation for inclusive innovation.

The indicators proposed by van der Merwe & Grobbelaar are discussed below for each of the interrelated TIS functions described in Chapter 2. Consideration is given to the responsible innovation formulation. The ethics of responsible innovation and the ethics of inclusive innovation are considered as sources of refinement of the TIS indicators presented by van Der Merwe & Grobbelaar for inclusive innovation. Van der Merwe & Grobbelaar address the functions as defined by Hekkert, et al. (2007) and do not include the development of positive externalities (Bergek, et al., 2008). As the latter function represents an aggregation of the effects of the other functions, it is not discussed below either.

4.3.1 Knowledge development and knowledge diffusion

Van der Merwe & Grobbelaar treat *knowledge development* and *knowledge diffusion* as separate functions, following the Hekkert, et al. (2007) formulation. These functions are

combined in the discussion that follows. Van der Merwe & Grobbelaar see value in the production of knowledge on service provision for marginalised communities, with the inclusion of marginalised communities as active participants in the generation of knowledge. The capacity for evaluation of the outcomes and extent of interventions for the marginalised must be present. The availability of platforms for knowledge exchange among stakeholders, including those form marginalised communities, is required, especially with a view to including knowledge held by the marginalised.

These indicators resonate with responsible innovation, in that they consider the experiences of stakeholders (in this case, the marginalised in particular) and the inclusion of their knowledge in the innovation process. An inclusive knowledge framework may result from and also promote interactive learning and the flow of technology and knowledge among stakeholders (Hekkert, et al., 2011); in the case of inclusive innovation, this would also apply to knowledge from, and for, the marginalised. Inclusive knowledge development and diffusion would support the call for an understanding of science, technology and innovation as a social system that is mediated by culture, values, beliefs and local practices, among diverse social groups (Saidi & Douglas, 2017).

Absent from the knowledge function indicators of van der Merwe & Grobbelaar, however, is knowledge on the long-term consequences of innovation, as would be demanded by responsible innovation and by an inclusive innovation that has a longer-term view. A suitable indicator to add to the list would be the research capacity to generate knowledge that anticipates and mitigates uncertain consequences of the innovations being developed, as was suggested in Section 3.5.2. A capacity for the evaluation of innovations, as proposed by van der Merwe & Grobbelaar, does however bespeak the reflexivity and anticipation (Stilgoe, et al., 2013) of the ethics of care approach (Groves, 2015) that are required for the longer-term responsible innovation view.

An ethics of care features prominently in these indicators. Knowledge development and diffusion are usually at the heart of a TIS, as they concern the substance, performance and evolution of the TIS with regard to its knowledge base (Bergek et al., 2008). The desire for knowledge about the marginalised and their needs, and the insistence on inclusion of such

knowledge in decisions about innovation, exhibit care at a fundamental level in the innovation system. This resonates with the exhortation by Groves (2015), that the ethics of care be practised early in the innovation process, as this would enable the early shaping of innovation priorities towards inclusion.

Inclusion of the marginalised as sources of knowledge, reflects the capabilities approach, in that these stakeholders are given the opportunity to express that which they value. In so doing, they have the opportunity to guide innovation in a way that would bring them closer to the kind of life that they would desire.

These indicators treat the marginalised not only as providers of knowledge, but insist on enabling them to be recipients of knowledge, through providing space for them on knowledge platforms. This further reflects the capabilities approach, as it enhances the agency of these stakeholders.

4.3.2 Entrepreneurial experimentation

Van der Merwe & Grobbelaar advocate for inclusive innovation projects to develop a deep understanding of marginalised stakeholders so as to identify barriers to their market involvement. To this end, they suggest systemic policy interventions and identify the need for sustainable business models, for inclusion of marginalised stakeholders in these business models, and for linking formal and informal stakeholders. They assert that some of this could be achieved through appropriate institutions. Foster & Heeks (2013) characterise inclusive systems of innovation that may be constituted locally and informally, and argue for the extension of the systems of innovation framework to such institutions.

Responsible innovation does not consider the involvement of stakeholders as entrepreneurs; it is concerned with innovation and innovation policy more than with business development. It is however appropriate for inclusive innovation to consider inclusive promotion of entrepreneurship, given the developmental focus of inclusive innovation. Here, again, the capabilities approach is evident, in that the scope of possibilities of marginalised stakeholders

is expanded as they gain opportunities to create the life they would wish for, through entrepreneurship.

While van der Merwe & Grobbelaar call for sustainable business plans, the plans for sustainable entrepreneurship neglect consideration of the sustainability of the innovations that are propagated through entrepreneurship. Lacking, is an anticipation of possible negative consequences of innovation, as a form of care. However, given the integrated nature of the TIS functions, other functions, such as guidance of the search, may be relied upon to direct the entrepreneurial activities towards responsible and inclusive technologies. In addition, the indicator suggested above for the development of knowledge on the long-term consequences of innovation, serves the purpose of anticipation.

4.3.3 Guidance of the search

For *guidance of the search*, van der Merwe & Grobbelaar express the need for a clear vision and shared goal amongst stakeholders towards inclusivity, as well as legislative support for inclusivity. Monitoring and evaluation of inclusive innovation projects and the definition of outcome indicators are advocated.

Monitoring and evaluation suggest the virtue ethics attributes of anticipation and reflexivity and therefore an ethics of care (Groves, 2015). A “responsible” approach would include consideration of societal and environmental sustainability in guiding technology development under this function, thus strengthening anticipation. Such orientation towards the future would enhance inclusivity by mitigating the proliferation of innovations that preferentially pose unintended harm to the marginalised.

4.3.4 Market formation

Van der Merwe & Grobbelaar suggest inclusive policies and institutions as essential for the market formation function. The imperatives of responsible innovation would demand that the nature of the market be guided in the direction of protecting the future and would

enhance inclusive innovation. As in the case of entrepreneurial experimentation, market formation towards a responsible approach to inclusive innovation, is best ensured through other guiding functions. Guidance of the search would here, too, play a role in delineating the nature of the market, through guidance of technology development pathways, based on anticipation.

4.3.5 Resource mobilisation

For *resource mobilisation*, van der Merwe & Grobbelaar consider availability of, and access to, funding and the involvement of marginalised groups as human capital. This recognition of the knowledge resources possessed by the marginalised, recalls the capabilities approach as it assigns agency to such communities.

Resource mobilisation can be done for short, medium term or long-term activities. Consideration of longer-term resource mobilisation to support activities that might examine and/or mitigate the potential harms of innovation would support the anticipation pillar of the ethics of care. A suitable indicator in this regard, would be the deployment of resources towards understanding the consequences of inclusive innovation.

4.3.6 Creation of legitimacy

Finally, the indicators proposed by van der Merwe & Grobbelaar for the *creation of legitimacy* are the reputation of investment into inclusive innovation projects, resistance to change which inhibits innovation, and government commitment to innovation projects.

Creation of legitimacy is highly relevant to a responsible approach to inclusive innovation, as public opinion on the future harms of innovation and public acceptance of new products is a powerful force in directing the innovation process. On the other hand, convincing action to anticipate and safeguard against unintended consequences of innovation, is a powerful tool in creating legitimacy for new products. To augment those proposed by van der Merwe & Grobbelaar, the addition of indicators that strengthen reflexivity and anticipation would

address the imperatives of responsible innovation. Commitment of government to considering and protecting against harmful consequences of innovation, and communication of this commitment would be a form of reflexivity. Engagement with stakeholders on the ethical and environmental challenges associated with innovation would aid both reflexivity and anticipation, while supporting legitimacy. It would also serve the capabilities approach in giving stakeholders agency. Such engagement would inform the guidance of the search in directions that are acceptable to stakeholders.

The emphasis on inclusion of marginalised stakeholders in inclusive innovation systems may, as Foster & Heeks (2013) point out, have negative impacts on innovation. Social and cultural norms may interfere not only with the adoption of innovations, but also with stakeholder participation and engagement for the process of innovation, posing a threat to the creation of legitimacy. The consequent negative impacts may manifest as the resistance to change listed by van der Merwe & Grobbelaar as an indicator for the creation of legitimacy. Understanding of local norms would aid inclusion, and such understanding is aided by knowledge of the local environment. Here, the knowledge development function plays a role in elucidating the local context. Ethics themes playing a role in addressing local knowledge, are the ethics of care and the capabilities approach, as discussed above in the context of the development of knowledge that includes the needs of the marginalised and regards the marginalised as knowledge sources.

4.3.7 Summary

The discussion on TIS indicators of inclusivity has reinforced the themes identified as providing normative guidance to responsible innovation and inclusive innovation, as described in Chapter 3. In particular, the ethics of virtue, the ethics of care, and the capabilities approach have been highlighted. The augmented indicators, incorporating both the inclusive components advocated by van der Merwe & Grobbelaar, and additional indicators of responsible innovation, are shown in Table 1. These indicators would support inclusive technological innovation system analysis especially in developing countries, where inclusion of the marginalised is an imperative.

Table 1. Summary of existing and proposed indicators for TIS functions.

TIS function	**Indicators (Bergek, et al., 2008; Hekkert, et al., 2007)**	**Inclusive innovation indicators suggested by van der Merwe & Grobbelaar** (2018)	**Additional indicators derived from responsible innovation considerations**
Knowledge development and diffusion	Bibliometric analyses, numbers of R&D projects, researchers and patents, and increases in technological performance.	Production of knowledge on marginalised settings and on service provision for marginalised communities, with the inclusion of marginalised communities as active participants in the generation of knowledge; the capacity for evaluation of the outcomes and extent of interventions for the marginalised; availability of platforms for knowledge exchange among stakeholders, including those form marginalised communities.	Research capacity to generate knowledge that anticipates and mitigates uncertain consequences of the innovations being developed.
Entrepreneurial experimentation	The number of new entrants and diversification of existing actors; the variety of technologies and their applications and of the use of complementary technologies.	Systemic policy interventions; sustainable business models; inclusion of marginalised stakeholders in business models; linking of formal and informal stakeholders.	Sustainability of the innovations propagated through entrepreneurship and anticipation of possible negative consequences of innovation are addressed by other functions.
Guidance of the search	Expectations of the potential for growth and future opportunities in the TIS; regulatory and policy pressures and incentivisation; and expressions of interest and demand from leading customers.	A clear vision and shared goal amongst stakeholders towards inclusivity; legislative support for inclusivity; monitoring and evaluation of inclusive innovation projects; the definition of outcome indicators.	Technology development guided by societal and environmental sustainability considerations.
Market formation	Market phase and size; customer bases, their articulation of demand and their purchasing processes; actors' strategies; and the impact of standards.	Inclusive policies and institutions.	The guidance of technology development pathways towards protecting the future, is addressed by other functions.
Resource mobilisation	Changes in the volume of capital as well as seed funding and venture capital; changes in the volume and quality of human capital; and changes in other, complementary, assets.	Availability of, and access to, funding; and the involvement of marginalised groups as human capital.	Deployment of resources towards understanding the consequences of inclusive innovation.
Creation of legitimacy	The strength of TIS legitimacy and its alignment with current legislation and industry and societal values; the influence of legitimacy on demand, legislation and company behaviour; and the factors and actors that influence legitimacy, as well as the mechanisms of influence.	The reputation of investment into inclusive innovation projects, resistance to change which inhibits innovation, and government commitment to innovation projects.	Commitment of government to considering and protecting against harmful consequences of innovation, and communication of this commitment; engagement with stakeholders on the ethical and environmental challenges associated with innovation.

4.4 TIS functions and the ladder of inclusive innovation

The TIS functional indicators as defined by Hekkert, et al. (2007) and Bergek, et al. (2008) contain some elements of the Foster & Heeks (2013) ladder of inclusive innovation that was discussed in Section 3.5. While the TIS focus is not on a particular category of actors, such as the marginalised in the case on inclusive innovation, an ethos of stakeholder inclusion is present nonetheless. Thus the first level of the ladder of inclusive innovation is evident in an implicit intention for inclusion of diverse actors in the TIS formulation.

The TIS indicators for entrepreneurial experimentation, market formation, and resource mobilisation, highlight the diversity of actors and markets that participate in the TIS. Thus inclusion is present in these indicators in terms of consumption (the second level of the ladder), as this level addresses goods and services that are accessible and affordable by the intended beneficiaries. In TIS indicator terms, these goods and services are accessible to diverse actors and markets, which may include the marginalised, even though the latter are not explicitly mentioned.

Impact (the third level of the ladder) in the form of economic prosperity is assumed for technological innovation systems, but is not considered in the TIS formulation in the form of improved well-being. Thus the third level of the ladder is partially present in the TIS formulation.

As the actors of technological innovation systems are assumed to have agency, inclusion at the fourth level of the ladder of inclusive innovation, namely process, is present in the TIS indicators. This level of the ladder addresses the involvement of the intended beneficiaries in the development of the innovation.

Structural pressure for inclusion (the fifth level of the ladder) relies on institutions, organisations and relations that support innovation. This is reflected in the regulatory and policy pressures and incentivisation that are present in the guidance of the search TIS function.

The post-structure level of the ladder, namely an inclusive frame of knowledge and discourse, resonates with the creation of legitimacy in technological innovation systems. Legitimation enables social acceptance and institutional compliance of innovations, and in so doing shapes an inclusive worldview. This is possible within an inclusive frame of knowledge and discourse as required by ladder level 5. Again, TIS does not speak to the inclusion of marginalised actors, but the functions have the potential to accommodate a more inclusive set of stakeholders.

As discussed in Section 3.5, levels 5 and 6 of the ladder of inclusive innovation are considered to be aspirational rather than what is found in practice. The TIS functions, however, show evidence of the kind of inclusion contemplated at these higher levels, particularly in the guidance of the search and creation of legitimacy functions, as suggested above. Thus, the TIS framework could assist in operationalising the higher-level aspirations of inclusive innovation, if the scope of inclusion in TIS could be extended to the marginalised groups that are the focus of inclusive innovation, using the indicators suggested by van der Merwe & Grobbelaar (2018) and the augmentations proposed above.

4.5 Context and developing countries

The influence of international technological innovation systems on developing country TISs was reviewed in Section 2.4, and much support for international involvement was identified in the literature. Because of the predominant historical direction of technology transfer – from the industrialised to the developed world – TIS analyses in developing countries risk being focused on such external factors. In addition, TIS analyses applied to developing countries without adaptation of the conceptual framework, may be inappropriate.

The recent focus on context in technological innovation system analysis highlighted in Section 2.3.2, begins to address the limitations of the TIS approach, but does not yet address the inclusion of the marginalised as beneficiaries of innovation. Inclusive innovation may be regarded as innovation that takes place in a particular context: the context of the marginalised. Explicit consideration of inclusivity in the TIS indicators would provide a means of assessing the extent to which technologies or technological fields are developing in a way that supports the inclusion and the well-being of the marginalised.

Four types of contextual structures, namely the technological, the sectoral, the geographical and the political, were articulated by Bergek at al. (2015). Two of these context structures contain elements that pertain to inclusion. First, the geographical context includes cultural norms, regulations, labour markets and political systems. Inclusion would not only consider cultural norms, but incorporate the cultural knowledge of stakeholders into innovation processes for the knowledge development function. It would also disseminate knowledge in ways that respect cultural norms. Inclusive regulations and political systems are active in the entrepreneurial experimentation and the guidance of the search functions. Labour markets are active in the market formation function.

Second, the political context, which refers to institutions for policy-making, education, and financial support, is active in most TIS functions. Each of these institutions could accommodate a more inclusive approach with consideration to marginalised stakeholders. The ethical support for inclusive TIS functions as considered in Section 4.3, therefore also supports an emphasis on context for more nuanced analysis of the extent of inclusion of marginalised groups in technological innovation systems.

Inclusive innovation is of particular concern in developing countries, which are typically characterised by high levels of poverty and inequality. The developing country TIS analyses discussed in Section 2.3.3, showed that some adaptation of the TIS formulation might be necessary for rich analysis of TIS in developing countries. Blum et al. (2015) showed knowledge diffusion in a developing setting to be hampered by bottlenecks in the local transfer, retention and exploitation of knowledge. They also identified culture as an institutional factor relevant to TIS in a developing country. These are context factors that, as shown above, would benefit from considerations of inclusive innovation and the indicators guided by its ethical base.

As discussed in Section 3.6, consideration of context and of the differential TIS evolution in developing and developed countries, has not addressed the long-term social and environmental consequences of technological innovation and has not been considered in TIS analyses. Responsible innovation adds such a dimension, and TIS indicators derived from the

ethical foundation of responsible innovation, as suggested in Section 4.3, would enable TIS analyses that are explicitly directed at considering the long-term consequences of innovation.

The addition of indicators for an inclusive and responsible orientation to the TIS functions, would enhance policy recommendations and evaluation of policy implementation in developing countries.

4.6 Conclusion

This chapter has discussed the functions of technological innovation systems in the context of inclusive innovation and responsible innovation. It has reviewed an expansion of the indicators for inclusive technological innovation systems that has been suggested in the literature. It has suggested further enhancement of these indicators, with reference to the ethical foundations of inclusive innovation and responsible innovation. It has argued that enhancement of these indicators would enable richer and more nuanced analysis of technological innovation systems in developing countries. It has also argued that the TIS framework could assist in the realisation of the higher-level goals of inclusive innovation.

5 Conclusion

This work has discussed an expansion of the technological innovation systems framework with the aid of concepts derived from inclusive innovation and responsible innovation. The reconceptualisation of the TIS functions, in particular through enhancement of their indicators, has been guided by the ethical underpinnings of inclusive innovation and responsible innovation. The discussion has been motivated by the limitations that have been identified in the scope of the TIS functions in their application to developing countries, the imperative that exists for inclusive innovation to promote the social and economic well-being of marginalised groups, and the importance of anticipating the future consequences of innovation in the analysis of technological innovation systems. The work addresses the gap that exists in the literature with regard to consideration of the social and environmental consequences of technological innovation systems.

Both responsible innovation and inclusive innovation have the goal of societal benefit. Inclusive innovation can be considered a special case of responsible innovation, with a greater focus on benefit to the poor and the marginalised. Another distinction is that responsible innovation is more concerned with the future consequences of innovation. This work has argued that the future orientation of responsible innovation would enhance conceptualisation of inclusive innovation, since the potential harms and unintended consequences of innovation are of concern for marginalised communities, and should be considered when the pathways of technological innovation are designed and analysed.

The ethical bases for both responsible innovation and inclusive innovation lie in an ethics of care and an ethics of virtue. At greater levels of stakeholder inclusivity, the capabilities approach becomes apparent in inclusive innovation. These ethical principles have been discussed with regard to a set of augmented indicators for technological innovation systems from the literature, which had been formulated to aid in the assessment of inclusion. This study has found that additional indicators derived from responsible innovation, would further strengthen the TIS framework by enabling a longer-term view of the consequences of innovation.

Evidence has been presented that the TIS framework entails an inclusivity that reflects that of inclusive innovation, but without the focus on the marginalised. For inclusive innovation, higher levels of inclusivity are thought to be aspirational rather than reflected in practice. These levels represent inclusion particularly with regard to institutions, organisations and relations that form part of an innovation system, and an inclusive frame of knowledge and discourse. However, the TIS functions accommodate these aspirations, and have the potential to guide and test the operationalisation of inclusivity at these levels, as long as the scope of stakeholders and the nature of their inclusion are sufficiently broad.

An expanded set of technological innovation system indicators presents an analytical tool for assessing technological innovation systems, especially in developing countries, where inclusion of the marginalised as beneficiaries of, and participants in, innovation is an imperative. It responds to the call for greater emphasis on context in TIS analyses, by providing indicators relating to the context of the marginalised. While the call for attention to context is intended to take account of the differential evolution of TISs in different settings, the expanded set of indicators contributes a normative element to TIS analysis, towards guiding the development of technologies or technological fields in a way that supports the inclusion and the well-being of the marginalised. In addition, the responsible orientation of the expanded indicators is directed at considering the long-term consequences of innovation and avoiding negative impacts. The expanded TIS conceptualisation provides for a richer and more nuanced analysis of technological innovation systems.

The study has not tested the revised technological innovation system indicators that have been discussed. Future work should conduct case studies of technological innovation in developing countries, with a view to validating and further refining the TIS indicators. The utility of the expanded indicators in policy making, particularly in developing countries, should also be examined.

References

Alexander, L. & Moore, M., 2016. *Deontological Ethics. The Stanford Encyclopedia of Philosophy.* [Online]
Available at: https://plato.stanford.edu/entries/ethics-deontological/
[Accessed 12 March 2017].

Altenburg, T., 2009. Building inclusive innovation systems in developing countries: challenges for IS research. In: B. Lundvall, K. Joseph, C. Chaminade & J. Vang, eds. *Handbook of Innovation Systems and Developing Countries.* Cheltenham: Edward Elgar Publishing Limited, pp. 33-56.

Asheim, B. & Gertler, M., 2005. The geography of innovation:regional innovation systems. In: J. Fagerberg, D. Mowery & R. Nelson, eds. *The Oxford Handbook of Innovation.* Oxford: Oxford University Press, pp. 291-317.

Balabanian, N., 2006. On the presumed neutrality of technology. *IEEE Technology and Society Magazine,* 25(4), pp. 15-25.

Bento, N. & Fontes, M., 2015. The construction of a new technological innovation system in a follower country: Wind energy in Portugal. *Technological Forecasting & Social Change,* Volume 99, p. 197–210.

Bergek, A. et al., 2008. Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research Policy,* Volume 37, p. 407–429.

Bergek, A. et al., 2015. Technological innovation systems in contexts: Conceptualizing contextual structures and interaction dynamics. *Environmental Innovation and Societal Transitions ,* Volume 16, p. 51–64 .

Bertland, A., 2009. Virtue Ethics in Business and the Capabilities Approach. *Journal of Business Ethics,* Volume 84, p. 25–32.

Binz, C., Truffer, B. & Coenen, L., 2014. Why space matters in technological innovation systems—Mapping global knowledge dynamics of membrane bioreactor technology. *Research Policy ,* Volume 43, p. 138–155 .

Blum, N., Bening, C. & Schmidt, T., 2015. An analysis of remote electric mini-grids in Laos using the Technological Innovation Systems approach. *Technological Forecasting & Social Change,* Volume 95, p. 218–233.

Carlsson, B. & Stankiewicz, R., 1991. On the nature, function and composition of technological systems. *Journal of Evolutionary Economics,* 1(2), p. 93–118.

Carlsson, B., 1997. On and off the beaten path: the evolution of four technological systems in Sweden. *International Journal of Industrial Organization ,* 15(6), p. 775–799.

Chataway, J., Hanlin, R. & Kaplinsky, R., 2014. Inclusive innovation: an architecture for policy development. *Journal of Innovation and Development,* Volume 4, pp. 33-54.

Coenen, L., 2015. Engaging with changing spatial realities in TIS research. *Environmental Innovation and Societal Transitions ,* Volume 16, p. 70–72.

Coenen, L., Benneworth, P. & Truffer, B., 2012. Toward a spatial perspective on sustainability transitions. *Research Policy,* 41(6), p. 968–979.

Cozzens, S. & Kaplinsky, R., 2009. Innovation, Poverty and Inequality: Cause, Coincidence, or Co- Evolution?. In: B. Lundvall, C. Joseph & J. Vang, eds. *Handbook of Innovation Systems and Developing Countries; Building Domestic Capabilities in a Global Setting.* Cheltenham: Edward Elgar, pp. 57-82.

Cozzens, S. & Sutz, J., 2012. *Innovation in Informal Settings: A Research Agenda,* Ottawa: International Development Research Centre.

DCTI, 2013. *Cleantech-Standortgutachten 2013.* [Online]
Available at:
http://dcti.de/en/cleantech/definition.html
[Accessed 18 November 2017].

de Saille, S., 2015. Innovating innovation policy: the emergence of 'Responsible Research and Innovation'. *Journal of Responsible Innovation,* 2(2), pp. 152-168.

Dosi, G., 1988. The nature of the innovative process. In: *Technical Change and Economic Theory.* London: Pinter Publishers.

Edquist, C., 1997. Systems of Innovation Approaches - Their Emergence and Characteristics. In: C. Eqquist, ed. *Systems of Innovation: Technologies, Institutions and Organizations.* London: Pinter, pp. 1-35.

Edquist, C., 2013. Systems of Innovation: Perspectives and Challenges. In: *The Oxford Handbook of Innovation.* Oxford: Oxford University Press, pp. 181-208.

Eizagirre, A., Rodríguez, H. & Ibarra, A., 2017. Politicizing Responsible Innovation: Responsibility as Inclusive Governance. *International Journal of Innovation Studies,* 1(1), pp. 20-36.

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,* 25(3), pp. 333-355.

Freeman, C., 1987. *Technology Policy and Economic Performance: Lessons from Japan.* London: Pinter.

Gault, F., 2010. *Innovation Strategies for a Global Economy: Development, Implementation, Measurement and Management.* Cheltenham:IDRC.

George, G., McGahan, A. & Prabhu, J., 2012. Innovation for Inclusive Growth: Towards a Theoretical Framework and a Research Agendajo. *Journal of Management Studies,* 49(4), pp. 661-683.

Gosens, J., Lu, Y. & Coenen, L., 2015. The role of transnational dimensions in emerging economy 'Technological Innovation Systems' for clean-tech. *Journal of Cleaner Production,* Volume 86, pp. 378-388.

Grinbaum, A. & Groves, C., 2013. What is 'responsible' about responsable innovation . In: R. Owen, M. Heinz & J. Bessant, eds. *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society.* Chichester : Wiley .

Groves, C., 2015. Logic of Choice or Logic of Care? Uncertainty, Technological Mediation and Responsible Innovation. *Nanoethics,* Volume 9, p. 321–333 .

Hansen, T. & Coenen, L., 2015. The geography of sustainability transitions: Review, synthesis and reflections on an emergent research field. *Environmental Innovation and Societal Transitions ,* Volume 17, p. 92–109 .

Heater, B., 2017. *Microsoft finally kills off the Kinect, but the tech will live on in other devices.* [Online]
Available at: https://techcrunch.com/2017/10/25/microsoft-finally-kills-off-the-kinect-but-the-tech-will-live-on-in-other-devices/
[Accessed 18 November 2017].

Heeks, R., Amalia, M., Kintu, R. & Shah, N., 2013. *Inclusive Innovation: Definition, Conceptualisation and Future Research Priorities,* Manchester: Centre for Development Informatics, Institute for Development Policy and Management, University of Manchester.

Hekkert, M. et al., 2007. Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting & Social Change,* Volume 74, p. 413–432.

Hekkert, M., Negro, S., Heimeriks, G. & Harmsen, R., 2011. *Technological Innovation System Analysis,* Utrecht: Utrecht University.

Hursthouse, R. & Pettigrove, C., 2016. *Virtue Ethics. The Stanford Encyclopedia of Philosophy.* [Online]
Available at: https://plato.stanford.edu/archives/win2016/entries/ethics-virtue/
[Accessed 12 March 2017].

Jacobsson, S. & Bergek, A., 2011. Innovation system analyses and sustainability transitions: contributions and suggestions for research. *Environmental Innovation and Societal Transitions ,* 1(1), pp. 41-57.

Johnson, B. & Andersen, A., 2012. *Learning, Innovation and Inclusive Development,* Aalborg: Aalborg University Press.

Johnson, B. & Lundvall, B., 2003. National systems of innovation and economic Development. In: M. Muchie, P. Gammeltoft & B. Lundvall, eds. *Putting Africa First; the making of African innovation systems.* Aalborg: Aalborg University Press, pp. 13-28.

Kebede, K. & Mitsufuji, T., 2017. Technological innovation system building for diffusion of renewable energy technology: A case of solar PV systems in Ethiopia. *Technological Forecasting & Social Change,* Volume 114, p. 242–253.

Kimmitt, J. & Munoz, P., 2015. *Re-thinking the Ethics of Inclusive Innovatio.* York, International Social Innovation Research Conference.

Lorentzen, J. & Mohamed, R., 2010. *... to each according to his (or her) needs. Where are the poor in innovation studies?* Conference on Innovation for Development: Frontiers for Research, Policy and Practice.

Lundvall, B. & Borrás, S., 2005. Science, technology, and innovation policy. In: *The Oxford Handbook of Innovation.* Oxford: Oxford University Press, pp. 599-631.

Lundvall, B., 2007. National Innovation Systems - Analytical Concept and Development Tool. *Industry and Innovation,* 14(1), pp. 95-119.

Lundvall, B., Vang, J., Joseph, K. & Chaminade, C., 2009. Innovation system research and developing countries. In: B. Lundvall, K. Joseph, C. Chaminade & J. Vang, eds. *Handbook of Innovation Systems and Developing Countries.* Cheltenham: Edward Elgar Publishing Limited, pp. 1-30.

MacIntyre, 1981. *After Virtue.* Notre Dame: University of Notre Dame Press.

Malerba, F., 2005. Sectoral systems: how and why innovation differs across sectors. In: J. Fagerberg, D. Mowery & R. Nelson, eds. *The Oxford Handbook of Innovation.* Oxford: Oxford University Press, pp. 380-406.

Marin, A. & Arza, V., 2009. The role of multinational corporations in national innovation systems in developing countries: from technology diffusion to international involvement. In: B. Lundvall, K. Joseph, C. Chaminade & J. Vang, eds. *Handbook of Innovation Systems and Developing Countries.* Cheltenham: Edward Elgar Publishing Limited, pp. 280-310.

Markard, J., Hekkert, M. & Jacobsson, S., 2015. The technological innovation systems framework: Response to six criticisms. *Environmental Innovation and Societal Transitions ,* Volume 16, p. 76–86 .

Markard, J., Raven, R. & Truffer, B., 2012. Sustainability transitions: An emerging field of research and its prospects. *Research Policy,* Volume 41, p. 955–967.

Murphy, J., 2015. Human geography and socio-technical transition studies: Promising intersections. *Environmental Innovation and Societal Transitions* , Volume 17, p. 73–91.

OECD, 2015. *Innovation Policies for Inclusive Growth,* Paris: OECD Publishing.

Opderbeck, D., 2007. A Virtue-Centered Approach to the Biotechnology Commons (Or, The Virtuous Penguin). *Maine Law Review,* Volume 59, p. Article 5.

Owen, R., Macnaghten, P. & Stilgoe, J., 2012. Responsible research and innovation: From science in society to science for society, with society. *Sciecne and Public Policy,* 39(6), pp. 751-760.

Pandza, K. & Ellwood, P., 2013. Strategic and ethical foundations for responsible innovation. *Research Policy,* 42(5), p. 1112–1125.

Preston, C. & Wick, F., 2016. Broadening the lens for the governance of emerging technologies: Care ethics and agricultural biotechnology. *Technology in Society,* Volume 45, pp. 48-57.

Rawls, J., 1971. *A Theory of Justice.* Cambridge(Mass.): Harvard University Press.

Rawls, J., 2001. *Justice as Fairness: A Restatement.* E. Kelly (ed.), Cambridge: Harvard University Press.

Ribeiro, B. et al., 2018. Introducing the dilemma of societal alignment for inclusive and responsible research and innovation. *Journal of Responsible Innovation,* 5(3).

Ribeiro, B., Smith, R. & Millar, K., 2017. A Mobilising Concept? Unpacking Academic Representations of Responsible Research and Innovation. *Science and Engineering Ethics,* 23(1), pp. 81-103.

Robeyns, I., 2016. *The Capability Approach. The Stanford Encyclopedia of Philosophy.* [Online] Available at: https://plato.stanford.edu/archives/win2016/entries/capability-approach/ [Accessed 31 August 2018].

Saha, A., 2016. Inclusive Innovation, Development and Policy: Four Key Themes. In: M. Leach, ed. *IDS Buletin Vol. 47 No. 2A: States, Market and Society - New Relationships for a New Development Era.* Brighton: Institute of Development Studies, pp. 101-112.

Saidi, T. & Douglas, T., 2017. Towards the socialization of science, technology and innovation for African development. *African Journal of Science, Technology, Innovation and Development,* 10(1), p. 110–113.

Schmidt, T. & Dabur, S., 2014. Explaining the diffusion of biogas in India: a new functional approach considering national borders and technology transfer. *Environmental Economics and Policy Studies,* Volume 16, p. 171–199.

Schroeder, D., Dalton-Brown, S., Schrempf, B. & Kaplan, D., 2016. Responsible, Inclusive Innovation and the Nano-Divide. *Nanoethics,* Volume 10, pp. 177-188.

Schumpeter, J., 1934. Capitalism, Socialism and Democracy. In: New York: Harper & Row.

Sen, A., 1980. Equality of What?. In: S. McMurrin, ed. *Tanner Lectures on Human Values.* Cambridge: Cambridge University Press.

Sen, A., 1999. *Development as Freedom.* Oxford: Oxford University Press.

Sinnott-Armstrong, W., 2015. *Consequentialism. The Stanford Encyclopedia of Philosophy.* [Online]
Available at: https://plato.stanford.edu/entries/consequentialism/
[Accessed 12 March 2017].

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

Suurs, R., 2009. *Motors of Sustainable Innovation.* Utrecht:Utrecht University.

Tigabu, A., Berkhout, F. & van Beukering, P., 2015. Technology innovation systems and technology diffusion: Adoption of bio-digestion in an emerging innovation system in Rwanda. *Technological Forecasting & Social Change,* Volume 90, p. 318–330.

Tong, R. & Williams, N., 2016. *Feminist Ethics. The Stanford Encyclopedia of Philosophy..* [Online]
Available at: https://plato.stanford.edu/archives/win2016/entries/feminism-ethics
[Accessed 12 March 2017].

van der Merwe, W. & Grobbelaar, S., 2018. Systemic policy instruments for inclusive innovation systems: Case study of a maternal mHealth project in South Africa. *African Journal of Science, Technology, Innovation and Development,* 10(6), pp. 665-682.

Velasquez, M., 2006. *Business Ethics Concepts and Cases.* 6 ed. Upper Saddle River, New Jersey:Pearson Prentice Hall.

Viotti, E., 2002. National learning systems: a new approach on technological change in late industrialising economies and evidence from the cases of Brazil and South Korea. *Technologucal Forecasting and Social Chnage,* 69(7), pp. 653-680.

Von Schomberg, R., 2013. A vision of responsible research and innovation. In: *Responsible innovation: Managing the responsible emergence of science and innovation in society.* Chichester: Wiley, pp. 51-74.

Walrave, B. & Raven, R., 2016. Modelling the dynamics of technological innovation systems. *Research Policy,* Volume 45, p. 1833–1844.

Weaver, G., 2006. Virtue in Organizations: Moral Identity as a Foundation for Moral Agency. *Organization Studies,* 27(3), p. 341–368.

Weber, K. & Truffer, B., 2017. Moving innovation systems research to the next level: towards an integrative agenda. *Oxford Review of Economic Policy,* 33(1), pp. 101-121.

Wenar, L., 2017. *John Rawls. The Stanford Encyclopedia of Philosophy.* [Online] Available at: https://plato.stanford.edu/archives/spr2017/entries/rawls/ [Accessed 31 August 2018].

WHO, 2010. *Medical devices : Managing the Mismatch; Context dependency of medical devices,* Geneva: World Health Organization.

Wickson, F. & Forsberg, E., 2015. Standardising Responsibility? The Significance of Interstitial Spaces. *Science and Engineering Ethics,* Volume 21, p. 1159–1180.

Wieczorek, A., Hekkert, M., Coenen, L. & Harmsen, R., 2015. Broadening the national focus in technological innovation system analysis: The case of offshore wind. *Environmental Innovation and Societal Transitions ,* Volume 14, p. 128–148.