Energy Policy 123 (2018) 104–116

Contents lists available at ScienceDirect

Energy Policy

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

Knowledge flow in low-carbon technology transfer: A case of India's wind power industry

Daisuke Hayashi

Department of International Relations, Ritsumeikan University; Department of Political Science, University of Zurich, 56-1 Toji-in Kitamachi, Kita-ku, Kyoto 600-8577, Japan

ARTICLE INFO

Keywords:
Technology transfer
Technological capabilities
Knowledge
Innovation
Wind power
India

ABSTRACT

The degree of knowledge flow in low-carbon technology transfer is influenced by its organizational mechanism. While transfer mechanisms involving greater cross-border interaction and recipient effort may provide more learning opportunities, there remains a gap about the causal mechanisms and contingent variables involved in technology transfer and technological capability development. This study offers one of the first firm-level causal analyses of transfer mechanisms and technological capabilities, taking into account various firm- and context-specific factors. To this end, India's wind power industry is analyzed using firm-level data and semi-structured interviews conducted in 2013 with 15 wind turbine manufacturers covering 76% of the market share and 12 other organizations working on wind power. The analysis demonstrates that innovation capabilities are accumulated mainly through transfer mechanisms enabling recipients' engagement in research and development. Mergers and acquisitions as well as international research and development centers are among the most effective examples. Joint ventures could be appropriate if a local partner gains a large majority shareholding. The knowledge transfer through wholly foreign-owned enterprises may be restricted because intellectual properties are tightly controlled by their parent firms. The creation of a predictable, performance-oriented market enhances firms' financial resources and consequently encourages knowledge acquisition and capability development.

1. Introduction

Technology transfer is one of the key drivers of leapfrogging in climate change mitigation. In the context of climate change, leapfrogging suggests that developing countries may be able to skip emissions-intensive development stages by incorporating more sustainable, low-carbon technologies that are currently available (Goldemberg, 1998; Watson and Sauter, 2011). Besides the build-up of internal knowledge, the access to external knowledge is crucial for successful leapfrogging (Lee and Lim, 2001; Lewis, 2013).

IPCC (2000, p.3) defines technology transfer as a "broad set of processes covering the flows of know-how, experience and equipment" between various types of actors. As this definition indicates, both technology hardware and the associated knowledge are essential elements of technology transfer. However, a lion's share of low-carbon technology transfer to developing countries involves only a limited flow of technology-related knowledge (Bell, 2012). Thus, many developing countries lack the capability to design and manufacture low-carbon technology and hence depend on the technology developed abroad (Lema and Lema, 2013; Pueyo, 2013). For a sustained impact of low-carbon technology transfer on climate change mitigation, recipient firms need to manage the technology innovation processes and ensure long-term adoption and improvement of low-carbon technology (Ockwell et al., 2008). Because knowledge acquisition is essential to capability development, it is important to accelerate the shift from pure sale of technology hardware to transfer of technological knowledge to developing countries (Bell, 2012; Watson et al., 2015).

The degree of knowledge transfer is partly influenced by the organizational mechanisms of technology transfer (Lema and Lema, 2016; Ockwell et al., 2008; Schneider et al., 2008). For example, technology transfer mechanisms involving substantial cross-border interaction and recipient effort may create more learning opportunities (Lema and Lema, 2016). However, the mechanisms' long-term knowledge dividends are highly situational (Rai and Funkhouser, 2015) and the causal mechanisms and contingent variables involved in technology transfer and technological capability development require further empirical

Abbreviations: CDM, Clean development mechanism; CEO, Chief executive officer; C-WET, Center for Wind Energy Technology; FY, Fiscal year; GBI, Generation-based incentive; IPP, Independent power producer; kW, Kilowatt; M&A, Merger and acquisition; MW, Megawatt; O&M, Operation and maintenance; R&D, Research and development; WFOE, Wholly foreign-owned enterprise

E-mail address: dhayashi@fc.ritsumei.ac.jp.

https://doi.org/10.1016/j.enpol.2018.08.040
Received 27 December 2017; Received in revised form 15 August 2018; Accepted 19 August 2018

investigation (Lema and Lema, 2013). This study aims to fill this gap by addressing the following questions:

1) How do different technology transfer mechanisms foster technological capabilities of recipient firms?
2) In what ways do firm- and context-specific factors influence the choice of technology transfer mechanisms?

To this end, India's wind power industry is analyzed using various firm-level statistics and semi-structured interviews conducted in 2013 with 15 wind turbine manufacturers and 12 other organizations working on wind power. A firm-level analysis is useful because firm strategies play a pivotal role in technology transfer and capability development. Wind power is a prominent option for low-cost, low-carbon electricity (IPCC, 2014). India ranked fourth in the world in terms of wind power generation capacity in 2015 (GWEC, 2016), and was home to several globally competitive wind turbine manufacturers and a number of smaller turbine manufacturers. These turbine manufacturers pursued a wide range of technology transfer mechanisms to build up their technological capabilities (Hayashi, 2015; Mizuno, 2011, 2007). The large variations in technological capabilities and technology transfer mechanisms make India's wind power industry an appropriate case for empirical analysis.

The remainder of this paper is structured as follows. Section 2 reviews the literature and develops a framework for analyzing the linkages between technology transfer mechanisms and technological capabilities, while Section 3 explains the empirical strategy. Section 4 shows how different technology transfer mechanisms result in varying degrees of technological capabilities, and how this is influenced by various firm- and context-specific factors. Section 5 discusses the contributions and limitations of this study. Finally, Section 6 concludes the paper, discussing the main findings and contributions to the literature.

2. Literature review

2.1. Low-carbon technology transfer and technological capabilities

Numerous studies on low-carbon technology transfer examine the factors leading to technology transfers. One major research field on low-carbon technology transfer is the Kyoto Protocol's Clean Development Mechanism (CDM) for climate change mitigation projects in developing countries. Scholars measured the number of CDM projects involving technology transfer and related it to country- or project-level factors such as openness to trade and project size (e.g., Dechezlepretre et al., 2008; Hascic and Johnstone, 2011; Murphy et al., 2015; Schmid, 2012). Studies also identified various factors affecting the access to low-carbon technology such as intellectual property regime, cost of labor and capital, and education and skill base (Rai and Funkhouser, 2015). While these studies help in explaining whether and why low-carbon technology transfers occur, they fail to clarify how different technological content is transferred and the consequences thereof. By using CDM projects as a unit of analysis, these studies also fall short in understanding how firm characteristics influence technology transfer activities. This is an important omission as firm strategies play a key role in technology transfer and capability development (Lema et al., 2016; Urban et al., 2015).

An emerging literature explains the role of knowledge transfer in fostering technological capabilities, using firms as a unit of analysis (Bell, 2012; Doranova et al., 2011; Watson et al., 2015). Technological capabilities can be defined as "the skills—technical, managerial or organizational—that firms need in order to utilize efficiently the hardware (equipment) and software (information) of technology, and to accomplish any process of technological change" (Morrison et al., 2008, p. 41). Bell (2012) distinguishes between two types of technological capabilities: production and innovation. While production capabilities refer to the resources necessary for producing industrial goods at given efficiency levels and input combinations, innovation capabilities are the resources needed to generate and manage technological change (Bell and Pavitt, 1993, p. 163).

Creation of production capabilities requires the transfer of capital goods and basic operation and maintenance (O&M) knowledge of the transferred technology, while innovation capability accumulation requires the transfer of advanced knowledge for adapting, improving, and further developing the acquired technology (Bell, 2012). Bell and Figueiredo (2012) stress that routine production work does not accumulate innovation capabilities, for which firms need to actively invest in learning to innovate. Accumulating innovation capabilities is particularly important because technological catch-up is not just achieving higher production efficiency levels, but is also about enhancing dynamic efficiency by creating capabilities for innovation (Bell and Figueiredo, 2012).

2.2. Determinants of knowledge flow in technology transfer

The degree of knowledge transfer depends on the organizational arrangements of technology transfer (Easterby-Smith et al., 2008; Lema and Lema, 2016; Ockwell et al., 2008). Mowery et al. (1996) demonstrate that equity-based joint ventures promote greater technological knowledge transfers than contract-based alliances. Schneider et al. (2008) argue that technology transfer mechanisms involving long-term, repetitive exchanges (e.g., foreign direct investment: FDI) provide a greater incentive for continuous knowledge transfer. According to Lema and Lema (2016, 2012), unconventional transfer mechanisms (acquisitions of foreign firms, overseas research and development (R&D), and joint R&D) require substantial cross-border interaction and recipient effort. Such mechanisms may provide more learning opportunities than conventional transfer mechanisms (trade, FDI, joint ventures, and licensing agreements). Long-term knowledge dividends of technology transfer are highly situational, but their organizational arrangements provide an "early indication" of the degree of knowledge transfer (Rai and Funkhouser, 2015, p. 353). There remains a knowledge gap about the causal mechanisms and contingent variables involved in technology transfer mechanisms and technological capability development (Lema and Lema, 2013).

Knowledge acquisition through technology transfer can be understood with the exploration-exploitation framework, which exhibits a trade-off between exploration of "new possibilities" and exploitation of "old certainties" (March, 1991, p. 71). While exploitation is reflected in terms such as "refinement, choice, production, efficiency, selection, implementation, execution," exploration is associated with "search, variation, risk taking, experimentation, play, flexibility, discovery, innovation" (March, 1991, p. 71). Exploration and exploitation compete for scarce resources, and so firms need to strategically decide on how to balance the two activities (Lavie et al., 2010; Levinthal and March, 1993; March, 1991; Raisch and Birkinshaw, 2008). While exploration helps firms renew their knowledge base, those engaged exclusively in exploration will not gain the returns on its knowledge. Exploitation may enhance firms' short-term performance, but those pursuing only exploitation will suffer from obsolescence of knowledge. Scholars argue that both exploration and exploitation are necessary for firms' survival and prosperity (e.g., Levinthal and March, 1993). Thus, firms need to strike a balance between technology transfer for creating production capabilities (exploitation) and that for accumulating innovation capabilities (exploration).

The determinants of exploration and exploitation can be firm or context specific. Firm-specific factors include absorptive capacity and financial resources. Cohen and Levinthal (1990) argue that external knowledge is often critical to innovation processes, but firms cannot benefit from simply being exposed to it, and instead need to develop the ability (absorptive capacity) to "recognize the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen and Levinthal, 1990, p. 128). Absorptive capacity can be generated in