Green Innovation and Finance in Asia

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Abstract

Green innovation and green finance are two key components of sustainable development. In the most populous, fastest growing region in the world, Asian countries are pressed to maintain economic growth while addressing climate change and environmental externalities. Japan, South Korea, and China have each implemented policies to promote green innovation and finance conducive to such ends. While each country possesses unique capabilities, the extent to which they can promote environmentally adjusted multifactor productivity growth, green patent registrations, green bond issuances, green foreign direct investment, and environmental, social, and governance information disclosures stands to impact on their shifts to sustainable growth paradigms.

Keywords: environmentally adjusted multifactor productivity; green patents; green bonds; green FDI; ESG information disclosure; sustainable development; green growth; Asia

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JEL codes: O16, O31, O38, O44, O47, O57, Q01, Q48, Q55, Q58, R11

Accepted: 1 July 2020.

1. Introduction

In response to calls for economic growth that accounts for climate change, natural resource scarcity, and other widespread environmental challenges, green innovation has become increasingly central to corporate management and the coordination of activities (Fujii et al., 2013). The Organization for Economic Cooperation and Development (OECD) defines green or eco-innovation as "the development of products (goods and services), processes, marketing methods, organizational structure, and new or improved institutional arrangements which, intentionally or not, contribute to a reduction of environmental impact in comparison with alternative practices" (OECD, 2009). Complementary to the green innovation process are green finance mechanisms that shore up public and private financial capital for product research, development, and diffusion. At its core, green finance comprises "all forms of investment or lending that consider environmental effects and enhance environmental sustainability" (Volz et al., 2015).

In recent years, green innovation and finance are in priority measures throughout Asian economies with resource and carbon intensive growth models. Most developing economies in Asia are more carbon intensive than their advanced economy counterparts. This can be inferred from Figures 1 and 2, where total primary energy supply (TPES) growth in China and Asia are accompanied by markedly larger surges in carbon dioxide (CO_2) emissions compared with OECD countries, Japan, and the rest of the world. Moreover, TPES and CO_2 emissions throughout the Asia grew alongside a 36% population increase (from 2.96 billion to over 4.03 billion) (World Bank, 2019) over the period 2000 to 2015. This latter trend positioned Asia as not only the most populous, but also one of the largest consuming, environmentally impactful regions on the planet.

[Figures 1 and 2 around here]

At the same time, many developing Asian countries are among the most vulnerable to climate change and its negative effects on ecosystem continuity, human wellbeing, and economic activity. Considering the substantial energy demand that will accompany the Asian population boom that is forecasted to surpass 5 billion by 2030 (United Nations Department of Economic and Social Affairs, Population Division, 2015), Asia is pressed to leverage green finance for low-carbon energy and other green innovations conducive to sustainable development agendas that encompass climate change mitigation and adaptation.

To do so, however, requires novel methods for bridging existing green finance gaps. The Asian Development Bank (ADB) estimates that there is a $3.6 trillion gap in climate-resilient infrastructure investments throughout 45 of its member countries (ADB, 2017). Similarly, the Association of Southeast Asian Nations (ASEAN) and the United Nations Conference on Trade and Development (UNCTAD) expect Asian countries to require US$110 billion in yearly investments in power, transport, information and communication technology, water, and sanitation infrastructure through to the year 2025 (ASEAN and UNCTAD, 2015). Deriving modern, localized solutions to these challenges requires a holistic analysis of green finance and innovations.

The aim of this paper, therefore, is to review the state of green innovation and finance as indicators of progress towards sustainable economic growth in major economies throughout Asia. To do so, this paper compares recent trends in China, Japan, South Korea, and India, and provides an overview of country and firm-level developments. Specifically, green patent registration trends are assessed as crucial components of the green innovations affecting sustainable development. Furthermore, firm-level environmental, social, and governance (ESG) transparency is examined alongside the increasingly popular green bond and green foreign direct investment (FDI) finance mechanisms to shed light on the inputs driving many green innovations conducive to sustainable growth. Finally, relevant policy supports are outlined to provide important contextual considerations.

The remainder of this paper is structured as follows. Section 2 compares the green growth and patent trends in select Asian and Western economies. Section 3 describes recent green bond, green foreign direct investment (FDI), and firm level environmental, social, and governance (ESG) performance trends in select economies. Section 4 outlines the policies behind green economies and green growth. Finally, section 5 provides concluding remarks and suggestions for future studies.

2. Green growth through innovation

2.1. Environmentally adjusted multifactor productivity (EAMFP)

Environmentally adjusted multifactor productivity (EAMFP) "measures a country's ability to generate income from a given set of inputs, while accounting for the consumption of natural resources and production of undesirable environmental outputs" (Cárdenas Rodríguez et al., 2018). As EAMFP measures the growth rate of the pollution adjusted total factor productivity in a way that is more accurate as an index of technical progress than standard total factor productivity (TFP), assessments of EAMFP growth could serve as a starting point for analyzing countries pursuing green growth and sustainable development via green innovation. Importantly, EAMFP is derived from the following growth accounting transformation function (Cárdenas Rodríguez et al., 2018) that builds upon models previously developed by Brandt et al. (2013; 2014):

$$H(Y, R, L, K, S, t) \geq 1$$

where Y depicts gross domestic product (GDP) (the desirable output of the economy), R depicts air pollution flows (undesirable outputs of the economy), L, K and S respectively denote labor, produced capital, and natural capital, and t denotes time. Inputs L, K, and S and undesirable output

R are increasing while the desirable output *Y* is decreasing in *H*. Assuming the homogeneity of *H* and temporal optimality, the following equation expresses *EAMFP* growth:

$$\frac{\partial lnEAMFP}{\partial t} = \frac{\partial lnY}{\partial t} - \varepsilon_{YR}\frac{\partial lnR}{\partial t} - \varepsilon_{YL}\frac{\partial lnL}{\partial t} - \varepsilon_{YK}\frac{\partial lnK}{\partial t} - \varepsilon_{YS}\frac{\partial lnS}{\partial t}$$

Figure 3 depicts EAMFP growth for seven major economies. China experienced explosive growth, with the largest, a 41.63% growth rate from 1991 through 2003. Regarding this, Fujii et al. (2015) note that productivity in Chinese industrial sectors increased largely due to greater environmental and economic performance improvements between 1992 and 2008. South Korea's growth trend is one of the most remarkable, rising by roughly 65% from 1991 to 2012. Japan experienced the lowest level of 24.87% growth over the same period. Finally, India's growth from a local low of -3.3% from 1991 to 1992 to 45.96% by 2013 is notable especially when compared with developed country levels.

[Figure 3 around here]

Overall, the substantially greater EAMFP growth throughout Asian economies could be rooted in the fact that developing countries such as, China, South Korea, and India start from comparatively lower EAMFP levels. As they show higher potential to reduce CO_2 emissions at lower cost and increase their productivity through improving technological adoption, property rights, and contracting rights (Kumar and Managi, 2014), they also demonstrate promising potential for EAMFP growth in coming years.

2.2. Green patents

Fundamental to any green or sustainable growth strategy is green innovation. Aghion and Howitt (1988) and Stokey (1998) provide a backdrop for the importance of green innovation, noting that the optimal path to sustainable development involves equipping economies with pollution-free, growth-driving industries. Akao and Managi (2007) add that such clean industries are essential to maintain the marginal productivity of capital as environmental regulations grow stricter along optimal paths to sustainable development. As green innovation encompasses new products, processes, and business models that allow firms to meet the environmental, economic, and social performance aspects (for example, the “triple bottom line”) of sustainable development (Fujii and Managi, 2019), it remains an important mechanism for the clean industries driving green growth-based sustainable development.

Green patents are often associated with energy intensity improvements (Wurwood and Noailly, 2018) and more broadly indicate the progress of green innovation (Haščiči and Migottoi, 2015). The OECD (2014) classifies green patent data based on the technologies related to achieving four policy objectives:

1) air, water pollution, waste disposal, and other “traditional domains” of environmental management;
2) adaptation to water scarcity;
3) protection for ecosystem health and biodiversity; and
4) energy, greenhouse gas emissions abatement, transportation, and buildings conducive to climate change mitigation.

The OECD triadic patent families is a set of patents from the European Patent Office (EPO), the Japan Patent Office (JPO), and the US Patent and Trademark Office (USPTO) that protect the same invention. As triadic patent family data only include internationally protected patents that are the first of their kind to be applied for in distinct domestic patent offices, it generally includes higher value patents and more clearly reflects country-level inventive performance (OECD, 2009). Figure 4 provides an overview of OECD triadic patent family-sourced global and country-level environment-related (green) technology patents between 1985 and 2013.

[Figure 4 around here]

Asian countries have led global patent registration growth and consistently increased their relative shares of global green patents in recent years. Much of this global upswing occurred in Japan, where the number of patents increased by nine times from 322 to 2,854 over the same period. South Korean patents increased from just 2 in 1985 to over 354 by 2013, while Chinese patents grew from just 1 to 133 over the same period.

As a global leader in patent registrations, Japan produced more green patents than the U.S. and Germany combined from the early 2000s onward. In fact, between the years 2005 to 2009, Japanese firms dominated the green technology patent arena, yielding 32% of all green patents registered with the USPTO. Specifically, Panasonic Corp. (579 patents), Honda Motor Co. Ltd. (396 patents), Toyota Motor Co. (316), Sony Corp. (248 patents), Nissan Motor Co. Ltd. (229 patents), and Hitachi Ltd. (159 patents) were among the top 10 green patent producing companies (Breitzman and Thomas, 2011).

The Korea Intellectual Property Office (2010) reports that the number of international patent applications in South Korea steadily rose from 1,573 in 2000 to 9,639 in 2010. Over a similar period from 2002 to 2008, the number of new and renewable energy-related patent applications grew from 13 to 113. A notable policy that promoted green patents related to emissions reductions was Korea's cap-and-trade programme that covered nitrous oxide (NO_x), sulfur oxide (SO_x), and particulate matter (PM) emissions from 136 factories throughout Seoul, Incheon, the Gyeonggi area, and over 24 counties.

Both before and during the programme, technological patents played a role in South Korea's emission reduction strategies. For example, between the years 1995 and 2004, South Korea introduced a wide range patents related to NO_x emission reduction technologies. These included 94 selective catalytic reduction (SCR) patents, 37 selective non-catalytic reduction (SNCR) patents, 2 SCR/SNCR hybrid patents, 11 corrugated-type catalyst patents, and 19 nano-type TI catalyst patents. (KIPO, 2007). Subsequently, from the years 2005 to 2010, Korea accounted for 23.1% of global SCR patents for NO_x emission abatements (Kim and Kang, 2010). Meanwhile, South Korea also introduced 17 combustion modification (CM) and 32 post-combustion (PC) technology patents for SO_x emissions abatements and 11 CM and 66 PC technology patents for NO_x emission abatements from 1995 through 2006 (OECD, 2009).

Turning to China, between 1990 and 2014, its green technology patents increased by sixty times and surpassed the respective three-fold and 18-fold increases experienced in OECD and fellow BRIICS countries (Linster and Yang, 2018). While each of China's five-year plans targeted specific green technology developments, green patent registrations throughout China increased due to efficiency improvements, sustainable green patent prioritization, greater shares of research and development (R&D) expenditures, and economic growth (Fujii and Managi, 2019). From 2010 to 2014, 20% of patents related to environmental management (for example,. air and water pollution abatement) technologies, while 76% related to eco-friendly buildings and energy technologies conducive to climate change mitigation (OECD, 2017). However, Chinese green patenting really took off following the *12th Five-Year Plan* covering the period 2011 to 2015 and strong government promotion of pollution control technologies for addressing air and water contamination (Fujii and Managi, 2019).

3. Green finance mechanisms and performance

3.1. Green bonds

Noted for their risk-alleviating features and appeal to institutional and socially responsible investors, green bonds are gaining prominence in green finance. The Green Bond Principles published by the International Capital Market Association (ICMA, 2018) define green bonds as debt securities with the proceeds exclusively applied to finance or re-finance projects or assets related to renewable energy, energy efficiency, low-carbon transportation, green building, water and sanitation, sustainable agriculture and forestry, biodiversity and ecosystem conservation, or eco-friendly technologies and process. Between 2008 and 2017, just 20% of the roughly US$291 billion in green bonds outstanding allocated to finance assets collectively associated with 108 million tCO_2e of GHG emissions reductions, 1.5 million megawatts (MW) in renewable energy capacity additions, 57 million megawatt hours (MWh) of annual renewable energy generation, and 737 million MWh in annual energy savings (Tolliver et al., 2019). As such, green bonds are gaining prominence among green finance mechanisms with demonstrable impacts on environmental and sustainability outcomes.

When an institution issues green bonds, an independent party is often employed to provide a Second Party Opinion to verify the issuer's overarching objectives, strategy, policy, and Use of Proceeds alignment with the Green Bond Principles (GBP) or other objective framework. Additionally, issuers can have their green bonds certified against a recognized external green standard or label of a qualified, accredited third party. To date, prominent green bond certification standards include:

1) The Climate Bond Initiative (CBI) Climate Bonds Standard;
2) The Green Bond Assessment and Verification Guidelines of the People's Bank of China (PBoC) and China Securities Regulatory Commission (CSRC);
3) The European Union (EU) Green Bond Standards of the EU High-Level Expert Group on Sustainable Finance; and
4) The Association of Southeast Asian Nations (ASEAN) Green Bond Standards.

The organizations that certify green bonds aim to assure investors that their certification standards are transparent and based on rigorous scientific criteria. As such, certified bonds are generally more appealing to a broader range of socially responsible and environmental profit-seeking investors aiming to line their portfolios with eco-friendly, fixed payment securities (Chatzitheodorou et al., 2019).

Global green bond issuance volumes have expanded precipitously from the inaugural, €600 million (roughly US$848 million) European Investment Bank (EIB) Climate Awareness Bond in 2007 to include some US$1.45 trillion outstanding from roughly 900 issuers worldwide by 2018 (Climate Bonds Initiative, 2018a). Of this, issuances throughout Asia accounted for nearly half of the US$180 billion outstanding in proceeds earmarked to renewable energy. Asian issuances also accounted for US$241 billion outstanding for low-carbon transportation and nearly US$ 3 billion outstanding for waste management, making it a leader in green bond earmarking for both of these sectors (Climate Bonds Initiative, 2018a).

Figure 5 depicts yearly green bond issuance volumes between 2013 and 2017. China issued nearly half the volume of the U.S. (approximately US$47 billion), rising from its first-year issuances of US$161 million in 2014 to over US$22 billion by 2017. India, Japan, and South Korea respectively issued US$6.5 billion, US$5.6 billion, and US$2.1 billion. Next, Table 1 provides an overview of green bond issuers in Japan, South Korea, China, and India. Though rising issuances throughout the region allude to expanding green finance applications, tracking proceeds allocations provides a more in-depth assessment of environmental impacts and green growth implications of green bond investments.

[Figure 5 and Table 1 around here]

Between 2008 and 2017, over US$2.9 billion was allocated to low-carbon transportation, renewable energy, clean water and wastewater treatment, ecosystem and resource management, energy efficiency, and waste management projects in China (Tolliver et al., 2019). Firms operating in India also reported US$2.7 billion in allocations over the same period to similar sectors.

However, these reported allocations pale in comparison the US$11 billion allocated in the U.S. over the same period (Tolliver et al., 2019). While climate and other domestic policy targets throughout the region stand to promote green bond-based investments in sustainability-enhancing renewable energy infrastructures (Tolliver et al., 2020a), various macroeconomic, institutional, and other factors will all affect the capacity of each country to expand green bond issuances (Tolliver et al., 2020b) as sustainability investment vehicles.

3.2. Green foreign direct investment (FDI)

As recently as 2016, foreign direct investment (FDI) inflows totaled nearly US$1.45 trillion globally and accounted for roughly 10% of global gross fixed capital formation (UNCTAD, 2017). As a conduit for the transfer of capital and modern technology across borders, FDI can serve as an important channel for spurring green innovation and investment behind environmentally sound economic growth and development (Johnson, 2017). There is empirical evidence that FDI inflows stimulate regional economic growth, reduce emissions intensities, and contribute to green growth strategies (Hille et al., 2019). Importantly, FDI is "the largest source of financing across all public and private sources" (Buchner et al., 2011) and has the potential to deliver the greening effects of clean technology transfer, technology leapfrogging, and domestic spillovers of environmental management best practices (Gallagher and Zarsky, 2007). There is therefore a growing call for "green FDI" to incite the international transfer of environmentally friendly industries, technologies, and practices (Golub et al., 2011).

The United Nations Commission on Trade and Development (2017) defines green FDI as "the transfer of technologies, practices, or products by MNEs [multinational enterprises] to host countries … such that their own and related operations… generate significantly lower GHG emissions than would otherwise prevail in the industry under business-as-usual (BAU) circumstances." This paper compares green FDI for environmentally friendly technologies listed in the Financial Times (2019). The data comprises 288,885 FDI projects worth total capital investments of US$15.1 trillion between January 2003 and November 2019. The environmental technology cluster of the FDI dataset represents investments in technologies that are conducive to greenhouse gas emissions reductions, cleaner production and less pollutive industrial processes, and other environmentally beneficial outcomes.

Between January 2003 and November 2019, 8,125 FDI projects for environmental technologies throughout 30 industrial sectors were registered globally. This represents capital investments of US$1.04 trillion (2% of total global FDI) with an average investment of US$127.9 million per project. As depicted in Figure A1 in the Online Supplementary Material, the renewable energy, electronic components, business services, engines and turbines, industrial equipment, metals, and chemicals were the sectors that employed the largest volumes of capital expenditures (each surpassing US$7 billion) of green FDI for environmental technologies.

Table 2 shows the inter-country FDI investments in environmental technologies in 30 industrial sectors between the years 2003 and 2019. Overall, US$142 billion in investments were made across the assessed seven countries. Approximately 80% of the FDI provided by Germany, the country that allocated the largest volume of FDI, went to the U.K. (totaling over US$27.4 million) and the U.S. (totaling over US$12.7 million). Roughly 75% of the green FDI allocated to India, the largest recipient country, flowed from the U.S. (roughly US$15 million), China (roughly US$9.4 million), and the U.K. (roughly US$9.3 million). Japan stands out among major economies as providing and receiving some of the lowest green FDI volumes. Namely, it allocated the third lowest volume of US$8.4 million and received the second lowest volume of US$5.8 million.

[Table 2 around here]

3.3. Environmental, social, and governance (ESG) performance

Conventional management theory focuses on enhancing financial performance and maximizing shareholder benefits (Friedman, 1970). Green or sustainable business theory, on the other hand, emphasizes the reduction of externalities and the maximization of social value through environmental, social, and governance (ESG)-related activity that takes into account the needs of shareholders, consumers, customers, communities, and other relevant stakeholders (Freeman and McVea, 2001). On the value of ESG activities, Xie et al. (2019) employ a data envelopment analysis of 6,631 firms across 11 industries and 74 countries in the year 2015 and show that ESG information disclosure has strong positive linkages with corporate efficiency, the return on assets, and the market value components of corporate financial performance. Through an operational performance evaluation of 308 Japanese firms between 2008 and 2016, Broadstock et al., 2019 add that ESG strategies positively affect firm-level eco-efficiency up to a certain point. Though there is evidence of greenwashing in the corporate sector (Delmas and Burbano, 2011), studies such as these demonstrate the merit of further investigating potential positive linkages between ESG activities and corporate performance in Asia and elsewhere.

In Asia, many government-backed investment funds channel considerable capital into ESG activities, signaling their importance to society and effectively inducing similar capital allocations from private investors. Two prominent examples include the Government Pension Investment Fund of Japan (GPIF) and the Government Employees Pension Service (GEPS) of South Korea. GPIF began investing in global environmental stock indices and, to date, has benchmarked roughly 1.2 trillion yen invested in global environmental stock indices that overweigh comparatively carbon-efficient companies and encourage integration of better carbon disclosure in ESG equity (GPIF, 2018). GFPS plans to add ESG factors as an evaluation criteria for US$100 million in private equity investments. This follows the US$83 million it allocated to an ESG-incorporating global equity fund that pioneered ESG investing among South Korean pension schemes (Kim, 2019).

The MSCI ESG Indices, the Dow Jones Sustainability Index (DJSI), the FTSE4Good Index, the Asian Sustainability Rating (ASR) and other rating tools each measure corporate ESG performance. Of existing indices, Bloomberg's ESG disclosure scores targets over 3,600 firms in 73 countries with coverage that is growing by 11-12% annually (Siew, 2015). Due to this breadth of coverage and sectoral sensitivity, this study employs Bloomberg's ESG disclosure scores in assessing firm-level ESG performance.

For a comparison of private firm-level ESG performance in Asia, Table 3 displays the ESG-performance of the top five largest firms (by net revenues) in China, Japan, and South Korea for the years 2012, 2014, and 2016. Firms are ranked by the size of their corporate revenue. In the case of China, among the firms that consistently generated the largest revenues, the Agricultural Bank of China (AGRICULTURAL-A) showed marked improvement in its ESG and environmental disclosure scores as its revenues increased from 2012 to 2014.

[Table 3 around here]

Despite empirical evidence that there is a significant positive relationship between financial performance and environmental performance in Japanese firms (Fujii et al., 2013), Japan's case is more nuanced. For example, while the Toyota Motor Company (TOYOTA MOTOR) showed a respective rise and fall in both revenues and ESG disclosure scores from 2012 to 2014 and from 2014 to 2016, its environmental disclosure remained constant and then decreased over the same two time periods. Meanwhile, NTT (NIPPON TELEGRAPH) and Hitachi (HITACHI LTD) showed steady ESG and environmental disclosure score improvements despite eventual decreases in revenue by 2016. Finally, though 2016-year data for South Korea was limited, Samsung (SAMSUNG ELECTRON), Hyundai (HYUNDAI MOTOR), and LG increased ESG and environmental disclosure scores alongside increases in revenue in 2012 through 2014.

4. Policies behind green economic growth

In a green economy, investments in carbon emission and pollution reductions, energy and resource efficiency enhancements, and biodiversity and ecosystem service preservation are the main drivers of growth and employment (UNEP, 2011). Sustainable development initiatives such as these are dependent on policy measures that stimulate clean technology R&D investment and a societal shift to clean industries (Acemoglu et al., 2012). Still, targeted policies for these green investment initiatives are important yet non-uniform across countries and regions.

For example, in many parts of the world, countries take unilateral action in biodiversity and ecosystem preservation programs. On the one hand, these efforts could potentially bolster carbon sequestration, raw material management, watershed protection, ecotourism-based income, rare species habitat, and other benefits that bolster ecosystem health, social well-being of local citizens, and global climate sustainability. Nevertheless, regional heterogeneity and related knowledge, value, need, and priority discrepancies among local populations renders it difficult for policymakers to implement effective strategies for preserving natural capital (Halkos and Managi, 2017). Understanding how such divergences tie into economic activity is thus necessary for effective ecosystem and biodiversity-related policy measures (Wilson, 2010; Perrings and Halkos, 2012; Halkos and Jones, 2012; Halkos, 2013; Halkos and Matsiori, 2017), especially in Asia.

Furthermore, many of the aforementioned green economy investment areas are highly interrelated and thus require broad, complex policy measures. For example, as carbon and pollution reductions are largely influenced by energy performance and efficiency, energy system improvements are increasingly salient to emissions curbing pursuits of the Paris Agreement (Löschel and Managi, 2019). In many contexts, Feed-in-tariffs (FiTs) that mandate guaranteed prices for the sale of renewable energy-based electricity over pre-determined periods are the most effective, cost-efficient policies for promoting low-carbon energy development (Menanteau et al., 2003; Butler and Neuhoff, 2008; Fouquet and Johansson, 2008; Couture and Gagnon, 2010). In other cases, renewable portfolio standards (RPSs) that oblige electric power utilities to procure a minimum percentage of their power from renewable generation sources are effective tools for both reducing electricity sector CO_2 intensity (Upton Jr. and Snyder, 2017) and increasing the overall supply of efficient, low-carbon energy (Martin and Saikawa, 2017).

Of course, effective approaches for reducing emissions through energy improvements vary by sector, community, and country. For example, in residential sectors in Asia and elsewhere, GDP growth (Lee and Chang, 2008; Karanfil and Li, 2015; Osman et al.; 2016; Tolliver et al., 2018) and urbanization (Holtedahl and Joutz, 2004; Lin and Ouyang, 2014) largely affects energy consumption. As such, effective energy conservation strategies for this sector rely on price (Ayres et al., 2013; Jessoe and Rapson, 2014; Jessoe and Rapson, 2015) and non-price (Allcott, 2011; Asensio and Delmas, 2015) policy interventions. In the steel, iron, and other manufacturing sectors, however, addressing technology gaps related to comparative development levels are key to enhancing energy efficiency and driving down net emissions (Fujii et al., 2010; Lin and Wang, 2014; Takayabu et al., 2019). While the precedent-setting European Union Emissions Trading System (EU ETS) led to greater efficiency across firms throughout the manufacturing sector during its first period of compliance (Löschel et al., 2019), the impacts of cap and trade systems on energy consumption and emissions patterns throughout Japan, China, and greater Asia require further examination.

5. Conclusions

The amount of green innovation and finance in Asia has increased to meet growing demand for sustainable economic development. Japan, China, and South Korea are each increasing their green patent registrations and green bond issuances. While Japan has been a global leader in green patenting since the mid-1980s, South Korea and China largely increased their pollution abatement-related green patents due to growing market demand to address environmental concerns. Much of this was driven by government policies, highlighting their importance in such pursuits. Conversely, while China has been a global leader in green bond issuances since 2015, issuances from large financial corporations and development banks in Japan and South Korea continue to grow.

Somewhat surprisingly, Japan and South Korea received far fewer volumes of green FDI than their Western counterparts did. Furthermore, environmentally adjusted multifactor productivity growth was larger in China and South Korea than in their developed country counterparts. Finally, most large-revenue firms in Japan, South Korea, and China showed revenue growth to that coincided with environmental, social, and governance (ESG) information disclosure.

The findings of this study reveal insights for future contributions to the literature on green innovation and finance throughout Asia and globally. First, as robust data is published and updated, future studies could add to the discussion on ESG information disclosure and firm-level performance in India and other developing Asian economies that was previously infeasible due to the existing data limitations. Additionally, as firm-specific green bond and green FDI allocation information become more prevalent, future research could highlight the ESG impact of specific firms in particular countries by analyzing the frequency, volume, environmental impact, and other relevant data that shed light on green investment outcomes.

Acknowledgments

This research is supported by the following Grant in Aid from the Ministry of Education, Culture, Sports, Science and Technology in Japan (MEXT): Grant in Aid (20H00648), Ministry of Environment, Japan (1-2001). Any opinions, findings, and conclusions expressed in this material are those of the authors and do not necessarily reflect the views of the agencies.

The authors would like to express sincere gratitude to the designated discussants, Alistair Munroe and Ken-Ichi Akao, Asian Economic Policy Review (AEPR) Managing Editor Colin McKenzie and his colleagues, and participants of the AEPR Conference for their constructive comments that substantially aided in improving the paper.

Online Supplementary Material

Table A1: Green growth policy precedents and agendas

Figure A1: Annual FDI capital expenditures per industrial sector (in millions of USD)

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Table 1: Green bond issuers and total issuance volumes, 2013-2017

Country	Rank	Issuer	Type	Volume (US$ million)
Japan	1	Development Bank of Japan	Development bank	$2,155.7
	2	Mitsubishi UFG	Financial corporate	$1,214.8
	3	Sumitomo Mitsui Banking Corp	Financial corporate	$1,086.5
	4	Toyota	Non-financial corporate	$710.5
	5	Mizuho Financial Group	Financial corporate	$588.9
	⋮	⋮	⋮	⋮
	20	Japan Excellent	Financial corporate	$36.1
		Total Issuances in Japan		**$7,782.4**
South Korea	1	Export-Import Bank of Korea	Development bank	$1,350.1
	2	Korea Hydro & Nuclear Power	Government-backed entity	$600.0
	3	Korea Development Bank	Development bank	$576.9
	4	Hyundai Capital Services	Non-financial corporate	$500.0
	5	K-Water	Government-backed entity	$300.0
	6	Hanjin International	Non-financial corporate	$300.0
	7	Lotte Property & Development Company	Non-financial corporate	$200.0
		Total Issuances in South Korea		**$3,327.0**
China	1	Shanghai Pudong Development Bank	Development bank	$7,589.1
	2	Bank of China	Financial corporate	$6,005.9
	3	Bank of Beijing	Financial corporate	$4,456.2
	4	Industrial and Commercial Bank of China	Financial corporate	$4,451.7
	5	Bank of Communications	Financial corporate	$4,355.1
	⋮	⋮	⋮	⋮
	95	China Jushi	Non-financial corporate	$31,414.0
		Total Issuances in China		**$59,665.4**
India	1	Greenko Investment Co.	Non-financial corporate	$1,000.0
	2	State Bank of India	Government-backed entity	$650.0
	3	Indian Renewable Energy Development Agency Ltd.	Non-financial corporate	$560.6

	4	Indian Railway Finance Corp.	Government-backed entity	$500.0
	5	Azure Power Energy	Non-financial corporate	$500.0
	⋮	⋮	⋮	⋮
	19	Hero Future Energies (Hero Wind Energy)	Non-financial corporate	$72.2
	Total Issuances in India			**$7,084.6**

Source: Created by the authors using data from the Climate Bonds Initiative (2018b).

Table 2: Green FDI between select countries, 2003-2019

		Destination							Total
		China	*South Korea*	*Japan*	*India*	*U.S.*	*U.K.*	*Germany*	
Source	*China*	0	190.8	1672.8	9443.3	5283.9	3369	868.9	**20828.7**
	South Korea	620.6	0	561.1	1752.9	3094.2	576.7	0	**6605.5**
	Japan	1715.9	196.2	0	1671.1	2801.8	1930.3	177.3	**8492.6**
	India	66.7	7.9	0	0	424.3	83.2	434.4	**1016.5**
	U.S.	6300.1	1451.4	2653.1	15149.8	0	6594.1	3821.7	**35970.2**
	U.K.	610.7	227.4	43.3	9352.1	8641.8	0	946.1	**19821.5**
	Germany	1928.5	1352.4	934.4	5160.8	12701.7	27403.8	0	**49481.5**
Total		**11243**	**3426**	**5865**	**42530**	**32947.7**	**39957.1**	**6248.4**	**142217**

Note: All values represent capital expenditures (CAPEX) expressed in $US million.

Source: Created by authors using data from Financial Times (2019)

Table 3: ESG scores of five largest firms by revenue

Year	Rank	China				Japan				Korea			
		Company	*Rev.*[1]	*ESG*[2]	*Env.*[3].	*Company*	*Rev.*	*ESG*	*Env*	*Company*	*Rev.*	*ESG*	*Env.*
2012	**1**	IND & COMM BK-A	$133	33.33	10.71	TOYOTA MOTOR	$236	34.3	29.46	SAMSUNG ELECTRON	$179	59.92	65.12
	2	AGRICULTURAL-A	$103	24.12	8.04	JX HD	$136	34.71	30.23	HYUNDAI MOTOR	$75	50.41	52.71
	3	BANK OF CHINA-H	$98	28.51	8.04	NIPPON TELEGRAPH	$133	44.21	45.74	POSCO	$56	44.63	31.78
	4	CHINA STATE -A	$87	42.15	31.01	HITACHI LTD	$123	49.17	50.39	LG ELECTRONICS	$49	56.2	57.36
	5	SAIC MOTOR-A	$75	28.93	20.93	NISSAN MOTOR CO	$119	44.63	51.16	KOREA ELEC POWER	$44	36.36	24.81
2014	**1**	SINOPEC CORP-H	$451	36.51	19.01	TOYOTA MOTOR	$257	35.54	29.46	SAMSUNG ELECTRON	$196	61.16	69.77
	2	PETROCHINA-H	$371	34.44	21.49	JAPAN POST HOLDI	$152	6.22	9.92	HYUNDAI MOTOR	$85	54.96	57.36
	3	IND & COMM BK-A	$163	33.33	10.71	HONDA MOTOR CO	$125	45.45	48.06	SK INNOVATION	$63	51.65	43.41
	4	CCB-H	$143	28.51	8.04	JX HD	$124	37.19	34.88	POSCO	$62	45.87	38.76
	5	AGRICULTURAL-A	$130	29.82	12.5	NIPPON TELEGRAPH	$109	49.17	51.16	LG ELECTRONICS	$56	56.61	54.26
2016	**1**	LENOVO GROUP	$45	50.41	50.39	TOYOTA MOTOR	$237	33.06	27.13	--	--	--	--
	2	ALIBABA GRP-ADR	$16	7.85	0	HONDA MOTOR CO	$122	44.63	46.51	--	--	--	--
	3	HUISHAN DAIRY	$0.71	14.88	0	NISSAN MOTOR CO	$102	54.96	61.24	--	--	--	--
	4	--	--	--	--	NIPPON TELEGRAPH	$96	52.07	54.26	--	--	--	--
	5	--	--	--	--	HITACHI LTD	$84	52.07	54.26	--	--	--	--

Source: Created by authors using Bloomberg ESG data (2016)

1 – Revenue, expressed in $US billions.

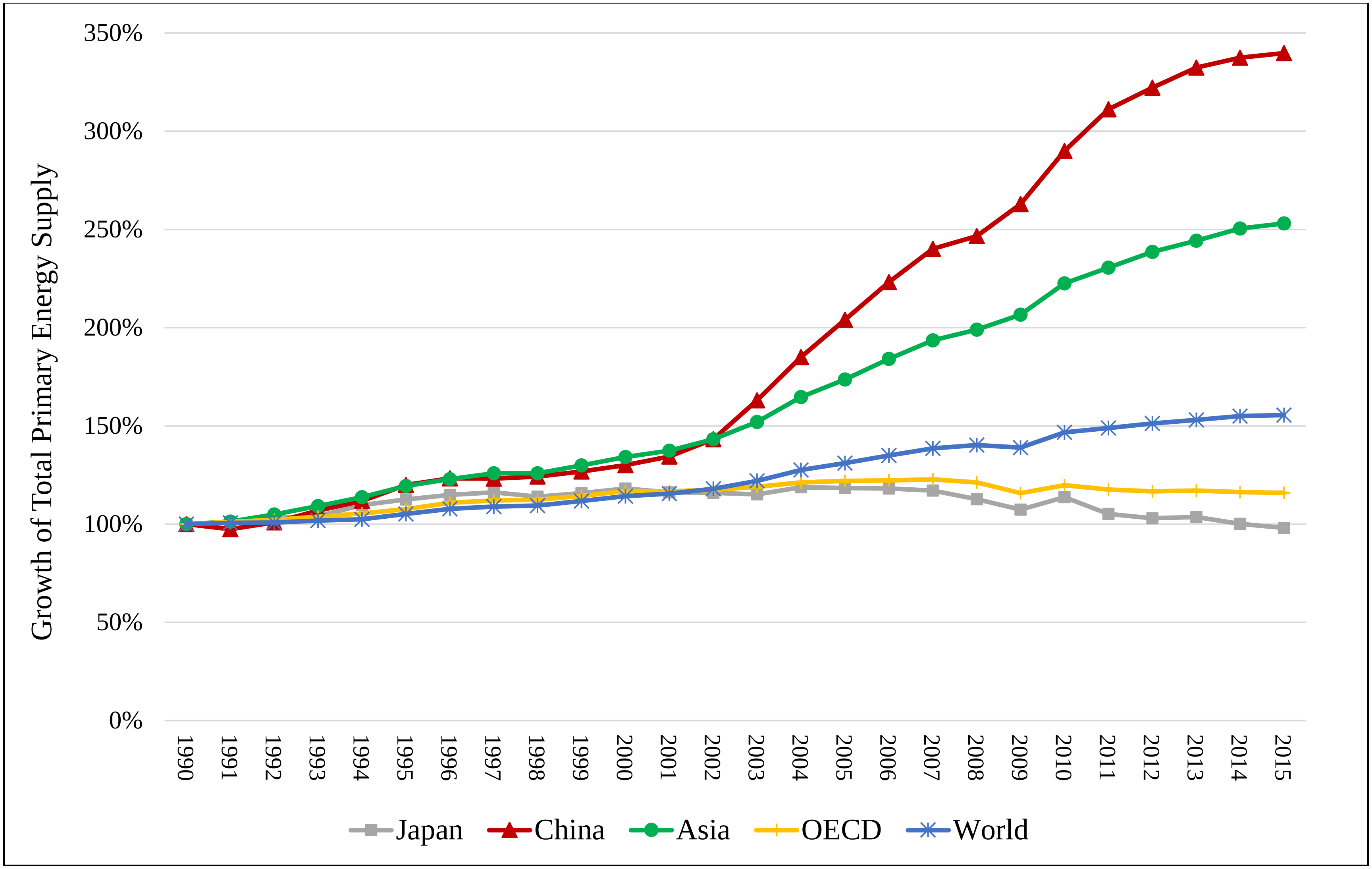
2 – Proprietary Bloomberg Environmental, Social, Governance Disclosure Score (ESG);

3 – Proprietary Bloomberg Environmental Disclosure Score (Env.)

Note: Table 3 includes only companies that disclosed ESG data that were thereby included in data collected by Bloomberg; Data for Indian firms is lacking from the year 2011 onward.

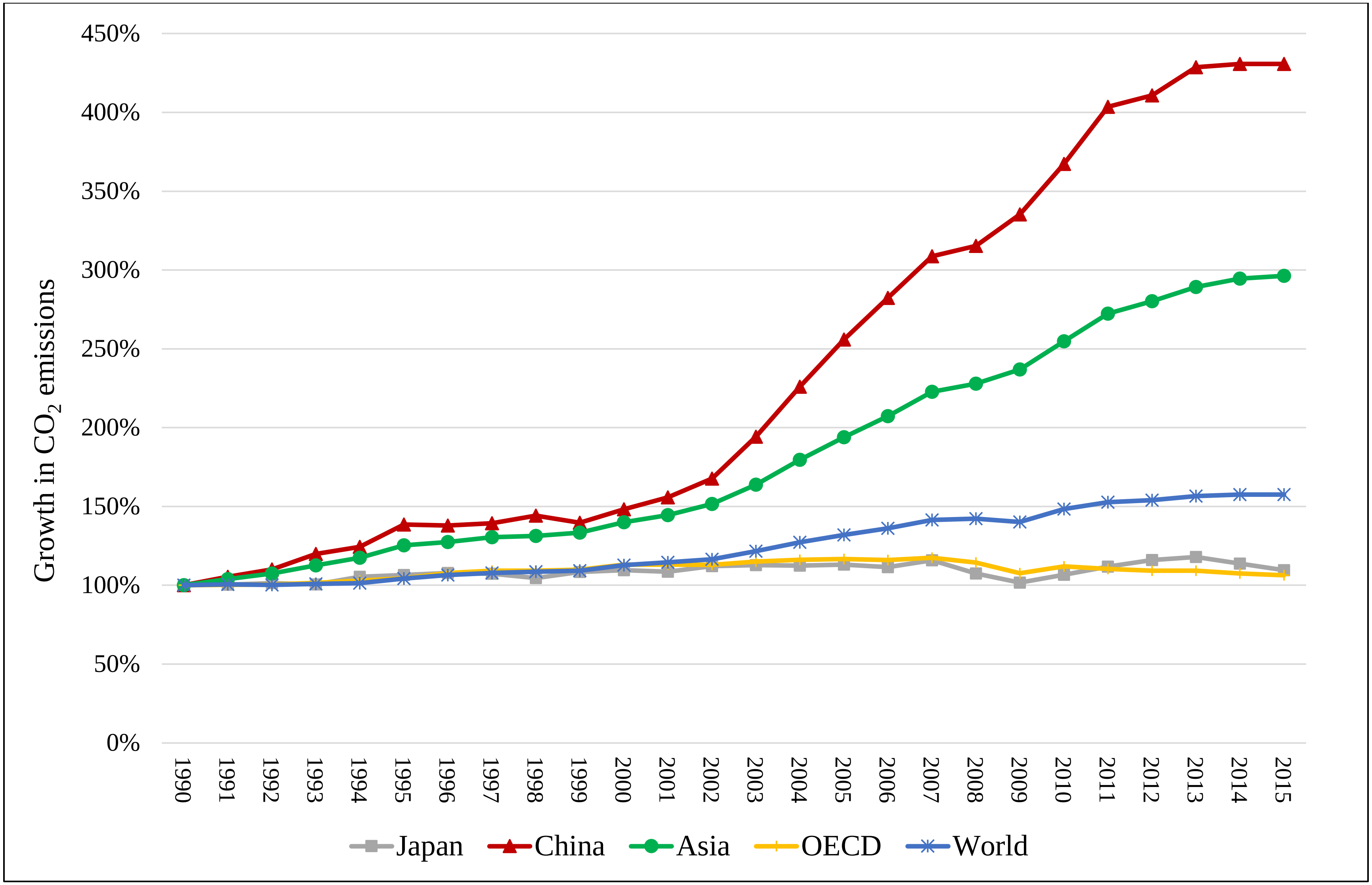
Figures

Figure 1: Total primary energy supply, 1990-2015


350%
300%
250%
200%
150%
100%
50%
0%
Growth of Total Primary Energy Supply
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Japan
China
Asia
OECD
World

Source: Adapted by authors from data from IEA's World Energy Balance 2017.

Figure 2: CO_2 emissions, 1990-2015


450%
400%
350%
300%
250%
200%
150%
100%
50%
0%
Growth in CO_2 emissions
1990
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1994
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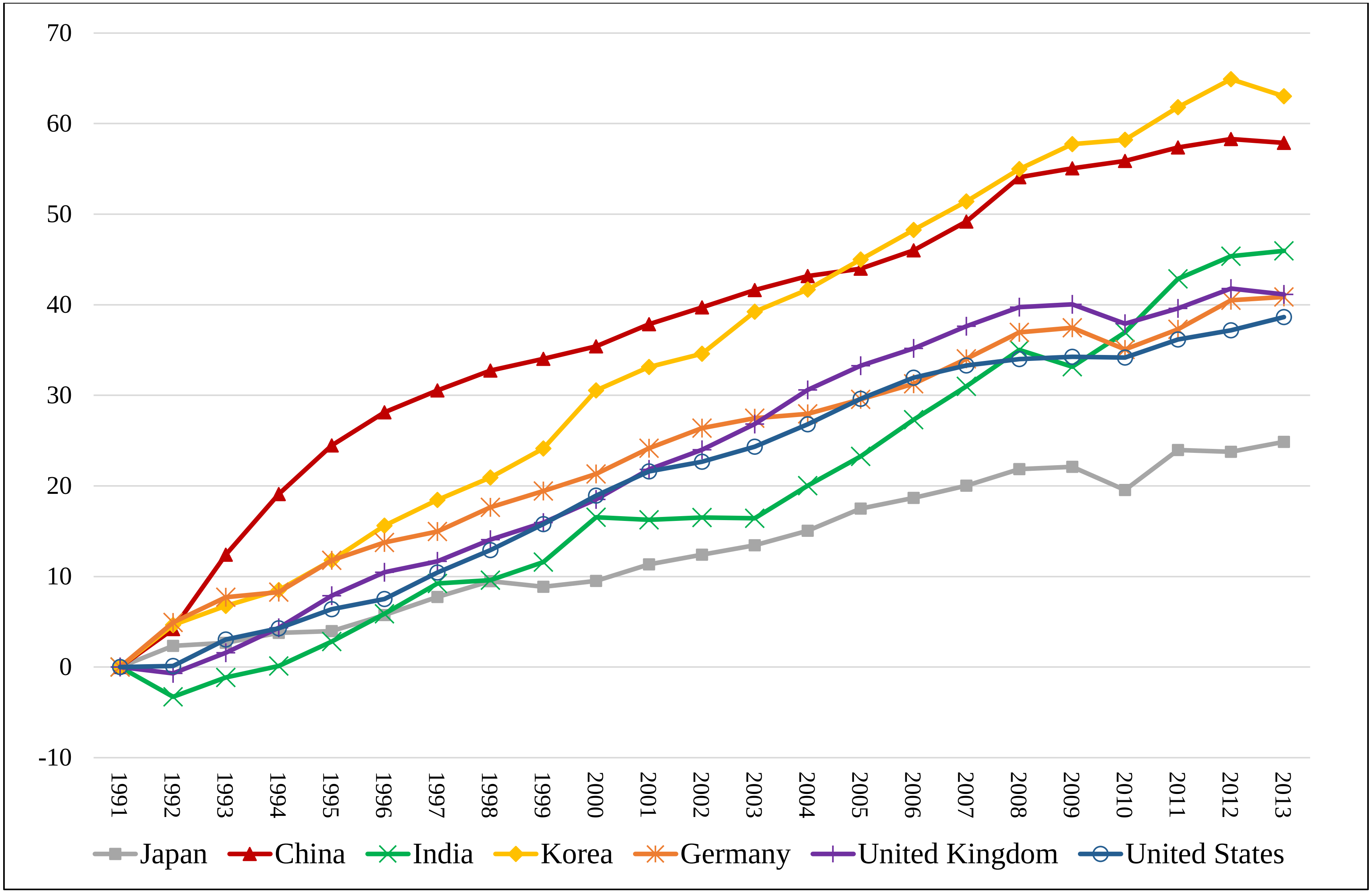
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Japan
China
Asia
OECD
World

Source: Adapted by authors from IEA CO2 emissions from Fuel combustion 2017 data (IEA, 2017)

Figure 3: Cumulative EAMFP growth, 1991-2013


70
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50
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-10
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2011
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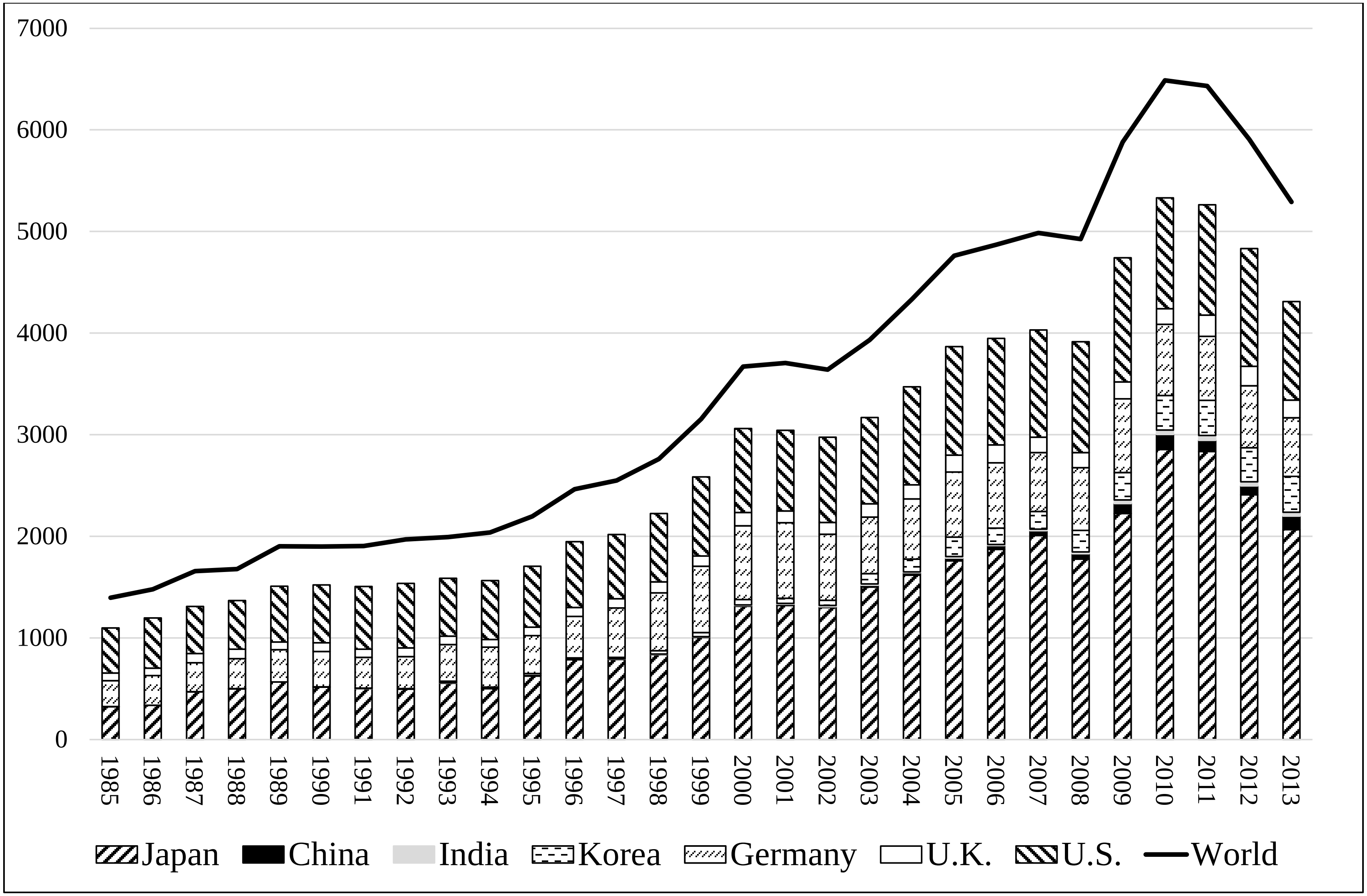
Japan
China
India
Korea
Germany
United Kingdom
United States

Source: Adapted by authors using data from OECD Statistics (OECD, 2019).

Figure 4: Number of green patents, 1985-2013


7000
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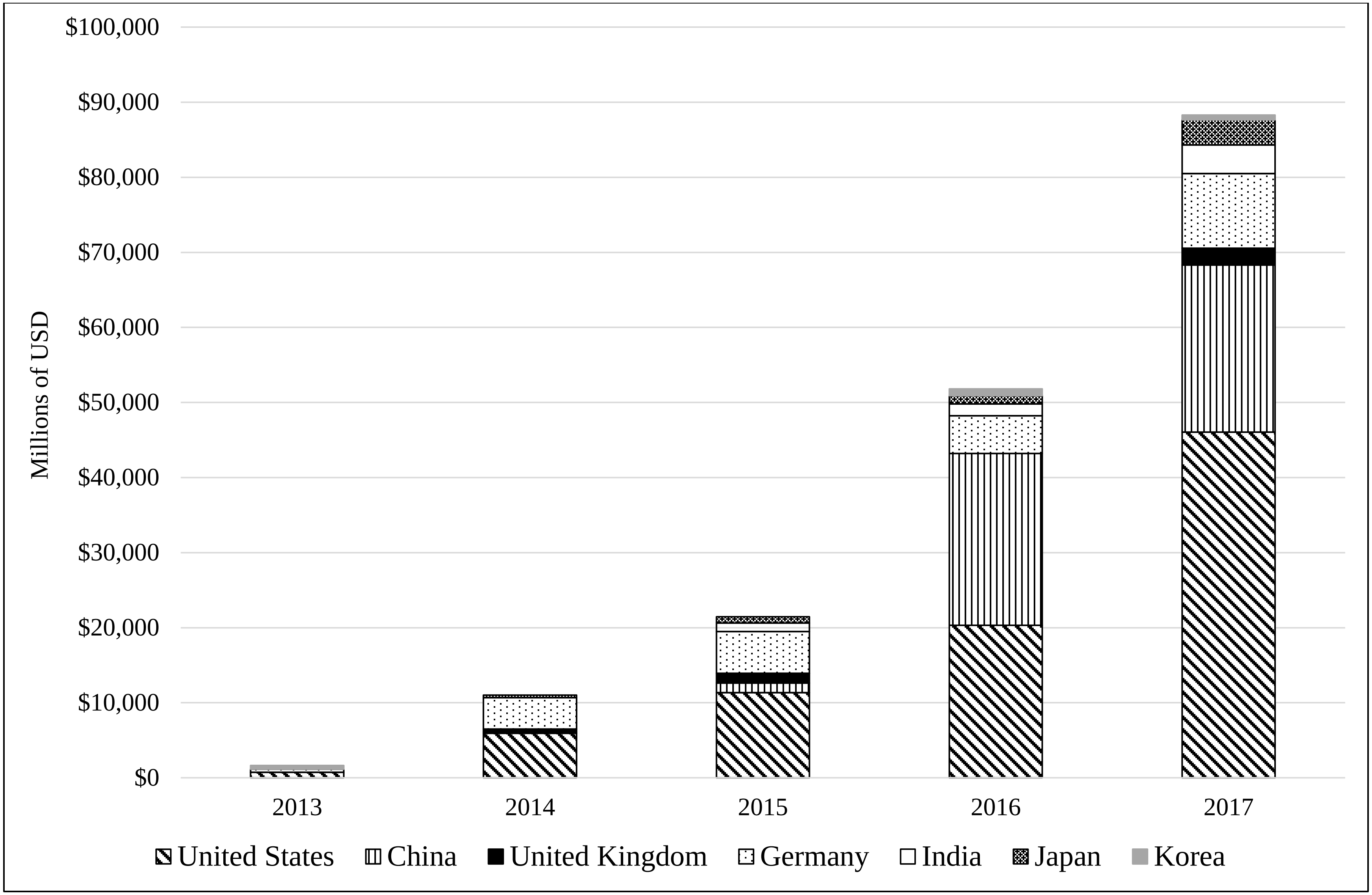
2010
2011
2012
2013
Japan
China
India
Korea
Germany
U.K.
U.S.
World

Source: Adapted by authors using data from OECD Statistics (OECD, 2019)

Figure 5: Annual green bond issuances, 2013-2017


$100,000
$90,000
$80,000
$70,000
$60,000
$50,000
$40,000
$30,000
$20,000
$10,000
$0
Millions of USD
2013
2014
2015
2016
2017
United States
China
United Kingdom
Germany
India
Japan
Korea

Source: Created by authors using data from Climate Bonds Initiative (2018b).