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Innovation and international technology transfer: The case of the Chinese photovoltaic industry

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ABSTRACT

China is the largest solar photovoltaic cell producer in the world, with more than one third of worldwide production in 2008, exporting more than 95 percent of what it produces. The purpose of this paper is to understand the drivers of this success and its limits, with a particular emphasis on the role of technology transfers and innovation. Our analysis combines a review of international patent data at a detailed technology level with field interviews of ten Chinese PV companies. We show that Chinese producers have acquired the technologies and skills necessary to produce PV products through two main channels: the purchasing of manufacturing equipment in a competitive international market and the recruitment of skilled executives from the Chinese diaspora who built pioneer PV firms. The success of these firms in their market is, however, not reflected in their performance in terms of innovation. Rather, patent data highlight a policy-driven effort to catch up in critical technological areas.

1. Introduction

There is a large consensus in the international community that effective mitigation of climate change will require the massive deployment of carbon-friendly technologies on a global scale.[1] Yet the very notion of technology diffusion remains a tricky issue in climate negotiations, as evidenced by the creation of a working group under the United Nations Framework Convention on Climate Change (UNFCCC) dedicated to this issue.[2]

In international discussions, the precise scope of technology diffusion remains ambiguous. It refers to the deployment of technology-based solutions to reduce greenhouse gas (GHG) emissions, such as wind turbines, solar panels, and nuclear power plants. But it also alludes to the transfer of the technical knowledge required to produce these turbines, panels or plants by local firms in developing countries. The latter interpretation of transferring knowledge is favoured by developing countries, and explains their request in climate talks for relaxing intellectual property rights (IPR). Although the deployment of technological goods is what matters to address climate change, the transfer of technological capabilities is indeed the key to developing countries obtaining a share of the green business pie. From a general interest point of view, it also reduces costs through increased competition.

The case of the Chinese photovoltaic (PV) industry is particularly interesting in this respect. In 2009, the deployment of solar panels in China had hardly started. Yet with more than 35 percent of worldwide production capacity in 2008 (of which 98 percent was exported), the Chinese domestic industry is the world leader in the production of PV cells and modules. In a nutshell, China has succeeded in acquiring the technologies for producing solar PV, without deploying PV systems in its territory. This case suggests that technology deployment and the diffusion of production technology are two distinct issues.

The purpose of this paper is to understand the drivers and limitations of this Chinese success in mastering a production technology that had initially been developed in industrialized countries. The main questions we will address are: how did Chinese firms manage to acquire production technologies and skills? Which segments of the PV supply chain does it concern? Have IPR impeded this process? Is China now able to produce new technologies domestically?

We address these questions empirically, by combining both quantitative and qualitative evidence. On the quantitative side, we rely on a dataset comprising 79,642 PV-related patents to analyse cross-country innovation and technology transfers in the different segments of the PV industry. To supplement this quantitative analysis, we carried out a series of field interviews with PV actors in China.[3] These interviews allowed us to further understand specific

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[1] The Bali Road Map mentions for instance technology diffusion as a strategic objective.

[2] As the Ad Hoc Working Group on Long-term Cooperative Action under the Convention (AWG-LCA) created in 2009 under the UNFCCC (see http://unfccc.int/meetings/items/4381.php).

[3] You can refer to Appendix 1 for more information concerning interviewed actors.

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details of the economics of the Chinese PV industry, and provided qualitative information concerning the innovation and technology transfers to China.

The theoretical framework of our empirical analysis draws on the economic literature on technology transfer and absorptive capacities (for excellent surveys of this literature, see Keller, 2004, 2008). Within the Chinese context, our chief purpose is to highlight and explain the mechanisms of technology transfer in each part of the PV value chain. The paper is also related to the available literature on the photovoltaic industry. This includes the works of Yanga et al. (2003) and Marigo (2007). We also exploit a substantial body of professional literature published by public organizations (European Commission PV Status Report 2003, 2005, 2008, 2009; IEA, 2009; REDP, 2008), industry associations (EPIA, 2009, REN21, 2008) and consulting groups (McKinsey, 2008).

The paper is organized into four sections. In Section 1, we highlight the position of China in the global PV market. We then characterize and explain how technology transfer is occurring from developed countries to China in Section 2. Then, in Section 3, we focus on the innovation process in order to see whether China is now a major innovator. Section 4 presents our conclusions.

2. The global PV industry

This section yields an economic analysis of the PV sector in order to recast our understanding of the role of China in the rapid development of the PV industry on a global scale.

2.1. The demand

The large-scale deployment of PV generation capacity, and consequently the existence of a mass market for PV modules, is a very recent phenomenon. Until the late nineties, PV systems have been installed almost exclusively off of the grid, for marginal uses (communication devices, satellites, remote habitations) for which PV electricity was competitive compared to other available off-grid electricity sources. As illustrated in Fig. 1, the photovoltaic market took off around 1997 and it has been growing exponentially since 2003. Over the 2003–2009 period, the average annual growth rate was 45%. This acceleration is chiefly in industrialized countries, and mainly comprises on-grid installation. In 1996, 7.9% of PV systems were installed on-grid; by 2007, it had reached 80% (REN21, 2008).

This fast deployment of on-grid PV systems has been entirely driven by incentive policies initially implemented in a limited number of industrialized countries (mainly Germany, Japan, Spain, and the US). PV electricity cannot compete on the power grid because it is more expensive than traditional electricity sources. Therefore, the development of national markets requires economic incentives.

Besides various tax credits where the financial burden falls upon taxpayers, the main instrument aimed at stimulating the PV is the Feed-In Tariff (FIT). FITs consist of setting administratively-fixed guaranteed prices at which electricity suppliers must purchase renewable electricity from producers. FITs have been used since 1994 in Japan and then introduced in Germany in 2000, inducing the healthy growth from 2000 shown by Fig. 1. Spain also adopted a FIT in 2006, which was so generous that it led to a market boom in the country in 2008. Spanish authorities reacted in 2009 by setting a cap limiting the deployment of PV systems to 500 MW per year. Along with the economic downturn, this policy change explains why the market growth slowed down in 2009.

The majority of developed countries have now implemented FITs. A notable exception is the US in which 29 states have opted instead for the use of Renewable Portfolio Standards (RPS). RPS are mandates requiring each utility to have a minimum percentage of power that is sold or produced be provided by renewable energy sources. That is, they prescribe a quantity, not a price as in the case of FIT.

In contrast, policies promoting solar energy hardly exist in developing countries. Their priority is to find the cheapest source of energy to feed economic development, and therefore PV energy is mostly used in off-grid installations. In particular, China accounts for a very small share of the global PV demand (around 2.2% in 2009, *Source*: EPIA 2010).

2.2. The supply

Fig. 2 presents the PV supply chain. The industrial production process includes four technical stages that are briefly described in Box 1. Then the deployment of the PV system requires combining the modules with complementary equipment (such as batteries or inverters) into integrated systems which, once installed, can generate power. As explained in the introduction, we focus our analysis on the first four production stages, silicon, wafers/Ingots, PV Cells, and PV modules. They account for 60% of the average global cost of installed PV systems in 2006.

Table 1 shows the market share of Chinese producers in the different segments. In 2007, China was the world leader in cell production and module assembling (27%). China is followed by the UE (27%), Japan (23%), and Taiwan (9.2%) (REDP, 2008). This is relatively new: in 2003, China's market in cell and module production share was only 1.6%.

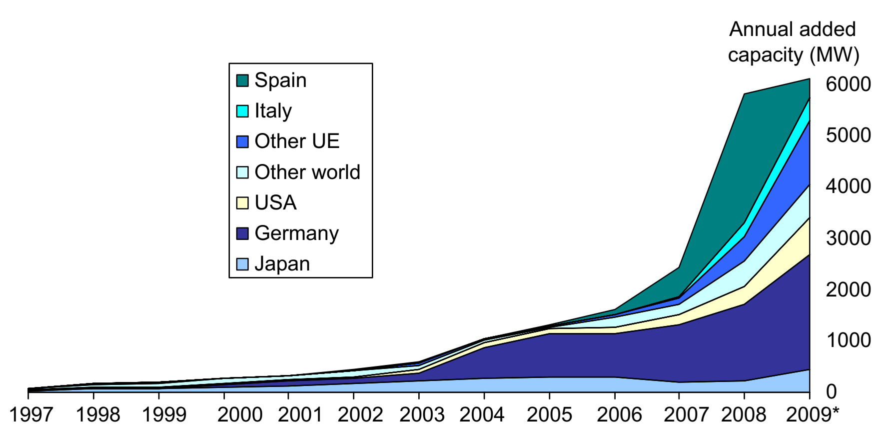

Fig. 1. Photovoltaic installation per year from 1997 to 2009. *Source* IEA (2009) and EPIA (2009). * forecasted.