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Technology transfer and cooperation for low carbon energy technology: Analysing 30 years of scholarship and proposing a research agenda

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ABSTRACT

While North-South technology transfer and cooperation (NSTT) for low carbon energy technology has been implemented for decades, South-South technology transfer and cooperation (SSTT) and South-North technology transfer and cooperation (SNTT) have only recently emerged. Consequently, the body of literature on NSTT is mature, while the body on SSTT and SNTT is still in its infancy. This paper provides a meta-synthesis of the scholarly writings on NSTT, SSTT and SNTT from the past 30 years. We specifically discuss core drivers and inhibitors of technology transfer and cooperation, outcomes as well as outcome determinants. We find policies and practices for low carbon development to be the main driver, both pushed by governments and international aid programs, as well as by firms that are interested in expanding overseas. Inhibitors include a non-existent market in the host countries and the abundance of cheap fossil fuel resources that price out renewables. The literature is divided on whether intellectual property rights are inhibitors or drivers of technology transfer to the Global South. Outcomes of technology transfer and cooperation are mixed with approximately one-third of instances reported as successful technology transfer and another one-third reported as failures. Core key success factors were identified as suitable government policies as well as adequate capacities in the recipient country. This analysis is then followed by an introduction of the papers of the special issue 'South-South Technology Transfer and Cooperation for Low Carbon Energy Technologies'. Finally, a research agenda for future work on NSTT, SSTT and SNTT is proposed.

1. Introduction

Global energy consumption is growing at a rapid pace. It may increase from about 13,650 Million tonnes of oil equivalent (Mtoe) in 2015 by nearly 30% to about 17,750 Mtoe in 2040 (EIA, 2017; IEA, 2017). Countries in developing Asia account for more than half of this increase due to their strong economic growth (EIA, 2017). Fossil fuels, especially natural gas and oil, are and will continue to be the primary energy sources to power these economies (IEE, 2016). This development will create carbon lock-in, i. e. make countries dependent on fossil-fuel based energy systems (Unruh, 2000). After all, assets such as natural gas plants or coal-fired power plants “cannot be […] understood as a set of discrete technological artefacts, but have to be seen as complex systems of technologies embedded in a powerful conditioning social context of public and private institutions” (Unruh, 2000, p. 818) that create “a self-reinforcing positive feedback [for a chosen] technological solution” (Unruh, 2000, p. 823). These fossil-fuel based energy systems will then further accelerate climate change, “the single greatest challenge of mankind” (UNEP, 2016, p. 3), with energy consumption contributing up to 80% of relevant greenhouse gas emissions (GHGs) (Akpan and Akpan, 2011).

How to escape carbon lock-in is thus a pressing question for policymakers around the world (Unruh, 2002). Technology transfer and cooperation for low carbon energy technology such as solar PVs, wind energy and hydropower has emerged as one possible response to it (Nakayama and Tanaka, 2011; Urban et al., 2015a). We define low carbon technology transfer and cooperation throughout this paper per the Intergovernmental Panel for Climate Change (IPCC) definition as a “broad set of processes covering the flows of know-how, experience and equipment for mitigating […] climate change […] The broad and inclusive term’transfer’ encompasses diffusion of technologies and technology cooperation across and within countries. It comprises the process of learning to understand, utilise and replicate the technology, including the capacity to choose it and adapt it to local conditions and integrate it with indigenous technologies” (Hedger McKenzie et al., 2000, p. 109).

Although much discussed both by practitioners and scholars, no comprehensive synthesis has been undertaken yet on the academic

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work on technology transfer and cooperation for low carbon energy technologies, as far as we are aware. The only literature synthesis we identified on technology transfer and cooperation, Enos and Yun (1997), does not specifically mention low carbon energy technologies. The aim of this paper is to provide a synthesis of the scholarly literature on technology transfer and cooperation for low carbon energy technologies. We specifically focus on solar PV, wind and hydropower as the three main sources of low carbon energy that are technologically mature and widely commercialised (Urban, 2018; Urban et al., 2015a). The three specific research questions addressed in this paper are:

- What are the main drivers and inhibitors of technology transfer and cooperation for low carbon energy technology (solar PV, wind, hydropower)?
- What have been the outcomes of this technology transfer and cooperation?
- What are outcome determinants?

To answer these research questions, we have analysed 30 years of scholarship on this topic, contained in 104 peer-reviewed articles. Via this literature review, we introduce the special issue 'South-South Technology Transfer and Cooperation for Low Carbon Energy Technologies' which was edited by the two authors of this paper. We hope that this work proves to be instructive for scholars keen to advance the research on this topic as well as policy-makers and firms engaged with technology transfer and cooperation for low carbon energy technology.

The remainder of this paper is structured as follows. First, we provide background information regarding technology transfer and cooperation. We then outline the methods adopted to gather and analyse our sample of literature. Results of our analysis are presented and discussed in Section 4. Meanwhile, Section 5 outlines the contributions of our special issue 'South-South Technology Transfer and Cooperation for Low Carbon Energy Technologies'. The last section of this paper summarizes our argument and proposes potential lines for future research.

2. Background

The technology transfer and cooperation definition we outlined in Section 1 of this paper is not uncontested since it does not contain any notion of novelty. Xie et al., (2013, p. 472) define technology transfer and cooperation as "the use of equipment and/or knowledge not previously available in the host country", i. e. a movement of technology from country A to country B only counts as technology transfer and cooperation if the technology is novel to country B. We did not adopt this definition since most (if not all) scholarly writings that have been published under the heading 'technology transfer and cooperation' would need to be excluded from our review then with the case studies examined usually analysing a technology that was already in place (at least to some degree) in the host country before the technology transfer and cooperation took place. While scholars may not agree on whether technology transfer and cooperation entails an element of novelty or not, most conceptualize the term as containing two *dimensions,* as also evident from the definition of Xie et al., (2013, p. 472). These are *hardware* and *software*[1]*;* this distinction was introduced by Bell (1990), acknowledged by the IPCC in 2000 (Hedger McKenzie et al., 2000), and further refined by Bell (2009), Ockwell et al. (2010) and Ockwell and Mallett (2012, 2013). Hardware refers to the technology that is needed to create the relevant physical assets. It thus comprises the capital goods and equipment as well as services such as engineering services. Meanwhile, *software* refers to the skills needed upon the completion of the relevant physical asset. It can be further distinguished between *know-how* and *know-why*. Know-how are the skills enabling the operation and maintenance of the physical asset. Meanwhile, know-why is the ability to understand the principles of how the physical facility at question works. These know-why skills are thus essential for the replication as well as innovation of the asset, as also discussed by Kirchherr and Matthews (2018, p. 548).

Technology transfer and cooperation which usually occurs via the private sector, e.g. argued by IPCC (2000), Kulkarni (2003), Schneider et al. (2008) and Lewis (2011), is distinguished in three *types* for this work: North-South technology transfer and cooperation (NSTT), South-South technology transfer and cooperation (SSTT) and South-North technology transfer and cooperation (SNTT) (Lema et al., 2015; Winstead, 2014). NSTT is technology transfer and cooperation from developed to developing countries, SSTT from developing to developing countries and SNTT from developing to developed countries (Urban, 2018). Admittedly, developing countries consist "of a diverse set of countries from emerging economies to low-income countries" (Lema et al., 2015, p. 185); we define those countries as developing countries that are denoted by the World Bank as low income (LI), lower middle income (LMI) or upper middle income (UMI), while developed countries are those denoted as high income (HI) (Lema et al., 2015; Winstead, 2014; World Bank, 2017). Urban (2018) argues that most of the literature on low carbon energy technology transfer and cooperation is on NSTT, yet the rise of emerging economies like China and India and their increasing innovation capacity is challenging this dominant technology transfer and cooperation paradigm. We investigate which type of technology transfer and cooperation is examined most frequently in the scholarly literature in Section 4.1.

The literature often examines drivers as well as inhibitors of technology transfer and cooperation which enable or impede it in the first place. Both drivers and inhibitors are further distinguishable in push and pull factors with push factors originating in the site of origin and pull factors originating in the site of use (cf. Erickson and Chapman, 1995 or Rai et al., 2014). For instance, Erickson and Chapman (1995, p. 1130) write that "renewable energy technology transfer [and cooperation would be] a supply push rather than a demand pull". We further present and discuss the various drivers respectively inhibitors of technology transfer and cooperation (distinguished in push and pull factors) in Section 4.2 of this paper.

A successful technology transfer and cooperation is one that does not only provide hardware to a recipient country, but that also enables it to operate, maintain, replicate and innovate this technology. Meanwhile, the technology transfer and cooperation outcome is judged to be 'mixed' if the recipient has received the technology and is able to operate and maintain it, but unable to replicate and innovate it.[2] Technology transfer and cooperation has failed if only hardware was provided (Ockwell and Mallett, 2012; Pueyo et al., 2011). Several scholars, e.g. Ockwell et al. (2010), Unruh and Carrillo-Hermosilla (2006) and Urmee and Harries (2009), have claimed that most technology transfer and cooperation endeavours have failed. We present our results on this in Section 4.3; this section then also outlines the key determinants of technology transfer and cooperation outcomes, according to the scholarly literature.

3. Methods

We built a database of relevant literature on technology transfer and cooperation for low carbon energy technologies, in specific solar PV, wind and hydropower, via numerous Scopus searches. A variety of keywords were used, e. g. 'technology transfer', 'technology transfer

[1] Lema and Lema (2012, p. 39) note that the using 'technology transfer' in combination with 'software' is misleading since "capabilities [which are meant by 'software'] are built and acquired rather than transferred". Hence, we use the term 'technology transfer and cooperation' which includes knowledge cooperation through staff exchange and training, joint R&D, joint ventures, licensing and mergers and acquisitions (M&A) etc.

[2] For an illustrative case study about the mixed results of SSTT in the hydropower sector, see Urban et al. (2015a, 2015b).

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