et al. 2013). Instead, they perceive the ambiguity as a danger: The vagueness allows deviation from the threefold objectives of sustainable development in favour of specific interests. Sustainability as a term therefore is open to co-option. Instead of leading to change, the concept of sustainable development enables politics and economy to maintain their status quo and continuing previous practices, while still profiting from a rebranding and seemingly doing the right thing (Redclift 2005). In the last years, labelling things as sustainable has become a normatively accepted disguise for economic growth, and as such appropriated even by neoliberal politics (Jessop 2012). Similarly, green activists put forward that the term has suffered a hostile take-over:

> "A 1980s term that was formerly emancipatory and critical of the system has been absorbed by Realpolitik and the economy, as well as ruling institutions and mindsets, and associated with meanings and reform options that are acceptable to them." (Unmüßig et al. 2012: 21)

The coexisting conceptualisations of (sustainable) development document that development is best perceived as a socially constructed phenomenon. As such, it must be understood as a contested, changing, and normative concept – and it is not the aim of research to give a satisfactory definition of the term. Rather, I acknowledge that manifold discursive positions have historically evolved and continue to co-exist contemporarily in science, in civil society, in policy, in institutions of development cooperation, with different agendas and aims.

As I am specifically interested in investigating and exposing in which way the concept of sustainable development is constructed in the policies of the BMBF aimed at cooperation with developing countries and emerging economies, the next section will deal with the potential impact of science (and its political frame) on sustainable development.

2.4 Science, innovation and (sustainable) development

The idea of knowledge as a precondition of (sustainable) development has a long tradition and continues to be maintained without big controversies in current development practice and policy (Hornidge 2012). Embedded in a discourse of knowledge for development, striving for knowledge as a driver of future development has become a normative goal that many governments and institutions adhere to (Hornidge 2014a). Similarly, and although certain aspects of the concept of knowledge for development are debated in the scientific community – such as its best use (Narayanaswamy 2013); the role of local or indigenous knowledge and problems of conceptualizing it as opposite of scientific knowledge (Agrawal 1995; Sillitoe 2000;

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Mosse 2001) – the development discourse in science has generally been affirmative of the role of knowledge (Hornidge 2013).

Factual types of knowledge often are transmitted through the formal educational system. Scholars generally endorse knowledge in form of literacy or other basic knowledge-related skills, and consequently push for the access to primary and secondary education (Klochikhin 2012: 48). The value attributed to knowledge is also reflected in development policies worldwide. Creating knowledge through education was one of the Millennium Development Goals (UNDP 2013a) and is one of the SDGs as well (UN 2015). The Human Development Index includes knowledge, measured through average and expected years of schooling (UNDP 2013b) and primary, secondary and tertiary education as well as capacity development on other levels are a focus of national development cooperation policy such as in Germany (BMZ 2010).

The role of science in the context of knowledge for development is more controversial and contested than that of education. While the role of education is mainly to transmit *existing* knowledge, science generally implies generating *new* knowledge. The idea of turning science, technology and innovation into a lever of a development process can be traced back to colonial times (Smith 2009). Since then, ideas of knowledge transfer and of science and technology as a panacea for development have prospered, often in modernist approaches. The World Bank's report on *Knowledge for Development* (1999) for example still followed this line of thinking (Hornidge 2014b). In current scientific literature, different perspectives on science and its impact on different aspects of human societies can be traced. Especially in view of (sustainable) development, perspectives cover a broad spectrum ranging from positive accounts to more reflexive views which stress the complexity of the interrelation between science and society, or on possible negative or unintended consequences of science.

Different scientific perspectives on the potential effects of science on development diverge in two main points, namely the scope and the scale addressed. Some concepts exclusively focus on isolated dimensions of development, such as the role of science for economic development, while other concepts look at the phenomenon from a more encompassing perspective and consider social and environmental aspects next to economic ones, thus displaying a larger conceptual scope. In view of their scale, perspectives differ regarding the level of development addressed: Regarding the potential contribution of science for development, some strands of literature focus on an overarching systemic level, such as on the transformation of societies towards sustainability (Geels 2004; Geels and Schot 2007; WBGU 2011). In contrast, other concepts rather address how science can contribute to solving concrete problem in smaller scale research projects. They are thus directed at a context-dependent, problem-specific level and often focus on the mode of knowledge creation.

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2.4.1 Innovation as impact of science on the real world

If science is viewed in terms of its relevance and applicability for (sustainable) development, a crucial element is to transform scientific knowledge into impact outside of science (Sarewitz et al. 2004; Douthwaite et al. 2007). The process of creating impact, thus describing the relation between science and societal aspects, can be illuminated through the concept of *innovation*.

There are conceptual linkages between innovation and technology. In everyday language, both terms often have connotations of *high-tech* and science-based inventions. Technology however primarily denotes "the practical application of knowledge especially in a particular area"; "a capability given by the practical application of knowledge"; as well as "a manner of accomplishing a task especially using technical processes, methods, or knowledge", and "the specialized aspects of a particular field of endeavour" (Merriam Webster 2017).

Other definitions, such as the Oxford Dictionary's, stress the scientific origin of the knowledge applied (Oxford Dictionaries 2017a). Interestingly, both definitions stress the process character of putting knowledge into practice rather than characterizing technology as a material technological object. In the sociology of technology, scholars similarly stress that technology may describe a physical artefact, a process or an activity, as well as the knowledge – or know-how – about creating an artefact or a related process. These may or may not be science-based (Bijker et al. 1987).

Like technology, innovation denotes a process and/or result of creating an effect on the *real world* through knowledge. As other terms analyzed here, innovation does not have a fixed definition, but is defined in context-dependent social processes of knowledge creation. Originally, innovation was introduced as an economic concept. The Austrian economist Joseph Schumpeter coined the term in the 1930s, defining innovation as a new combination of factors that lead to a commercial or industrial application of a new product, process, market, supply source or organisational change (Schumpeter 1934; Fagerberg 2006).

Until today, innovation is predominantly interpreted as a narrow, economy-related concept, including in science policy all over the world. However, it has also been redefined in multiple ways and is now widely conceived as a social process (Jamison 1989). In non-economic conceptualisations, innovation refers to any novelty which is implemented in a specific context, or to the process of its implementation – not necessarily aimed at economic benefits (Röling 2009). Objects of innovation can then be material phenomena, such as a technology, or non-material innovations, such as a new technique, organisational or process-related changes, or social processes (Ul Hassan et al. 2011).

Potentially, science-based innovations thus may occur at have various entry points to the *real world*. Scientific results or research-based technologies may be

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adopted in form of an innovative technology, product or process leading to poverty alleviation, enhanced food security, or solutions to other social, economic or environmental problems. Innovative ideas based on scientific results may change public perceptions and individual behaviour; they may influence policies and governance structures (Sumner et al. 2009).

An essential part of any innovation process is its adoption, dissemination or implementation. Only the actual uptake of an *invention* (or a new idea) in the real world converts it into an innovation (Jamison 1989). Linear theories, including the influential book on the *Diffusion of Innovations* (Rogers 1962), suggest that basic research is followed by applied research, which leads to product development, production and diffusion as a final step (Godin 2006). The idea of a linear innovation process was highly influential on past innovation policies, as well as policies and institutions of other policy fields, such as development cooperation or agricultural policies which promoted agricultural innovations via extension organisations (Chataway et al. 2006; Röling 2009).

Douthwaite et al. (2003) argue that a linear conception of innovation is closely related to a positivist research paradigm, which conceives of end-users of an innovation as passive recipients of a scientifically-tested novelty. Following from the perception that scientific knowledge a superior type of knowledge, it is thus the users' fault if an innovation is not successful. In contrast, constructivist approaches perceive innovation as a process of social interaction, learning and knowledge-generating. Research therefore does not only need to cover the investigation, but the implementation phase of an innovation as well. The users, included in the process, are part of a process of socially constructing an innovation.

While a few scholars still stick to the linear models, such as Balconi et al. (2010), most scholars both in economics as well as other disciplines now conceptualize innovation as a more complex phenomenon. In economy-targeted innovation, the idea of innovation as a complex process is now an established notion (among others Jamison 1989; Rosenberg 1991; Nelson 1995; Lundvall et al. 2002; Edquist 2006; Aghion et al. 2009). In development-oriented innovation research, linear models are equally considered as outdated. Different researchers shows that the interaction and cooperation of innovation producers and users, such as scientists and non-scientific stakeholders, is highly relevant to ensure high adoption rates: Users know best which characteristics to look for in potential innovations, and how to adapt new technologies according to their needs (Lundvall 1985; Douthwaite, Keatinge et al. 2001; Douthwaite 2002; Röling 2009; Arocena and Sutz 2012).

The conceptualisation of innovation as a non-linear and social process further extended the term's scope. Innovations are now recognized as not necessarily stemming from science. Other types of practical and non-scientific knowledge have led to major changes in practices or technologies throughout human history (Röling 2009). On the conceptual level, development-related concepts of innovation and

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technology, such as *appropriate technology* (Schumacher 1973) or *grassroots innovation* (Seyfang and Smith 2007) are mainly not science-based and show that innovation may spring from different valuable sources of knowledge applied in a new context, including local or indigenous knowledge. Scholars reflecting on innovation in view of development nevertheless acknowledge the opportunities inherent to science (Rhodes and Sulston 2009; STEPS Centre 2010).

Tracing effects

With the objective of science policy to cause effects in the real world, it is hard to get around the concept of impact. Tracing and measuring impacts of policy, or research undertaken in its frame, is scientifically difficult and *not* an objective here. It nevertheless seems essential to point at the pitfalls of *impact* and at the same time explain in which sense impact turns into a matter of investigation here.

In impact-oriented research, creating effects in form of innovations for sustainable development is considered as more significant than standard measures of evaluating science. Indicators such as numbers of peer-reviewed articles, or of measuring a purely commercial value of an innovation through the number of patents produced do not represent impact adequately (Douthwaite 2002; Maselli et al. 2006; STEPS Centre 2010; Ely and Oxley 2014). Results of technological and natural science-based research are often viewed in economic terms, defined as technology transfer or economic innovation, and measured through indicators such as numbers of patents, commercialisation of a product, or the amount of third-party funding from industry. In contrast, non-technological or non-commercial forms of innovation in society are investigated less and consequently conceptualized less. No standardized criteria for measuring knowledge transfer or social impact exist yet, that could serve as a base of comparable indicators for impact across different social sciences disciplines (Froese et al. 2014).

Nevertheless, science policy makers, science funding institutions as well as researchers themselves are increasingly interested in evaluating societal values of research, next to traditional indicators of scientific excellence and of economic usability (Bornmann 2013). In the US, for example, the National Research Foundation has introduced a criterion for evaluating the broader societal value of science next to scientific excellence – albeit contested and confusing to many researchers (Sarewitz 2011).[1]

1 The missing practice of an evaluation beyond economic benefits clearly sets impact-oriented research and science policy off from development cooperation and development policy, whose programmes have a stronger tradition of evaluation due to international agreements on aid effectiveness as well as strong pressures of accountability within donor countries. While evaluation has turned into a common practice among development cooperation agencies, researchers are reflecting about the adequacy of framing, measurement of results, and effects of evaluation on policy directions in this policy area as well (Holzapfel 2016).

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While most researchers engaged in applied, problem-solving types of researchers embrace positive outcomes and effects of their doing, many reject the idea of its measurement. Douthwaite et al. suggest that positivist, i.e. linear approaches to impact fail, as impact proves to be non-linear and complex. Culture, context and other circumstances matter, as knowledge emerges in social processes. Any ex-post impact assessment would require baseline studies to compare against (Douthwaite, deHaan et al. 2001; Douthwaite 2002; Douthwaite et al. 2003). Other scholars similarly put into question if it is possible to measure impact in a scientifically sound way at all: First, science-based impact can occur on many levels in many dimensions. Science may provide concrete solutions for specific problems, such as new treatments for a disease, a new agricultural practice to improve food security, an integrated resource management strategy to guide a socio-ecological system to a more sustainable pathway, the introduction of a pro-poor policy. Next to direct impact on the social, economic or ecological environment, impacts may consist in changes of behaviour, in policies, in mobilizing civil society for a certain cause, in developing individual or institutional capacities, etc. – manifold ways of conceptualizing impact co-exist (Bozeman et al. 2003; Pregernig 2007; Sumner et al. 2009; Brewer 2011; Wiek et al. 2014).

Second, unequivocally tracing causalities is often impossible: Impact may have multiple causes, complex factors, and may be a non-linear result of research. Constructivist approaches to impact also acknowledge the role of external circumstances. Existing networks among stakeholders and policymakers, the power constellations at place may open a window of opportunity for a research-based innovation, or keep it shut (Douthwaite et al. 2007; Sumner et al. 2009; Martin 2011; Ely and Oxley 2014).

Third, impact may also occur in unforeseen and unintended ways. For example, science-based innovation leading to economic growth might aggravate inequality at the same time, medical research might not produce expected impacts on reducing infection rates, the introduction of a new crop variety might lead to abandoning more nutritious ones, etc. (Douthwaite, deHaan et al. 2001; Sarewitz et al. 2004; Smith 2009). Ely and Oxley (2014) additionally emphasize that science may take decades in producing impact, while other effects may only be temporary, or endeavours of creating impact may be in vain. Viewed from yet another perspective, the appreciation of an impact as desirable or not itself involves normative decisions and depend on societal value judgements, thus complicating impact assessment from an ethical point of view (Martin 2011; Brewer 2011).

To add a further layer of complexity, it is necessary to distinguish between effects of research and effects of the science policy that frames it. Policies do not *control* research, but only frame it through its policy objectives. Science policy thus does not cause *direct* effects – apart from shaping the science system as such – but uses research as a mediator to affect reality. The European Commission there-

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fore puts into question if it is possible at all to determine causal relations between policy and effect (European Commission 2009). From a policy science perspective, scientists have also questioned the possibility of policy evaluations, doubting that evaluations of policy will produce meaningful results – due to the inherent normativity and the interest in institutional survival (Wildavsky 2007 [1979]; Jann and Wegrich 2009).

On this background, I do *not* aim for any type of impact evaluation, neither of research projects nor of science policy. Rather, I will convert the BMBF's assumptions about impact into a research subject and expose the ministry's conceptualisations of impact – and the effects these have on the projects (ch. 9, 10). Apart from scrutinizing complex causalities, it is a ground laying philosophical question if impact expectations on research are justified. Considering that an essential characteristic of science is that it is a *search* process seems to imply that knowledge-generation is an open-ended process without predetermined results.

Despite the restrictions in view of impact assessment outlined above, it is possible to outline the effects that science potentially may have on different developmental aspects. These range from intended or unintended consequences; from traceable to assumed effects; and from locally-bounded specific innovations to effects on a more systemic level.

2.4.2 Systemic impacts of science on sustainable development

Most countries, so-called developed as well as developing countries and emerging economies alike, strategize systemic impacts of science mainly in view of *economic* development, which they place in the heart of development (ch. 8). While in the academic community, the prevalence of economic growth and international competitiveness as main objectives of science policy are viewed critically (Ober and Paulick-Thiel 2015; Schaal et al. 2014), science and innovation policies are often set to contribute to economic development (Hornidge 2011; Evers et al. 2006).

Although the direct causality of science (in terms of expenditures on science, technology and innovation) triggering economic development (in terms of an increasing Gross Domestic Product) is up for debate, many international organisations and governments continue to base their science and innovation policies on this linear perception. Investments in science are believed to lead straight ahead to economic wellbeing (Hornidge 2013). International organisations promote investments in tertiary education, science and technology to build knowledge-based economies, often referring to cases of the *Asian Tiger* states, such as Korea, or BRICS countries with successful innovation systems and growth rates as models (among others Brito and Schneegans 2010; World Bank 2007; OECD 2012). Many governments have readily taken up the idea of a correlation. In their science policy, they promote knowledge society concepts, and thus emphasize the links between sci-

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ence, technology, innovation and the productive sector in commercial innovation processes (Bechmann et al. 2009; Hornidge 2007; 2011; 2013).

The notion of innovation systems is the widest spread conceptualisation of how science, technology and innovation lead to economic growth, developed in the 1980s by economists Freeman, Soete and Lundvall (Freeman and Soete 1997; Lundvall et al. 2002; Fagerberg 2006). The elements commonly considered as essential for an efficient innovation process in the innovation system approach are human capacities in public and private sectors, including social as well as scientific capital; a sound institutional frame; supportive governance structures, policies, incentives, and the availability of public and private funds. These elements are dynamically interlinked in the system. They interact, influence, and condition each other in the process of generating, disseminating, and using new knowledge (Lundvall et al. 2002; UN Millennium Project 2005; Hall and Dijkman 2006; Kadura et al. 2011). From a growth-oriented, economic perspective, embedded in innovation systems science turns into a means of structural development of the economy. The economic benefits of technological innovation in developing countries are stressed, based on the rationale that general economic growth at the same time leads to poverty reduction (among others Conway et al. 2010; Lundvall et al. 2009; Chaminade et al. 2009; Klochikhin 2012).

However, past experiences have shown that growth does not necessarily go hand in hand with improved living conditions for all – it does not simply trickle down to the poor or lead to social inclusion. Purely economic approaches to innovation are therefore increasingly questioned in the development science community. Scholars such as Arocena and Sutz (2012) put forward that among other factors, innovation as driver of pro-poor economic growth would require the integration of social objectives and innovation policies: Neither innovation capacity nor economic growth are guarantees for more equality or a fairer society. In fact, innovation systems can even enhance inequalities of income or education. Other negative side-effects of innovation include rising food prices after certain innovations, such as in the case of first-generation biofuels, when cultivation of biofuel crops started to compete with food crops (Altenburg 2009; Cozzens and Kaplinsky 2009).

Still, the potential for systematic and targeted poverty reduction or social inclusion through innovation is widely neglected in most economy-related innovation approaches (Cozzens 2008a; Altenburg 2009). A smaller body of literature therefore focuses on reshaping the economic innovation process into a more inclusive endeavour. *Products for the poor* are one possible pathway of letting marginal groups benefit from innovation, while at the same time opening business opportunities for firms in the process of elaborating affordable products for the poor (George et al. 2012). An additional element of an inclusive innovation system is to create labour opportunities within the innovation process (Altenburg 2009). Tackling structural

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challenges that affect developing countries, such as food security, sanitation, or public infrastructure is another dimension of pro-poor innovation. However, in most innovation systems, incentives are lacking for pro-poor innovation. In economic terms, pro-poor innovation is surrounded by a market failure situation. Issues relevant for poor or otherwise marginal social groups lack a market of affluent consumers as well as strong stakeholders who push the topic on the public and policy agenda; intellectual property rights on technologies hinder their usage in a pro-poor context. Adequate policies and support therefore are of major importance in making up for adverse market conditions. So far however, science policies are seldom geared towards a pro-poor innovation system (Cozzens 2008a; Arocena and Sutz 2010; 2012).

Like issues of social development, ecological concerns are still mainly neglected in economic innovation concepts. While ideas of green innovation systems have conceptually entered policy advice by international institutions such as the OECD (OECD 2011; 2013), the idea of transitions towards more sustainability-oriented innovation systems has not had far-reaching impact on worldwide policies (Stamm 2009). In most countries – industrialized as well as developing countries and emerging economies – economic development goals, to be reached through higher growth rates, continue to compete with ecologically defined development goals. This poses a normative dilemma especially for developing countries. Extending innovation concepts targeted at strengthening the economic dimension of development, sustainability-oriented innovation research therefore has developed approaches to reconcile economic development and sustainability (Stamm 2009; Altenburg and Pegels 2012). The models are directed at greening the economy and are above all targeted at developed societies (Markard et al. 2012). They are closely related to concepts of the *green economy.*

Innovation, social and ecological aspects of development

The different perspectives on innovation systems described above address a structural, systemic level of economic development, with different degrees of concern about social and environmental dimensions of development. Even the approaches oriented towards inclusive or green innovation systems approach innovation from a point of view *within* the market economy. They conceptualize innovation as a process that is inherently defined by economic viability. Rather than sketching alternatives to economy-driven innovation processes, they *adapt* innovation concepts with an economic focus. In contrast to these economy-related conceptualisations of innovation, a further body of critical development and sustainability research advocates non-economic conceptualisations of science, innovation and technology to reach inclusive, pro-poor development – often also including sustainable ecological perspectives.

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Some of these alternative concepts of innovation take a holistic, systemic view on the phenomenon of innovation for sustainable development, detached from the economy. Next to high-tech and economically viable innovations, other types of innovations, such as low-tech, social and institutional innovations might be equally effective in finding context-adapted, socially just solutions for development challenges. Innovations may be science-based but may equally be based on local knowledge (Smith 2009; STEPS Centre 2010; Ely et al. 2010). Allowing for a broad diversity in the type of innovation minimizes the risk of technological lock-in processes and thus ensures resilience in view of global challenges (Stirling 2009; STEPS Centre 2010; Leach et al. 2010; 2012).

Characteristically, the alternative, sustainability-oriented concepts of innovation reflect comprehensively about the intentional or unintentional consequences of a certain innovation. Science and innovation may lead to positive as well as negative impacts on socio-ecological-economical systems (STEPS Centre 2010; Hornidge et al. 2011). The WBGU (2011) states that in view of any technology to be introduced as alternative to an established one, systemic impacts on the global climate, on resources, on other environmental effects as well as on economic and social consequences should be considered carefully. Seemingly local-scale, problem-oriented innovations can have impacts on the systemic level, even if these were not originally intended. During the Green Revolution, for example, focus was put on new crop varieties for better yields. However, not much attention was paid to agricultural context, practice, adoption or further consequences of introducing new varieties. Thus, positive effects on yields were produced, but the introduction of the new technologies also had far-ranging impacts on the larger social, political and environmental scale (Douthwaite 2002; Smith 2009; Conway et al. 2010).

A potential consequence with positive systemic impact on society is the further development of science- and innovation related capacities accompanying science-based activities for development. General capacity development in science as well as science management leads to the development of a functional scientific system and a critical mass of academics (Gijzen 2005; Velho 2006). In addition, even outside of academia, well-educated staff with university degrees can make better-informed decisions both in the public as well as the private sector. Scientific education is also essential to adequately decide about, deal with or to adapt future science-based innovations for the benefit of all sectors of society (Arocena and Sutz 2010).

Put more generally, a functioning science (and higher education) system in developing countries can contribute to the capacity to develop in self-determined and self-reflective ways and to use one's own potentials. A (scientifically) educated critical mass of citizens may take better-informed decisions, set and achieve own societal goals. Next to strengthening democratic processes at national level, developing countries may also benefit from increased capacities in the international

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political context, such as in the UN, for example. Scientifically educated and capable citizens enable societies to reduce dependence on donor countries, to elaborate an own developing countries' approach to solving global problems (Cozzens 2008b; Conway et al. 2010; STEPS Centre 2010). It is little surprising that academic capacity development has turned into a common element of programmes for research cooperation between industrialized countries and developing countries or emerging economies. Examples include science capacity development initiatives by the German Academic Exchange Service (DAAD 2017) or within BMBF programmes for international cooperation (Borchardt et al. 2013).

2.4.3 Problem-oriented research

Next to the impact on the systemic level, science can also have a more immediate effects on a context-specific, smaller scale of sustainable development. Researchers have therefore begun to reflect about the impacts on society, on the real world, for the benefit of the problem owners. Gibbons et al. (1994) approached different types of knowledge production by establishing idealtypes of *mode 1* and *mode 2* science. In this conceptualisation, disciplinary, often non-application-oriented ways of producing knowledge in a *mode 1* type of science are differentiated from a *mode 2* science, which is characterized as interdisciplinary, context-sensitive, and conducted towards an application aim. It is characterized by heterogeneous organisational forms and leads to the creation of *socially robust knowledge* (Gibbons et al. 1994; Nowotny et al. 2001). Similar ideas of science are expressed in concepts of *post-normal science* (Funtowicz and Ravetz 1993). At the same time, ideas of non-linearity in knowledge creation also gained influence in economic innovation studies. Researchers recognized the need of opening up knowledge production towards non-scientific actors such as consumers or governments in order to produce usable results, models shifted towards concepts such as triple helix concepts or national systems of innovation (Lundvall 1985; Etzkowitz and Leydesdorff 2000; Edquist 2006).

A similar idea is expressed in the concept of transdisciplinarity, a concept originally developed by Mittelstrass and now widespread in sustainability sciences (Mittelstrass 2011). Like *mode 2* science, transdisciplinary approaches are characterized by problem-, policy-, and impact-orientation. Furthermore, all possible dimensions of a complex problem and all types of interventions, solutions or entry points for change are considered, including the technical and physical structural environment as well as the non-structural economic, sociological, institutional, political environment. In addition to the cooperation among scientific disciplines, as in interdisciplinary approaches, transdisciplinarity places even more emphasis on a *democratisation* of science (Funtowicz and Ravetz 1993) by additionally including non-academic stakeholders such as problem owners and policy makers in all stages

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of research, knowledge production and problem setting. Thus, within the process of knowledge production, different types of knowledge coexist at equal footing, including traditional, local, indigenous, everyday, lay knowledge as well as scientific and expert knowledge. The process of generating new knowledge turns into a process of coproduction (among others, Cash et al. 2003; Hirsch Hadorn et al. 2006; Pohl and Hirsch Hadorn 2008; Lang et al. 2012; Wiek et al. 2012; Jahn et al. 2012; Cornell et al. 2013).

The idea of coproduction as employed in transdisciplinarity thinking is not to be confused with the idea of coproduction in science and technology studies (Jasanoff 2004). However, it is closely related to the ideas of citizen participation and cooperation between different societal groups in sustainability discourse. Since the surge of sustainable development, participation and cooperation have been conceptualized as underlying principles, functioning both as means towards sustainable societies as well as emancipatory elements (Kuhn and Heinrichs 2011; Newig et al. 2011).

Transdisciplinary as well as other participatory concepts of converging science and society are in line with constructivist thinking in the sociology of science, which perceives all forms of knowledge to be socially constructed, a notion that questions the traditional positivist scientific perception of a factual reality (Evers 2000; Hornidge 2013). From this perspective, scientific knowledge is not impartial, objective or neutral, as in the Mertonian ideal, but coined by social norms and subjective values, shaped by interests (Weingart and Lentsch 2007; Irwin 2008). If scientific knowledge is as much socially constructed as other types of knowledge, and thus not more representative of the truth as other meanings, then scientific knowledge can also be challenged by the public in view of its underlying interests, its salience, etc. It is therefore very much in line with constructivist thinking to call for more participation of civil society stakeholders in science or in science policy agenda setting (Jasanoff 2003; Irwin 2008; Sismondo 2008).

The idea of transdisciplinary knowledge creation has been taken up by science policy, which promotes it as an adequate way of problem-solving in science (Jahn et al. 2012), it is taken up by policy advice, e.g. as part of a concept of transformative science (WBGU 2011). It is also recommended to and applied within the development research community, for research aimed at impact next to publications or patents (KFPE 1998; Stöckli et al. 2012; ZEF 2014a).

Instead of an ex-post impact assessment, which many constructivist scholars reject (ch. 2.4.1), a further approach to impact is *ex-ante project design*. As impact is not a naturally given consequence of scientific activity, scholars scientifically reflect about the practice or mode of science which affect the outcomes and the success of turning results into innovations. Different approaches have developed in different scientific communities (Douthwaite, deHaan et al. 2001; Douthwaite 2002; Douthwaite et al. 2003). To increase impact of research projects beyond transdisciplinary

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project design, some authors have provided additional frameworks for broadening innovation uptake paths while considering potential side-effects. Douthwaite et al. (2001, 2007) show that a constant reflection about a project's possible impact and the related pathways are essential for increasing diffusion of research results. The Follow the Technology Approach as a managing and monitoring approach, as well as the Participatory Impact Pathway Analysis (PIPA) as an ex-ante operational framework for designing impact-oriented research for development projects (Douthwaite, deHaan et al. 2001; Douthwaite et al. 2007) have resonated in international development research. PIPA has been adopted as an approach to impact on policy by the UK-based Institute for Development Studies, focusing on networks, actors, and power constellations in order to identify the pathways most promising for creating impact in form of influence on policy processes. The underlying assumptions about change, influence and impact are constantly reflected during research processes in order to adapt them in case they prove wrong (Ely and Oxley 2014). Similarly, the Follow the Technology Approach has been further developed into the Follow the Innovation Approach at ZEF, proposing a methodology for interaction with stakeholders at different levels in order to increase the chance of jointly creating promising innovations, and to open up windows of opportunities. (Ul Hassan et al. 2011; Hornidge et al. 2011).

2.4.4 International research cooperation and sustainable development

An important further element to be considered when contemplating science and its potential effects on society is the role of international cooperation. Science worldwide is increasingly carried out in international networks, as "[c]ollaboration enhances the quality of scientific research, improves the efficiency and effectiveness of that research, and is increasingly necessary, as the scale of both budgets and research challenges grow" (The Royal Society 2011: 6). Expecting potential benefits of science on economic, social and environmental development, many developing countries and emerging economies are increasingly interested in international science cooperation. Collaboration is seen as a means to link up to international state of the art research, to access knowledge and global scientific networks (KFPE 2010; Conway et al. 2010). However, there are potential downsides of international cooperation in science, often linked to a prevailing modernist paradigm.

US-President Truman's Inaugural Address (1949) is often described as the birth of development thinking. At the same time, it was a key event of publicly spreading the narrative of science and technological progress as drivers of development, which in the modernist approach paradigmatic at the time meant economic growth in a liberal market economy, with technological change as a basis of enhanced productivity. The transfer of expert knowledge and technologies from developed into

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less developed countries was proposed as a standard solution for catching up (Sillitoe 2000; Anderson 2002; Smith 2009; Klochikhin 2012).

Modernisation theory and its assumptions of knowledge for development have been criticized for many years, among other reasons for being too simplistic (Chataway et al. 2006), too linear (Evers 2000), for implying an expert-lay hierarchy (Sillitoe 2000; Illi 2001), or for maintaining North-South hierarchies and technological dependence (Shamsavari 2007). Nevertheless, ideas of modernisation and catch-up still underlie many policies and institutions (Smith 2009). The World Bank's report on Knowledge for Development (1999) for example still followed the modernist view of linear knowledge transfer and of science and technology as a panacea for development (Hornidge 2014b). The differentiation between "global/local, first-world/third-world, Western/Indigenous, modern/traditional, developed/underdeveloped, big-science/small-science, nuclear/non-nuclear, and even theory/practice" (Anderson 2002: 645), closely entwined with modernism, still underlie manifold types of cooperation today, including cooperation in science. Agendas are often set by partners from the industrialized world, while partners of developing countries and emerging economies are perceived as junior partners and recipients of knowledge or providers of data. Cooperation of this type may hamper its potential benefits (Sagasti 2004; Stöckli et al. 2012). Finding a suitable mode of cooperation is therefore crucial for international research projects. Transdisciplinary interaction requires bridging knowledges across different scientific and non-scientific, practical camps, which is challenging as such. The interaction between participants from different international contexts adds a further layer of complexity to the project set-up. Whereas in development cooperation, *participation* and *ownership* have turned into internationally accepted norms for successful partnerships, which have been agreed upon internationally in the Accra Agenda of Action and the Paris Declaration of Aid Effectiveness (OECD 2008), for other types of international cooperation comparable frameworks are missing.

Development- and sustainability-oriented researchers have mainly cooperated in models based on the idea of transdisciplinarity, which entails ideas of respecting and appreciating diverse knowledges. Symmetric partnerships between researchers from developed countries and developing countries, based on mutual interest and ownership, including joint agenda setting, decision making, implementation and management are strived for, but also critically reflected about (among others KFPE 1998; Bradley 2007; Zingerli 2010; Wiesmann et al. 2011; Stöckli et al. 2012). While a normative discourse on *partnership on eyelevel* prevails among researchers and policy makers alike, some authors argue that discourses on partnership are highly political (Cornwall and Brock 2005; Mosse 2001). Terms can be filled with different meanings and employed to fulfil diverging aims, underlying inequalities do not cease to exist. In this line, some authors conclude that in science cooperation between partners from industrialized countries, develop-

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ing countries and emerging economies, the partnership principles stated in policy documents and research proposals are often not transmitted into project practice. In addition to different socio-economic, institutional and epistemic backgrounds, diverging research interests and a lack of methodologies on international cooperation can lead to reproducing (neo)colonial patterns or patronage relationships as well as enhancing power imbalances (Fuest 2005; 2007; Maselli et al. 2006; Bradley 2007; Grosfoguel 2013; Zingerli 2010). It is therefore worthwhile to scrutinize what partnership means in practice in case of the BMBF-funded research projects for cooperation with developing countries and emerging economies in sustainability research (ch. 9, 10).

Next to project practice, partnership is heavily influenced through the accompanying policies. As the analysis in chapter 9 shows, the specific policies for funding international cooperation in sustainability research play an essential role in determining the projects realities and their actions. Through its international orientation, German science policy exerts influence on partner countries. National science policy, which is potentially open towards any scientific, technological or societal development goals (ch. 2.2), thereby turns into a policy of international scope. The objectives of policy for international cooperation thus turn into leveraging points for potential positive as well as negative impacts.

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