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Examining the patterns of innovation in low carbon energy science and technology: Publications and patents of Asian emerging economies

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HIGHLIGHTS

- Emerging economies witnessed significant achievement in publications and patents.
- Emerging economies secured demand-side management system.
- Strong technological oriented capabilities is evident in the catching-up phase.
- The technological activities were not fully fuelled by scientific outputs.
- Many economies caught-up with the world average of publications and patents.

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ABSTRACT

This paper focuses on selected Asian emerging economies. The study employs publications and patents as proxies for science and technology, and its analysis is divided into three main parts: production trends, catching-up trends and patterns of convergence. The findings resulted in four salient points to be considered by policy makers: (1) ASEAN-4 lagged significantly behind the more advanced economies (Korea, Taiwan and China) even though their performance was identical in the early 1990s. China has forged ahead in terms of scientific publications and patents production, but lags behind in patents quality; (2) compared to the world average, the region as a whole has high potential to forge ahead in low carbon energy scientific production. (3) Advanced economies in Asia kicked off their low carbon energy science and technology development more from technological rather than scientific production, with no straightforward co-evolution between the two competencies. This demonstrates the need for a strong science-based technological foundation and a high level of dynamism for low carbon energy technology development; and (4) the economies demonstrated contrasting development trends in their focus between the supply and demand sides of energy technology development. The performance of the advanced economies is higher in 'demand-side' low carbon energy innovations.

1. Introduction

Climate change and its accompanying threats to the environment and socio-economic wellbeing has emerged as one of the most challenging environmental issues faced by many economies in the world. Low carbon energy science and technology has been recognized by some observers as the "driving force" that defines the new configuration of socio-technical regimes in the next techno-economic paradigm (see Geels, 2012). Many economies have recognized its tremendous scientific and technological potential and committed their resources to align low carbon energy related research with their industrial development trajectories.

Asia in particular has received popular attention due to the region's rapid industrialisation and its huge potential to generate significant new demand for raw materials and pressure on local, regional and global environments (Berkhout et al., 2009). In addition, low carbon is also seen as a new industrial development opportunity in the region. From the perspective of Green Growth, low carbon can be viewed as a leapfrogging platform for emerging economies to pursue economic development without going down the conventional path of "grow first, clean up later". A large degree of the infrastructure required in the region still needs to be developed, and this provides a unique

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opportunity to avoid the high carbon, environmentally destructive dependency of industrialized countries (UNESCAP, 2012; Asian Development Bank Institute (ADBI), 2012). In this, a low carbon future provides possible grounds for technological catching-up, whereby latecomer[1] countries (i.e. those that arrived late on the industrial scene) manage to narrow the technology and income gap with the advanced countries (Sauter and Watson, 2008; Walz, 2010; Berkhout et al., 2011).

Many Asian "Tiger" economies – defined here to include China, South Korea, Taiwan, Singapore, Malaysia, Thailand, the Philippines and Indonesia – have made significant progress in industrializing their economies in the past few decades (Mathews and Cho, 2000; Jomo, 2003). Semiconductor and consumer electronics emerged to be the dominant sector in the manufacturing activities of these economies. However, some scholars witnessed uneven efforts in the path of pursuing sustainable development. While R&D and renewable energy related investments of China and South Korea have seen a quantum leap in the past decades (Hippel et al., 2011; Ru et al., 2012; Wang et al., 2012; Hassan et al., 2014), reflecting the seriousness with which these economies are pursuing sustainable development, other economies appear to be less impressive. Reading from the propositions in the literature, there is a general consensus that China and South Korea have learned and advanced their scientific and technological abilities, and thus are capable of reinforcing their economic development with low carbon energy science and technology. The low carbon energy scientific and technological convergence patterns between the developed countries and China and South Korea are generally framed in terms of the convergence of the level of scientific publications portfolio size (number of publications and number of publications per capita).

However, there are a few missing elements of the previous studies that should be recognized as a literature gap. First, while prior work (e.g. Shi and Lai, 2013) has tracked the changing share of emerging economies in global renewable energy related publishing output quantity, inadequate attention has been paid to tracking changes in the relative quantity of patenting among economies. By extending relative quantity metrics to patents, we are able to track not only the growth in the volume of scientific production activities of emerging economies, but also their dynamics of catching up in terms of technological innovations.

Second, a large number of previous studies have used neither a detailed classification of science and technology to describe the scientific and technological coverage of low carbon energy scientific publications and patents respectively, nor an inclusive coverage approach by allowing for exceptions of fossil fuel based energy and the demand-side of management systems for efficient use of energy. Many studies used a very narrow definition to describe low carbon energy scientific and technological innovations. For example, Hassan (2005) and Romo-Fernandaz et al. (2013) employed the "renewable energy" prefix as the basis for identifying low carbon energy related scientific publications. Luan et al. (2013) used "solar energy" as the keyword to track the trend of world patenting output quantity to explore the general trend of solar energy related innovations. The words "renewable" and "solar" in conjunction with other selected renewable energy related keywords were used as a basic filter in their search processes. This methodology had indeed filtered out relatively substantial and important information that contained fossil fuel based energy, scientific and technological innovations, as well as the demand-side of management systems from the emerging economies. These studies unconsciously disregarded the systemic efforts from the emerging economies in the process of pursuing sustainable development, and therefore lack a more comprehensive view that allows more systematic analysis of the low carbon energy science and technology innovations. This is clearly indicated in the UNFCCC Handbook for Conducting Technology Needs Assessment for Climate Change (UNDP, 2010), whereby the list of low carbon energy mitigation technologies has been covered more comprehensively, going beyond the more popular categories.

Third, there is a lack of a framework that is capable of systematically quantifying the convergence patterns of scientific and technological innovations between emerging and developed economies. One widely held view has been that emerging economies have failed to reinforce their economic development with low carbon energy scientific and technological innovations, leading to unsustainable development thereafter. This was the received message for emerging economies since the 1990s (see Freitas et al., 2012; Shi and Lai, 2013). Indeed, there are already concerns expressed by some development analysts about the potential impact of a low carbon economy to increase the technology gap between the advanced and latecomer countries. They raise a clear need to understand how latecomer countries can be included in its development without widening inequalities in reaping the environmental, social and economic benefits of technological change (Mytelka and Boyle, 2008). This can be essential, as low carbon technology transfer from the advanced to the less-advanced countries is becoming more contentious, as clearly observed in the various climate change negotiations to date (Ockwell et al. 2008; Khor, 2013).

Finally, most literatures on low carbon are more focused on specific countries (particularly China) and particular low carbon sectors. Understanding catching-up would require a more comparative approach to assess the overall performances of latecomer countries, and the efficacy of their catching-up strategies. This is particularly imperative for Asia – a region known for successful experiences of catching-up in the 20th century, but also one of the highest present-day contributors to the global carbon footprint (UNESCAP, 2012). Such concerns have led to the promotion of low carbon green growth in the region (Hobday, 1995), and the catching-up of Asian latecomers in low carbon science and technology (UNESCAP, 2012; Asian Development Bank Institute (ADBI), 2012). In order for such programmes to be successful, it is important for policy makers to understand how far latecomer countries like China, Malaysia, Indonesia, Thailand and the Philippines are progressing alongside more advanced countries like Japan, Taiwan and Korea and Singapore, and to use such understanding to improve low carbon policies and strategies for the region. Such an endeavour is particularly challenging considering the different levels of economic development and technological capacity of the countries involved.

The literature demonstrated the need for research that adopts the concept of catching-up and convergence theory to study the progress of low carbon energy science and technology in Asian emerging countries. The research questions of this study address the gaps of the previous studies from a longitudinal perspective. What are the production trends of low carbon energy science and technology of Asian emerging economies, and how are they evolving? What patterns does the growth of low carbon energy science and technology of Asian emerging economies reveal? Have the patterns revealed cumulative causation routines in the production of science and technology? Do these patterns converge with that of Japan[2] – a country that is renowned as having

[1] The term 'latecomer' refers to those countries that arrived late (or are recently emerging) on the industrial scene and their challenge is to narrow the productivity and income gap with the advanced countries. In this paper, we will use the word 'latecomer' and 'emerging' interchangeably.

[2] Japan has been renowned for its development of low carbon energy science and technology since the mid 1970s (see Ushiyama, 1999). Low carbon energy

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