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The effect of local and global learning on the cost of renewable energy in developing countries

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ABSTRACT

High upfront costs are a critical barrier for investments in clean infrastructure technologies in developing countries. This paper uses a case study of Thailand's electricity sector to create realistic estimates for the relative contributions of local and global technological learning to reducing these cost in the future and discusses implications of such learnings for international climate policy. For six renewable electricity technologies, we derive estimates for the share of locally and globally sourced goods and services, and analyze the effects of local and global learning during the implementation of Thailand's renewable energy targets for 2021. Our results suggest that, in aggregate, the largest potential for cost reduction lies in local learning. This finding lends quantitative support to the argument that the conditions enabling local learning, such as a skilled workforce, a stable regulatory framework, and the establishment of sustainable business models, have a more significant impact on cost of renewable energy in developing countries than global technology learning curves. The recent shift of international support under the United Nations Framework Convention on Climate Change towards country-specific technology support is therefore promising. However, our results also show that the relative importance of local and global learning differs significantly between technologies, and is determined by technology and country characteristics. This suggests that international support need to consider both the global perspective and local context and framework conditions in order to reap the full benefits of technological learning across the wide range of clean technologies.

1. Introduction

The global climate policy regime needs to significantly accelerate the diffusion of clean technologies to avoid dangerous impacts from climate change (UNFCCC, 2012). In addition to actions taken by the developed world, developing countries are expected to assume greater responsibility by implementing domestic policies that contribute to both domestic economic development and climate change mitigation (Kanie et al., 2010). Indeed many developing countries are already implementing domestic climate legislation, despite the gridlock in international negotiations (Nachmany et al., 2014; REN21, 2013; Townshend et al., 2013). However, high upfront costs remain a critical barrier for large-scale investments in clean technologies, especially in developing countries (IPCC, 2012; Schmidt, 2014). How to accelerate the development and transfer of clean technologies is, therefore, emerging as a central issue in the international climate policy negotiations (Ockwell and Mallett, 2012; Pueyo et al., 2012).

Experience in the industrialized world has shown that cost reductions and performance improvements of new technologies are often closely linked to policies aimed at increased production and deployment (Jänicke, 2012), driven by mechanisms collectively referred to as *technological learning* (Junginger et al., 2010). If successful, the increasing number of mitigation actions taken now by developing countries holds the promise to stimulate innovations and future cost reductions there as well. But technological learning encapsulates a diverse array of purposeful processes that some countries, sectors and organizations manage better than others

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(Bell and Figueiredo, 2012; Van Hoof, 2014). Besides creating financial incentives for investment, one of the key challenges for international climate policy is therefore to actively promote technological capabilities in developing countries and to enable countries to reap the full learning benefits from mitigation investments they make and attract (Benioff et al., 2010; Bhasin, 2013; De Coninck et al., 2008; Ockwell and Mallett, 2012).

Technological learning in developing countries, especially outside the largest emerging economies, follows distinct dynamics (Pueyo et al., 2011). The industries producing clean technologies are increasingly globalized (Gallagher, 2014; Lewis, 2012; Nahm and Steinfeld, 2014). Therefore, in a typical investment project, local firms in developing countries provide only part of the products and services. Learning in this share of the industry value chain is local in nature and driven by local market developments and policies – we will refer to it as *local technological learning* (Morrison et al., 2008; Mytelka, 2000). However, because a substantial share of components is typically sourced from abroad, the economics of local investments are also impacted by technological learning processes in other countries. For example, technological progress by Chinese solar cell producers improves the economics of solar investments around the world. This form of learning is driven more by global markets than by policies in individual countries (Peters et al., 2012). Future investment conditions for clean technologies in developing countries thus depend on a combination of global and local learning processes, which, in turn, depend on domestic and international regulatory, institutional and industrial contexts. Better understanding of the relative importance of the two can improve both domestic and international policy decisions.

Using a quantitative case study, this paper estimates the effect of local and global technological learning on the cost reductions of renewable electricity generation in Thailand. We employ a techno-economic model of the country's electricity sector to project the cost of implementing the country's renewable energy targets for 2021 (Kamolpanus, 2013). We derive estimates for the share of locally and globally sourced goods and services for six renewable electricity technologies and analyze, in different scenarios, the impact of local and global learning effects on the investment cost. Based on the results, we explore implications for the design of international low carbon technology support mechanisms.

The paper makes three main contributions. First, our case study informs the academic debate as well as international negotiations on the post-Kyoto climate policy regime of the United Nations Framework Convention on Climate Change (UNFCCC). In its support for technology development and transfer, the international climate policy regime has recently shifted its attention toward national policies and local technological learning. The analysis presented in this paper enhances the understanding of the merits of this shift, and informs the design and functional specification of the new international technology support mechanisms. Our quantitative approach and the focus on mitigation cost complements existing conceptual and qualitative work on the topic (Benioff et al., 2010; Bhasin, 2013; De Coninck et al., 2008; Ockwell and Mallett, 2012). Furthermore, it contributes to the growing body of literature on the economics of clean energy technology investments in developing countries (e.g., IRENA, 2012a; Schmidt et al., 2012). Finally, our paper is among the first to investigate the impact of local and global learning separately for a specific developing country case.

The next section will introduce the key theoretical constructs used in the analysis (Section 2). Section 3 introduces the case, before section 4 presents the model, the data sources, and the methodology. The results of the case study are presented in Section 5, and their policy implications discussed in Section 6.

2. Local and global technological learning

2.1. Technological learning in developing countries

Technological learning is understood here broadly as the accumulation of technological knowledge and experience, often also referred to as *technological capabilities*, in individuals and organizations (Bell and Figueiredo, 2012). Research on innovation processes has shown that the technological capabilities held by firms comprises not only information codified in capital goods or documents (patents, manuals, etc.), but also includes the tacit knowledge embodied in individual skills and firm routines (Dosi, 1988; Senker, 1995). These elements of knowledge are costly to transfer and therefore highly organization-specific (Von Hippel, 1994). This means that removing trade barriers and providing developing countries with intellectual property rights (IPR) and resources for technology imports is not sufficient to enable countries to catch up to the technological frontier (Bell and Pavitt, 1996; Ockwell et al., 2010). Rather, catching up requires building local technological capabilities through the cumulative, costly and time-consuming process of technological learning (Bell, 2010).

Technological capabilities and learning are increasingly being recognized as significant drivers of low carbon development (Byrne et al., 2011; Lema and Lema, 2013; Phillips et al., 2013). The international climate negotiations, too, are taking notice (Ockwell and Mallett, 2012). Improved technological capabilities hold the promise of removing barriers to the diffusion of clean technologies, thereby facilitating further emission reductions in the future (Sandén and Azar, 2005). Besides its effect on mitigation cost, the local build-up of technological capabilities is crucial for local industrial capacity, poverty reduction and economic growth. For many developing countries, investing in climate change mitigation is, for now, only desirable if the government can create opportunities for the local private sector to participate in the value chain of mitigation investments. However, in order to participate in the development and manufacturing of clean technologies, local firms in developing countries need to create the capacity to continuously absorb, adapt and improve new technologies (Bell and Pavitt, 1996).

Climate models increasingly incorporate learning as an endogenous process driven by mitigation investments (Kahouli-Brahmi, 2008; Van der Zwaan et al., 2002), but technological learning is not an automatic by-product of investments (Bell and Figueiredo, 2012). Rather, in the analysis of the development of mitigation policies and estimation of future mitigation cost, it is better understood as an *opportunity* that can be only adequately seized when both governments and firms create the necessary conditions. Organizations need to pursue conscious efforts to create the ability, in the form of a skilled workforce and organizational processes, to *absorb* the new knowledge and experience that they generate (Cohen and Levinthal, 1989). Furthermore, organizations innovate and learn through their interaction with users, suppliers, competitors, universities or regulators in *systems of innovation* (Fagerberg et al., 2007; Lundvall et al., 2009). The existence of formal and informal networks, as well as public funding for science and technology, are therefore critical drivers of technological learning. And, last but not least, learned capabilities degenerate rapidly if organizations have a rapid workforce turnover, face an instable regulatory framework, or pursue unsustainable business models.

2.2. Local and global learning effects in value chains

Most clean technologies are technological systems consisting of hundreds, or even thousands, of materials, components, and intermediate goods. Furthermore, mitigation investments involve numerous legal, financial, and regulatory services. The collective of