Global Environmental Change 23 (2013) 301–313

Contents lists available at SciVerse ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

# Technology transfer in the clean development mechanism: Insights from wind power

Adrian Lema [a,1], Rasmus Lema [b,*]

[a] Ministry of Climate, Energy and Building, Copenhagen, DK-1470, Denmark
[b] Department of Business and Management, Aalborg University Copenhagen, Frederikskaj 10B, Copenhagen V, DK-1790, Denmark

ARTICLE INFO

*Article history:*
Received 30 March 2012
Received in revised form 3 September 2012
Accepted 5 October 2012
Available online 7 November 2012

*Keywords:*
Technology transfer
Technological capabilities
Developing countries
Clean development mechanism
CDM
Climate change
Renewable energy
Wind power

ABSTRACT

International technology transfer is a key element in efforts to ensure low carbon growth in developing countries. A growing body of literature has sought to assess the extent of technology transfer in the clean development mechanism (CDM). In this paper we use the case of wind power CDM to expand the focus to how technology transfer occurs. We seek insights from the technology and CDM literatures to develop a framework with multiple technology transfer mechanisms. We then show empirically that technology transfer in CDM wind projects occurs through a greater variety of mechanism than is commonly assumed. The evidence suggests that the strengthening of host country capabilities changes the nature of technology transfer. The cases of China and India indicate that diversity in transfer mechanisms is an effect of the pre-existing industrial and technological capabilities. We show that CDM projects in China and India tend to utilise transfer mechanisms opened up prior to and independent of CDM projects, not the other way around. Our findings suggest that research and policy should pay more careful attention to the relationship between international low carbon technology transfer mechanisms and local technological capabilities.



## 1. Introduction

Greenhouse gas emissions in developing countries are expected to account for up to 70% of the global increase in emissions in the period 2002–2030. It is therefore commonly agreed that low carbon technology must play a key role reducing the climate change effect of economic growth in developing countries (IEA, 2008). The clean development mechanism (CDM) is typically viewed as one of the most important vehicles for the transfer of low carbon technology and know-how between developed and developing countries. Yet, fairly little is known about the process of technology transfer in CDM. In this study we use the case of wind power to open the technology 'black box'. We examine the mechanisms through which technology transfer occurs in CDM and how it differs between countries. This is important because there is increasing recognition that technology deliberations in the context of climate change mitigation need to be based on a deeper understanding of the processes and arrangements through which technology is 'transferred' internationally (Ockwell et al., 2008; Berkhout et al., 2010; Lema and Lema, 2012).

The CDM is a useful case for examining international technology transfer. A growing body of literature has sought to assess the degree to which technology transfer occurs in the CDM (e.g. Dechezlepretre et al., 2008, 2009; De Coninck et al., 2007; Hascic and Johnstone, 2011; Seres et al., 2010; UNFCCC, 2011). In this paper we seek to engage with and add to this literature by expanding the focus from *whether* technology transfer occurs in CDM projects to *how* it occurs (if and when it does).

### 1.1. Research questions and value added of the paper

The empirical analysis in this paper seeks to identify the key technology transfer mechanisms in wind power CDM projects. We use the term 'mechanisms' to refer to organisational arrangements for technology transfer. The paper is driven by the following research questions: What are the key mechanisms of technology transfer in wind power CDM projects? To what extent do different countries utilise a variety of transfer mechanisms in their different CDM projects? To what extent do CDM projects open up new transfer mechanisms that have not previously been utilised in host countries?

These types of questions have received almost no attention in the existing literature on technology transfer in CDM. In addressing

* Corresponding author. Tel.: +45 9940 2708.
*E-mail addresses:* anlema@ruc.dk (A. Lema), lema@business.aau.dk (R. Lema).

[1] The views and opinions expressed in this article are those of the authors and do not necessarily reflect the policy of the Danish Ministry of Climate, Energy and Building.

0959-3780/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.gloenvcha.2012.10.010

these questions we make conceptual, methodological and empirical contributions to the literature.

*Conceptual*: In order to address the research questions we develop a new framework to distinguish between different types of transfer mechanisms in CDM. We do this by drawing on the broader literature on technology transfer and technological learning and innovation in developing countries (e.g. Lall, 1993a; Bell and Pavitt, 1995; Bell and Figueiredo, 2012; Dunning, 1981; Maskus, 2004).

*Methodological*: As will be elaborated later, the existing studies of have considerable methodological weaknesses and we therefore adopt a novel approach in which we combine data on the specific organisational arrangements of CDM projects with detailed data on the nature of the utilised wind power technology and its origin. This allows for a deeper and more precise analysis of technology transfer mechanisms in CDM.

*Empirical*: The conceptual and methodological advances allow us to unearth new and substantial insights. We show that technology transfer mechanisms in China and India are more diverse – i.e. they include a broader variety of different types – than is commonly acknowledged. Much of the existing literature on technology transfer tends to assume that international trade and foreign direct investment are *the* channels of technology transfer (Less and Mcmillan, 2005; Brewer, 2008) although licensing is sometimes added to those (e.g. Popp, 2011, 137–139; Schneider et al., 2008, 2931). We find that the degree of diversity is closely associated with the industrial context of host countries, not least the pre-existing technological capabilities in the wind energy field. We find that CDM projects often reflect transfer mechanisms opened up prior to and independent of CDM projects. We also find that the nature of technology transfer changes – becomes more diversified – as local capabilities increase. This is an important insight with respect to the discussion about whether stronger local capabilities render technology transfer less relevant (Dechezlepretre et al., 2008; Doranova et al., 2010).

These findings advance the debate by specifying the nature of the mechanisms involved in CDM projects, but they also prompt important questions about the effectiveness of CDM as a vehicle of technology transfer. In turn, they raise much broader questions about what (low carbon) technology transfer is and how it occurs. Understanding technology transfer in CDM depends on an understanding technology transfer in general.

### 1.2. Structure of the paper

The remainder of the paper is structured as follows. Section 2 seeks insights from the general technology transfer literature and the existing empirical literature on technology transfer in the CDM. Section 3 draws on these insights and develops a framework with multiple technology transfer mechanisms. Section 4 explains the methods of data collection and classification. Section 5 presents the finding of the empirical analysis of the mechanisms involved in CDM wind power projects. Section 6 delves deeper into these findings and provides added insights by (a) highlighting the different industrial contexts of wind power CDM host countries and (b) discussing the relationship between technology transfer which occurs in and independent of CDM. Conclusions and policy implications are brought out in Section 7.

## 2. Insights from the literature

In this section we first seek insights from the literature and distinguish between a broad and a narrow view of technology transfer. We then outline the main tenets of the existing literature on technology transfer in CDM projects. We find that it tends to adopt the narrow view of technology transfer. We argue that the analysis of technology issues in CDM can benefit from broader insights. This requires conceptual and methodological advances which are addressed in subsequent Sections 3 and 4.

### 2.1. Technology transfer and innovation literature

There are two main ways at looking at international technology transfer (Lema and Lema, 2012). The first is the view that underpins the most influential literature in the debate on technology in the climate change context (World Bank, 2008, 2010; IPCC, 2007; Commission on Growth and Development, 2008). We term this view the 'narrow' view because it exhibits a bounded notion of technology and the transfer process. This view is often apparent in the UNFCCC climate change negotiations (see Ockwell et al., 2010) and in influential international organisations (such as Commission on Growth and Development, 2008; World Bank, 2010). The second is an alternative view that has grown out of the literature on technological learning and innovation in developing countries (such as Lall, 1993a; Bell, 1990; Ernst and Kim, 2002). We call this the 'broad' view because the notion of technology is wider and the mechanisms involved in the transfer process include a more wide-ranging array of phenomena.

These two views differ with regard to key assumptions and the associated scope of the understanding of four issues of key concern to this paper. Table 1 contrasts the narrow and the broad view of these four issues in stylised form. We discuss these differences in more detail below.

*The nature of 'technology'*: The term 'technology' often refers to physical equipment and machinery ('hardware'). In the narrow view, the notion of technological 'diffusion' typically refers

**Table 1**
Contrasting views on international technology transfer.

| | A (Narrow view) | B (Broad view) |
|---|---|---|
| 1. The nature of technology | 'Technology' refers to capital goods, product designs and operational know-how | 'Technology' refers not only to artefacts and operational knowledge (cell A1). It also includes skills and capabilities for technical change |
| 2. The transfer process | Technology transfer is the cross-border movement of 'technology' (cell A1) from supplier to host-country importer | Technology transfer not only involves movement of capital-embodied or paper-embodied technology (cell A2). It involves flows of people-embodied knowledge combined with a capability accumulation process in recipient organisations. |
| 3. Cross-border interaction | The transfer process (cell A2) is rooted in a transaction agreement pertaining to the transfer of goods, documentation and (possibly) related services. It is achievable through a unidirectional flow of resources from supplier to importer. | Effective transfer (cell B2) depends on a contractual relation that goes beyond the sale of capital or paper-embodied technology. It depends on 'thick linkages' that enable iterative knowledge flows between supplier and importer. |
| 4. Localised innovation | Cross-border transfer (cell A2 and A3) and local innovation are substitutable processes | Cross-border transfer (cell B2 and B3) and localised innovation are substitutable only in certain respects. They are predominantly complementary activities. |

*Source*: Drawing on Lema and Lema (2012), Table 6.