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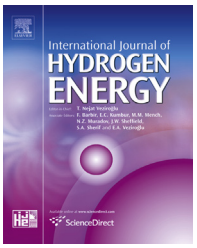

Bio-based economies in Asia: Economic analysis of development of bio-based industry in China, India, Japan, Korea, Malaysia and Taiwan

*Duu-Hwa Lee**

Institute of Applied Economics, National Taiwan Ocean University, Taiwan

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ABSTRACT

This study modifies dynamic GTAP model and builds four bio-industries database to forecast path of transitioning toward bio-based economy through developing bio-pharmaceutical, biohydrogen, bioplastics and GM crops in China, India, Japan, Korea, Malaysia and Taiwan to 2050. The results reveal that the bio-pharmaceutical industry is expected to have the largest role in four bio-industries, and Japan and India will be the most sensitive countries. Biohydrogen is the most sensitive and investing efficiency bio-industry. India will be the largest market for GM products and the most sensitive market to investment in GM products in Asia. India and China will be top two countries in the bio-plastics industry. Japan is the most sensitive and investment efficient for high-tech bio-industry production. Asian countries will pay large prices to achieve 2 °C and 4 °C targets but can ease the negative impacts by decrease usage of fossil fuel gradually and developing bio-economy aggressively.

Introduction

Bio-based industry (bio-industry) which is segment of bio-based economy (bioeconomy) stated by European Commission [1] that reduces greenhouse gas emissions and develops low-carbon bio-based economy [2–4]. European Commission [1] defines bio-industry as industry which uses renewable biological resources in innovative industrial processes for manufacturing biomass-derived products and services. Bio-economy will be the main driven power to generate smart growth and inclusive growth, reduce fossil fuel dependence, reduce energy and resource consumption, create green jobs [5] and support sustainable development [6–9]. In OECD countries, biotechnology drives innovation and growth in the bio-economy [7]. Development of the bioeconomy could make up to 2.7% of member state GDP in 2030 [10]. Industrial biotechnology which implies bio-industry can potentially be a key driver for developing a sustainable growth economy [11]. International collaboration and cooperation is a promising way to develop the bioeconomy. Therefore, Task 42 of the International Energy Agency is to support technological advances in biomass and biorefinery [12]. Government policies and industry programs are drivers of the low-carbon and bio-based economy [5,13,14]. Bioeconomy is a promising trend to achieve the target of climate change conference 2014 held by

* *Corresponding author*. No. 2, Beining Rd., Jhongjheng District, Keelung City 202, Taiwan. Tel.: +886 2 2462 2192x5407; fax: +886 2 2462 4565.
E-mail addresses: dhlee@email.ntou.edu.tw, dhlee@mail.ntou.edu.tw, lidolido.tw@gmail.com.
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United Nation and is needed to build a resilient low carbon economy.

The White House's national bioeconomy blueprint [15] for supporting the bioeconomy in the U.S. includes support genetic engineering, DNA sequencing, and automated high-throughput manipulations of biomolecules. In Europe, agricultural trends in the bioeconomy including debated genetic modification crops [16], forestry, and fishery [17], and health trends include biopharmaceutical bio-NME, biomarkers and genetic testing [8,18]. Industrial biotechnological (bio-industry) trends include fuel, chemical, material production industrial enzymes, biosensors and bioremediation, resource extraction and biorefineries [9]. The OECD [19] has identified three major bio-industries in the structure of the bioeconomy: agriculture, health and industrial biotechnology industry. Emerging bio-industries include bio-medicine, bio-chemicals, bioenergy, and GM crops industries [20,21] which are highly innovative next generation, state-of-the-art technologies and are expected to grow rapidly during transition to a bio-economy.

The GM crops are crucial to the success of the bioeconomy [22]. More than 18 million farmers in 28 countries planted biotech crops with 181.8 million hectares in 2014 [23]. The advantages of GM crops include 37% lower chemical pesticide use, 22% higher crop yields, and 68% higher profitability. Additionally, output had increased by USD133.3 in 1996–2013 [23] through improved cost effectiveness [24], which are the crucial factors for transitioning to bioeconomy.

An important and rapid growing sector of the biotechnology industry is biopharmaceuticals [25]. Biopharmaceuticals now include innovative medicines that promote a longer and healthier life, and to cure the diseases [26]. The biopharmaceutical industry requires a large capital investment, and it stimulates innovation for cost reduction and in large and commercial scale [27,28]. Developing countries require international cooperation to develop an innovative biopharmaceutical industry that can compete with developed countries in the world and create new economic growth for China, India, Brazil, Russia and South African [29]. Korea, Singapore and Taiwan have identified the biopharmaceutical industry as a strategic industry for economic growth in 21st century [30].

Biohydrogen is a promising clean alternative energy source that can replace fossil fuels [31–35]. Its desirable characteristics include cleanliness, abundance, affordability, high efficiency to use [36]. The production process is a safe, economical and sustainable [37,38]. Dark fermentation is the most promising method of biohydrogen generation because of its high production rates and treatment capacity for organic wastes [39,40], algae [41], agricultural residues [42] are the promising feedstocks for biohydrogen generation. Biohydrogen can be generated through clean renewable energy sources (RES) such as solar, wind, geothermal and ocean energy [31,43] and is expected to be an important clean fuel for the transportation sector] in the future [44]. This study analyzed biohydrogen because biohydrogen is expected to be the foundation of the future hydrogen economy and low-carbon bioeconomy.

Bioplastics is a promising alternative to petroleum-based plastics [45]. Bioplastics is the fastest growing bio-industry [7] and has drawn the attention of governments and investors globally [46]. In 2018, the market for bioplastics may reach 6.73 million tons [47]. The continents with the largest capacity for bioplastics production will be Asia (75.8%) followed by South America (12.2%) and Europe (7.6%). Production capacity of biodegradable bioplastics will continue to grow, and the bio-PLA and bio-PHA family will lead the trend [47]. Materials used to produce bioplastics include biomass [48], bio-waste [46,49] and lignin [50,51], wheat gluten [52], and by soil micro bacteria [53]. Growing interest in replacing traditional plastics by bioplastics to reduce organic pollution by aromatic compounds will increase the overall sustainability of plastics production. One of the most promising groups of bioplastics is the PHA family [54]. Biodegradable processing is a promising method of treating bio-waste through composting and methane fermentation. The bioplastic with the highest anaerobic biodegradation rate is PHB followed by PLA and PCL [55]. The bioplastic analyzed in this study was PHB for the reasons given above and because data for PHB were available for the countries analyzed.

Biohydrogen and bioplastic were picked as studied objects in this study because they are major emerging biochemical industries of bioeconomy. In the agriculture industry, GM crops could be developed because GM crops encourage the use of biotechnology to improve the income and production of small farmers in Asian countries, provide food security, feedstocks, climate-proof, drought resistance and salt tolerance [56] as parts of functions of bioeconomy. In the health industry, the biopharmaceutical industry could be developed because of the aging and low fertility rate are serious in Asian countries and rapid development of related health care and long-term care issues and industries.

Biotechnology has a huge potential to contribute economic growth and transition toward the bioeconomy for developing countries in Asia [57]. Asian countries are playing important roles in the development of biotechnology, bio-industry and bio-refinery for the bio-based green economy and clean future, which is important because half of the global population live in Asia. Some developing Asian countries are benefiting from large numbers of biotechnology scientists [58]. Balancing environmental protection and the need to reduce CO_2 emissions while maintaining economic growth is a struggle for the governments and people in the Asian countries. China, India, Japan, Korea, Malaysia and Taiwan are strong candidates for developing biotechnology for transitioning to a new bioeconomy when conventional petro-economy is descending in the future. This study focuses on the development and economic feasibility of transitioning to a bioeconomy in these six Asian countries.

A comprehensive economic impact model is needed to study the potential impacts of the bioeconomy and policies that can encourage investment such as computable general equilibrium (CGE), this study used CGE model to predict the path of transition to a bioeconomy. The Global Trade Analysis Project (GTAP) model is a global CGE model, which was developed by Hertel [59] in the mid-1980s. The GTAP center regularly provides an updated international database that a CGE model needed. For a fair comparison of the six countries and to predict the long-term path toward bio-based economy to 2050 annually, dynamic GTAP is an adequate model for this

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