International Collaboration and Green Technology Generation:
Assessing the East Asian Environmental Regime

Matthew A. Shapiro
Illinois Institute of Technology

November 2014

EAI Fellows Program Working Paper Series No. 46

Knowledge-Net for a Better World

The East Asia Institute(EAI) is a nonprofit and independent research organization in Korea, founded in May 2002. The EAI strives to transform East Asia into a society of nations based on liberal democracy, market economy, open society, and peace.

The EAI takes no institutional position on policy issues and has no affiliation with the Korean government. All statements of fact and expressions of opinion contained in its publications are the sole responsibility of the author or authors.

"International Collaboration and Green Technology Generation: Assessing the East Asian Environmental Regimes"
ISBN 978-89-92395-95-3 95340

The East Asia Institute
#909 Sampoong B/D, Euljiro 158
Jung-gu, Seoul 100-786
Republic of Korea
Tel. 82 2 2277 1683
Fax 82 2 2277 1684

EAI Fellows Program
Working Paper No. 46

International Collaboration and Green Technology Generation:
Assessing the East Asian Environmental Regime

Matthew A. Shapiro
Illinois Institute of Technology
November 2014

Abstract

This paper considers the extent to which the Northeast Asian countries — China, Japan, S. Korea, and Taiwan — are collaborating as a legitimate group to produce "green" R&D. Forcing a revision of traditional institutional analysis, such collaboration efforts can overlap with existing policies of regional coordination, but they can also pave the way for future, formal coordination efforts. Employing a mixed methods approach which triangulates data based on expert interviews as well as green patenting output over the last 33 years, it is confirmed here that the presence of the Northeast Asian environmental regime is strongly associated with the development of green R&D among countries in the region. It can be further confirmed that Northeast Asia is on the cusp of becoming a genuine counterweight to the existing dominance of the U.S. and Western Europe.

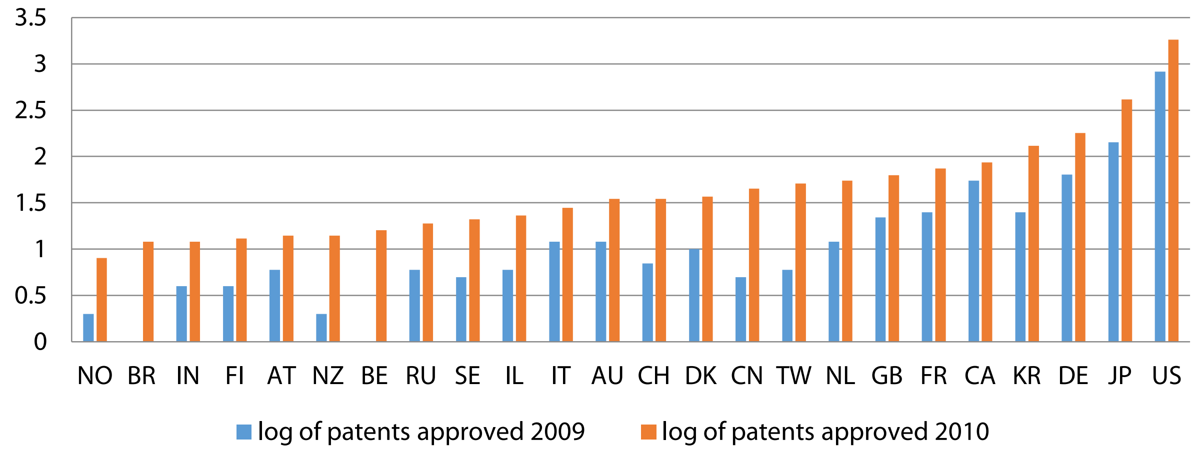
Introduction

INTER-COUNTRY R&D COLLABORATION IS ONE OF SEVERAL FORMS OF INTERNATIONAL COORDINATION AND collaboration, but it stands apart because the end product is not always tangible, the direction of transfers between/among collaborating countries is not clearly delineated, and the degree to which the benefits may accrue to collaborators is uncertain. Research on international R&D collaboration, largely exploratory in nature, has grown steadily over the last few decades (Wagner, 2005). To build on this foundation, this research project targets R&D collaboration

* Acknowledgements: I would like to thank the EAI Fellows Program on Peace, Governance, and Development in East Asia supported by the Japan Foundation, the Chiang Ching-kuo Foundation for International Scholarly Exchange in Taiwan, and YBM/KIS, an education institute in Korea, for their generous support for travel and research.

between/among four active producers and suppliers of high-technology: China, Japan, South Korea (henceforth, "Korea"), and Taiwan. Transfers abroad of such technology, specifically green technology[1], are extremely important for the Northeast Asian region: a large share of green technology originates in Northeast Asia, shown in Figure 1 for 2009 and 2010, and, under ideal conditions, this technology's dissemination can mitigate GHGs and other airborne pollution, reduce water pollution, reduce energy costs, and ultimately improve economic growth. To what extent, though, are these four countries collaborating with each other to generate this technology? Can we attribute such connections to tangentially-related policies and institutions, or is it a result of superseding regional concerns? Finally, and regardless of its causes, to what extent is Northeast Asia emerging as a singular hub for green R&D, offering a legitimate response to the dominance of North America and Europe?

Figure 1. Log-transformed Green-patent Counts by Country, 2009 and 2010



■ Note: Details about these data are provided in "Methods," below.

Models of international coordination have become more nuanced, building on existing research which focuses on formal and informal agreements, institutional design, or transnational advocacy networks;[2] however, study of formal institutions has overshadowed and even precluded deeper examinations of informal institutions such as the relationships among scientists and researchers. The overarching premise here is that these non-state actors are significant in the fostering of environmental regimes and for coordinating formal policies among nations. These are not necessarily the same individuals that can be found within Haas's (1990) "epistemic communities" — i.e., politically empowered, knowledgeable, and motivated around shared causes and beliefs — but rather they are assumed to have attributes consistent with Andonova et al.'s (2009) and Abbot's (2012) theories of transnational institutional complexity, namely that

[1] For the purposes of this research project, "green technology" refers to the USPTO's environmentally sound technologies index. See http://www.uspto.gov/web/patents/classification/international/est_concordance.htm for details. More details are provided in "Methods," below.

[2] See Kinne (2013), for example.

scientists act in ways similar to other non-state actors (e.g., Abbott et al.'s (2013) private transnational organizations) in creating bridges across countries in order to respond to environmental problems. Yet, scientists and researchers are ultimately constrained and/or facilitated by domestic and cross-national policies.

The past 40 years, particularly the last fifteen to twenty years, have yielded unprecedented efforts at cross-national environmental coordination, impacting how we approach two-level games in international negotiations (Barkdull & Harris, 2002; Gallagher, 2009). At the regional level, and when considering green R&D in particular, additional factors must be considered: fewer players make it easier to address collective action concerns, neighbors are more willing to share intellectual property because of pollution's negative externalities, and economic and political relationships between neighbors are strengthened.[3] We also know that environmental regimes at the regional level are not easily created (Keohane & Victor, 2011) and that, in Northeast Asia in particular, there are confounding factors such as varying levels of pollution, environmental institutions, and inadequate capacities to deal with pollution. Historical tensions and concerns about hegemony are also likely to affect collaboration within the region. For example, the East Asian Acid Deposition Monitoring Network's (EANET) attempts to address the pollution blowing out of mainland China; yet, China can claim that EANET challenges its national sovereignty.[4] Similarly, Korea has attempted to limit Japan's dominance by protesting against the placement of EANET's network center in Japan. China can also refuse to share large portions of its pollution and environment-related data (Brettell, 2007). These tensions are acknowledged here as well as the fact that, and in spite of them, the region has coordinated management, sufficiently funded national environmental agencies, strong regional nongovernment organizations, and a host of multilateral organizations (Shapiro, 2014; Solomon, 2007).

To better understand the nexus of informal and formal institutions, presented in the following pages is a platform for understanding environmental regionalism in Northeast Asia as well as a methodology for quantifying the output of R&D collaboration. Building on research of environmental coordination in Northeast Asia which outlines the region's science and technology-based epistemic community (e.g., Shapiro (2014)), two datasets are triangulated, one which assesses environmental regionalism via international R&D collaboration through a stakeholders approach and another which quantifies R&D collaboration through patenting networks based on the USPTO's environmentally sound technologies index. Accounting for both datasets allows us to verify for the first time whether the tendency for Northeast Asian collaboration is undercut by a weak collaborative record or whether it is inclusive, forward looking, and responsive to political influences. This approach enables us to describe how the connections across countries have developed and to identify which country partnerships have the

[3] This has largely been the case for the highly studied European Union (Anderson & Liefferink, 1997; Helm & Sprinz, 2000; Underdal, 1998), where success has been attributed in part to the creation of a European security regime via the Helsinki Act of 1975 and related multilateral institutional arrangements (Brettell, 2007).

[4] In addition, China can claim that dust storms which carry pollutants are natural, despite evidence that desertification, the cause of the dust storms, is anthropogenic.

greatest impact on technological growth. Before examining this formally, the phenomenon of international green R&D collaboration must be framed by theories of international coordination in order to understand country-level incentive structures and how the variables of analysis should be conceptualized.

Theories of International Coordination

Economic Growth and Technology

We know definitively that R&D collaboration plays a key role in economic growth.[5] Such findings build upon other work that uses R&D-based endogenous growth theory (e.g., Aghion and Howitt (1992), Helpman (1993), and Romer (1990)) to explain continuing steady growth in high income, highly capital-intensive countries for which the convergence properties of neoclassical growth theory would otherwise suggest declining growth rates over time. Several attempts have been made in growth accounting to extend the neo-classical model in ways that come close to capturing R&D collaboration effects on growth, showing that, for example, green innovation benefits both the producing sectors' comparative advantage and their current output (Fankhauser et al., 2013). None, however, makes explicit use of international R&D collaboration, much less R&D collaboration about environmental technologies.

In addition, there are spillover effects from foreign manufacturing R&D on domestic productivity for the OECD countries (including Korea and Taiwan) (Park, 2004). Local R&D has also been found to be a function of R&D expenditures in foreign industries (W. Keller, 2002b), and technology spillovers decrease significantly with greater geographic distance (W. Keller, 2002a), perhaps due to the importance of face-to-face interaction in technology diffusion (Gong & Keller, 2003). We know that collaborative (non-green) R&D as measured by patents has boomed in recent years and with significant effects on higher incoming earning countries' growth residual (Shapiro & Nugent, 2012), so one should assume that environmental technology generation arising from international R&D collaboration positively influences both technological growth and the environment.

Finally, while innovation and technology are clearly important at the country level, they also function as crucial mechanisms to address pollution and energy consumption. This, however, is due to the role of competitiveness in innovation. Building on arguments in Grossman and Helpman (1991) and Trefler (1995), innovation creates comparative advantage (and takes it away). In other words, spillovers and especially localized linkages lead to convergence (Grossman

[5] Kim (1999) investigates the important role of informal mechanisms in transferring technology to technology lagging countries when the latter are endowed with high levels of absorptive capacity; for a number of OECD countries over time, Frantzen (2002) finds that both international and domestic R&D spillovers increase TFP for large economies; Park (2004), in exploring the effects of R&D in domestic and foreign for fourteen OECD countries, Korea, Taiwan, and Singapore, identifies international R&D spillovers from foreign manufacturing research efforts by tracing trade flows and outsourcing across countries and sectors.

& Helpman, 1991), and localized linkages matter a lot in this regard (Jaffe et al., 2000; Jaffe, 1998), but there is an underlying disincentive to share information if the costs equate with decreased economic growth for the source country. This alludes to the underlying collective action problem that persists when addressing environmental problems across countries — a problem that may be addressed through policies that promote epistemic community building.

Advancing Cross-national Epistemic Communities

Keohane and Nye's (1989) concept of "complex interdependence" among nations — the notion that international regimes that focus on cooperation often involve common property resources such as security, trade, and the environment — is coupled here with Jervis's (1982) "reciprocity", in that it is assumed that short-term interests are sacrificed with expectations that there will be future reciprocation. The implication is that, to reach the Pareto-optimal outcome, all countries must ignore their dominant strategies, and mutual expectations about all parties' choices and actions must contribute to the efficacy of an international regime (Stein, 1982). These core assumptions have been validated time and again over the last several decades.

Research on cross-national environmental regimes has expanded significantly since Young's (1990) study of cross-national efforts to mitigate suboptimal outcomes with respect to environmental change, specifically ozone layer depletion, global warming, and biodiversity loss. The importance placed on non-state actors by Young (1990) is echoed here, as is the role of epistemic communities in fostering environmental regimes and coordinating policies among nations. Precisely, "epistemic communities are transnational networks of knowledge based communities that are both politically empowered through their claims to exercise authoritative knowledge and motivated by shared causal and principled beliefs" (Haas, 1990: 349). The epistemic communities of interest here are scientists and researchers that are expected to be able to resist short-term political concerns, inform policy makers, and see beyond the narrow view of opportunity costs of environmental policies.

While others such as Andonova et al. (2009) and Abbott (2012) offer parallel theoretical constructs in their focus on nongovernmental groups and complex institutions, in this paper, it is claimed that scientists act in ways similar to other non-state actors in creating bridges across countries in order to tackle environmental and energy-related issues. They do not operate independently of the related policies — R&D-related or otherwise — that are present in each of the connected countries, and they can affect international cooperation. This has been shown in the backdrop to the 1987 Montreal Protocol. In the years leading up to the Montreal Protocol, a number of studies indicated that international controls on chlorofluorocarbons (CFCs) were necessary to protect the ozone layer. On the basis of this information, a transnational epistemic community of atmospheric scientists took steps to influence the positions of the UNEP and the United States (Haas, 1990). What is unique about the approach adopted here is that the epistemic communities are not solely effecting change but are affected by existing policies connected to public

R&D allocations, regulations attempting to shift energy practices, opportunities for networking across countries, and market dynamics. Technology-oriented partnerships also lead to greater instances of international technology coordination, offsetting the costs of reducing environmental pollution and GHG emissions. Openness to technology from abroad can also limit growth if countries become excessively dependent on trade partners and if manufacturing is emphasized rather than innovation, but all four of the East Asian countries examined here have policy goals which incorporate innovation and provide the opportunity for sustainable, long-term growth (Shapiro, 2014).

The collective action problem mentioned already is a function of the number of participants. That is, as fewer nations coordinate, collective action problems such as climate change can be addressed with greater efficacy. The "club" model, evident in East Asia (Kelley, 2013), offers a framework in support of this view, bypassing complex problems by limiting negotiating to those countries that matter most (Victor, 2011). This model has been applied to climate accession deals (deals among countries to control greenhouse gas emissions), but it has not been frequently applied to green R&D efforts, thus ignoring investments in new knowledge in order to produce better and more affordable technology, either domestically (Keohane & Victor, 2011) or through international technology oriented agreements (de Coninck et al., 2008). What is important about the club approach is that it is tailored to each participating country, so one can claim that the club expands with outreach efforts by scientists and researchers to counterparts in other countries, regardless of whether any country is a technology leader or a technology follower.

There are many cross-state ties to address pollution (Shapiro, 2012, 2014), so it would be reductionist to attribute all instances of international green R&D collaboration to connections soley among scientists and researchers. As such, the institutional perspective is invoked, building on research focusing on trade (Haggard, 2013), international finance (Sohn, 2012), or barriers and facilitators to engagement by private transnational organizations and intergovernmental organizations (Abbott et al., 2013; Abbott, 2012; Bulkeley et al., 2012), but it is applied loosely, as the rules and guidelines drafted are general and difficult to enforce (Miyazaki, 2013). Even in a region like Northeast Asia where technocrats have successfully prohibited strikes, limited labor union organization, and focused on efficiency to legitimize government policies (Cheng et al., 1998), authority is ceded with regard to R&D-related pursuits, as scientists and engineers operate with relatively more freedom and perhaps in more obscurity than firms. This prospect challenges the entire premise that government intervention can be consistently, directly, and clearly tied to green R&D development, because it cannot. R&D-related pursuits and outcomes are challenging and the output is nearly always endogenous and thus difficult to predict. At the same time, R&D-related pursuits are precisely needed given China's, Japan's, Korea's, and Taiwan's levels of development (L. Kim & Nelson, 2000; L. Kim, 1999, 2001). The risks of R&D are great, but the potential gains are even greater (Frantzen, 2002; Link, Siegel, & Bozeman, 2007; Link, 2006; Salter & Martin, 2001).

Finally, we cannot ignore the role of competitiveness. According to patent data, the winners of the green innovation race are the producing sectors (Fankhauser et al., 2013), and China, Japan, Korea, and Taiwan all qualify, as shown in Figure 1. In addition, China is not only collaborating extensively with other countries, both within and beyond Northeast Asia, but it has become one of the world's leaders in the generation of green R&D patents. In other words, China has effectively hurdled the technology gap by investing huge amounts and funding into green R&D and encouraging collaboration across borders (Cainelli et al., 2012; Perkins & Neumayer, 2008). Whether this incentivizes collaborations or whether it raises concerns in China's neighbors about R&D leadership in the region has yet to be determined.

Methods

Since the initial call for greater application of the network approach (O'Toole, 1997), political scientists have been working to understand the implications and proper utilization of networks for the discipline.[6] In policy analysis, network analysis is playing an increasingly more important role; namely, understanding the connections and overall network structure of key actors (Lubell, Scholz, Robins, & Berardo, 2012; Robins, Lewis, & Wang, 2012). Research in this vein has addressed climate change-related policy in single-country studies outside (Ingold, 2011; Jost & Jacob, 2004) and within the Northeast Asian region (Yun, Ku, & Han, 2014). There has, however, been limited application of network-oriented analysis to study international political economy or its constituents (i.e., international relations and international economics), the exception of which is Kinne (2013), where it is shown that network strength facilitates bilateral cooperation.

To provide more robust findings, this paper bridges quantitative methods of network analysis with an institutional analysis which is based on stakeholder- and expert-based interviews. The triangulation of these two datasets provides for a grounded theory approach based on interviews that can complement existing theories of growth and interdependence. To identify perhaps the greatest shortcoming of this study, interviews were conducted solely with stakeholders and experts in Korea. The omission of Chinese, Japanese, and Taiwanese experts is significant, but the value of the Korean-based interviews should not be discounted. As shown in Shapiro and Gottschall (2011) and Shapiro (2012, 2014), Korea has played a crucial role in engaging countries within the region, in line with its "middle power diplomacy" status (S. Kim, 2014) and the geographic importance of Korea and the entire peninsula.

Key actors in Korea were identified through the probing of members of the "Presidential Commission on Sustainable Development" (now the "Presidential Committee on Green Growth"[7]). This commission arose from the Framework Act on Low Carbon, Green Growth, effective on April 14, 2010, to address climate change and energy issues and to target the growth of "green" industries. Ministers from each government ministry and specialists from academia, the private sector, and the non-profit sector comprise the 50 members of the commission. Employing a snowball sampling strategy, a sample of nineteen individuals — eight affiliated with the commission and eleven recommended by members of the commission — was established, and

[6] See Fowler et al. (2011) and Gerber et al. (2013) as examples.
[7] See http://www.ncsds.org/index.php/sustainable-development-councils/86-country-profiles/profiles/155-korea for details.

interviews were conducted in the summer of 2014.[8] The survey instrument focused on the following topics: leadership roles within Northeast Asia, pollution's effects on environmental coordination efforts, political and economic forces affecting coordination, technology-oriented goals affecting coordination, and prospects for shared norms across the Northeast Asian countries in dealing with climate change via technology.

With regard to the second dataset, the method to quantify international R&D collaboration here is consistent with a large body of research which taps patent-based analysis, such as Griliches et al., (1990), Hall et al., (2002), and Schmookler (1966).[9] Specifically, "green" patents are represented by the number of approved patents in accordance with the UPSTO's environmentally sound technologies index,[10] and such patents are counted by country and year from 1975 to 2013. By focusing specifically on green R&D, this approach effectively identifies epistemic communities producing green R&D generation, not unlike Dechezleprêtre et al.'s (2011) use of EPO patent data to show the dissemination of green technology across the world. Also acknowledged but not used here is the patent citations approach — the notion that connections among countries can be tracked by identifying whether the knowledge is foundational for subsequent research. As shown in Jaffe et al., (1998) and Jaffe et al. (2000), citations are a noisy signal of the presence of these kinds of knowledge spillover: knowledge spillovers are more likely to occur when there are patent citations, but a large fraction of citations do not correspond to any apparent spillover.[11]

Employing an analysis that reflects an iterative process of acknowledging and confirming evidence from both interviews and green patents, the intra-regional focus is expected to covary with the rise of environmental institutions across the region, with the current state of environmental pollution, and with cost-related concerns. Thus, an examination of differences across four different categories of green R&D — alternative energy, energy conservation, agriculture efficiency, and environmental purification and protection — can confirm the extent of Northeast Asian regionalism. In addition, green patents for Northeast Asia are examined in the context of the entire world's green patenting output, allowing one to identify when countries cluster together around a single country or in a more complex structure. Given the possible number of collaborating partners available in the world, the identification of a Northeast Asian cluster among the dozens of networked countries would provide robust evidence of regional coordination to address green R&D.

---

[8] From the first group, specialists were interviewed from KEEI, the University of Science and Technology, Yonsei University, Seoul National University (2), Sejong University, Chung-Ang University, the KDI Graduate School. From those recommended by commission members, those interviewed are from the KDI Graduate School, STEPI (2) , KISTEP, KETEP, GTCK, KEMCO, Jeju Technopark, KRIED and KEITI (interviewed together), Seoul National University, and Dongguk University.

[9] It is also consistent with studies of alternative measures of research output such as publications. Such research has shown, for example, that China's greatest overall international collaborator in terms of publication output is the U.S. (Wagner et al., 2014).

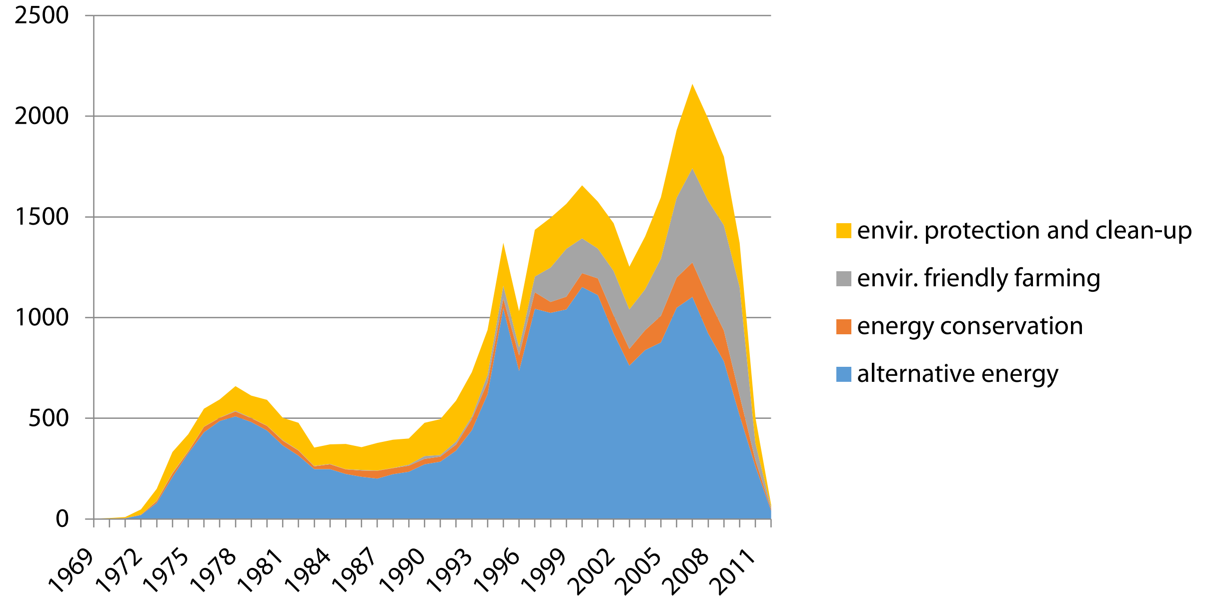
[10] See http://www.uspto.gov/web/patents/classification/international/est_concordance.htm for details.

[11] In the same light and relevant to the present focus on green R&D, Nemet (2012) uses the citation approach to show that energy technology originates in other sectors.

Results

Beginning with an overview of green R&D, Figures 1 and 2 represent 36,452 instances of international collaboration in green R&D for all countries; i.e., 36,452 approved patents from 1975 to 2013.[12] Alternative energy patents have dominated green R&D patenting over the years, while environmentally friendly farming, environmental protection and clean-up, and, to a lesser degree, energy conservation have accounted for roughly half of all green patents since the early/mid-2000s. Figure 3 shows that Japan is clearly the most prolific producer of green patents within Northeast Asia, but it also shows that China, Korea, and Taiwan have recently been producing green patents with amazing frequency. Note that, for Figures 2 and 3, declines in the most recent years are not evidence of declining patenting activity but, rather, represent the lag time required for patents to move from "applied" to "approved" status. It is for this reason that 2009 and 2010 were presented in Figure 1 rather than the most recent years' data.

Figure 2. Green R&D Patents over Time and by Technology Type, All Countries



Moving from descriptive to network analysis, Figure 4 presents the connections among co-inventor pairs using NodeXL.[13] For all of the following network analysis figures, the Fruchterman-Reingold force-directed algorithm is used to produce the layout, and groups are determined within the data by clustering via the Clauset-Newman-Moore cluster algorithm. Edge opacities are based on edge weight values, and within-country collaborations are represented by

[12] 2,132 cases of international collaboration were omitted from the original 38,584 instances of green R&D collaboration for Figures 1 and 2, as these would have effectively double-counted those instances of cross-national connections that occurred between different researchers from the same country. These cases are included in subsequent network analyses.
[13] See http://nodexl.codeplex.com/ for details.

Figure 3. Green R&D Patents over Time, Northeast Asia Only

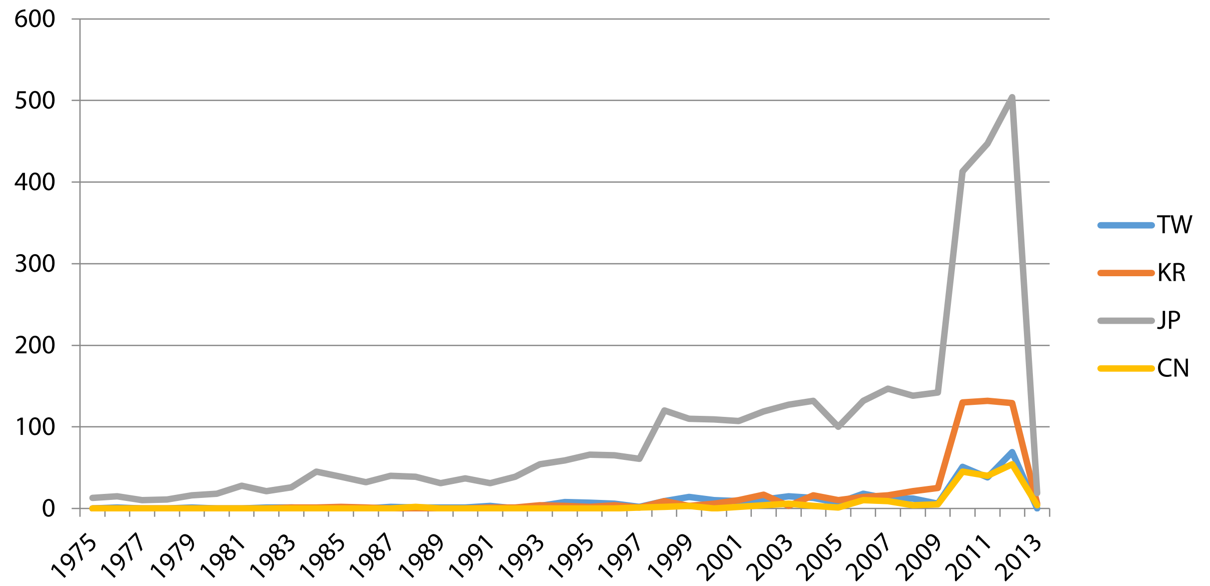
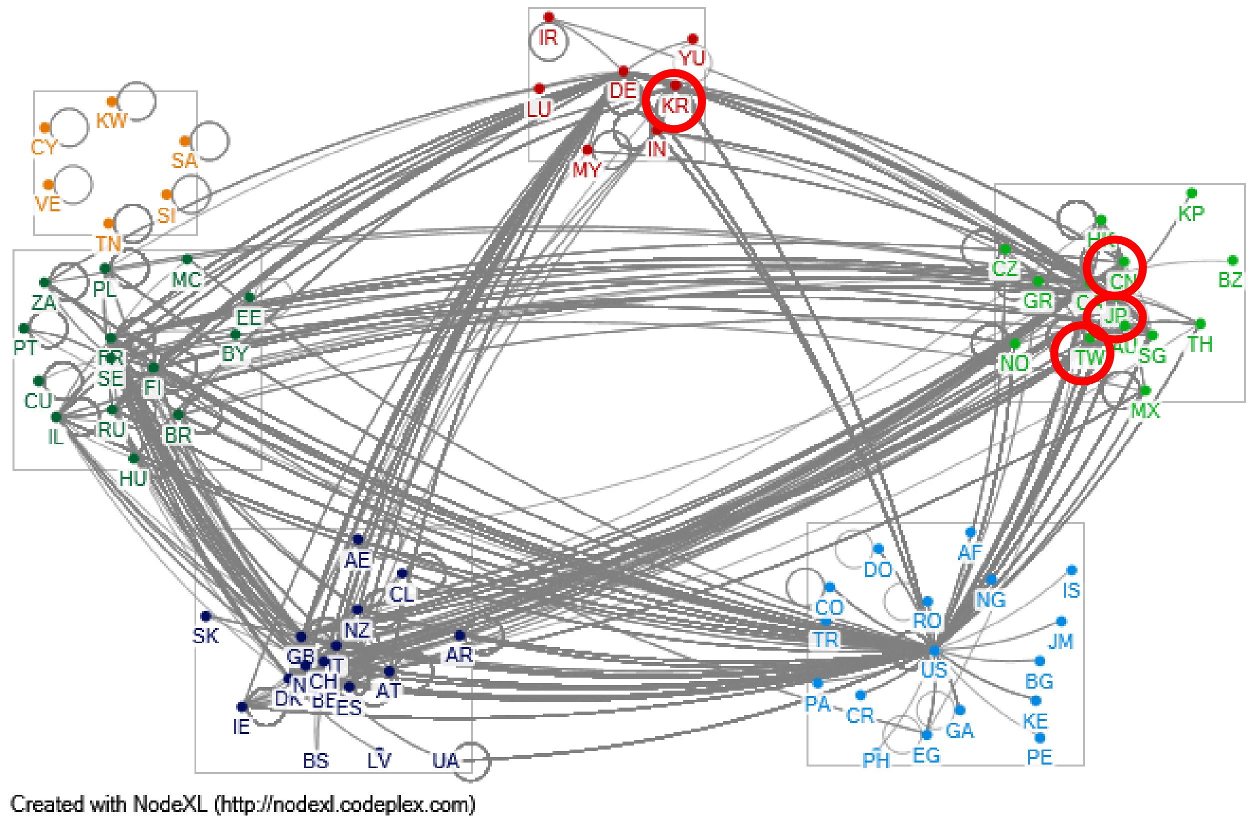


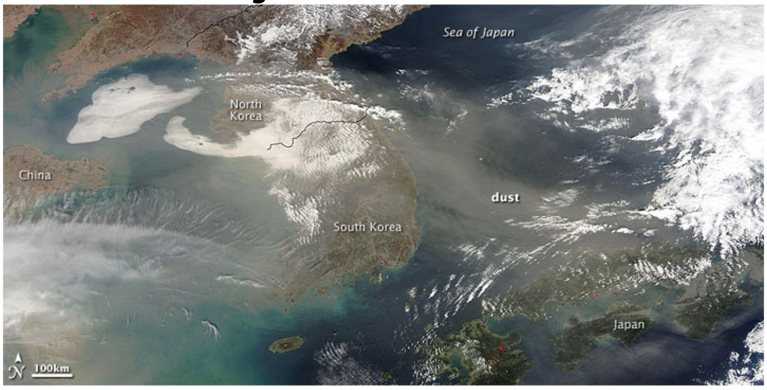
Figure 4. Green R&D Clusters Based on All Patents



■ Note: Red circles indicate China (CN), Japan (JP), Korea (KR), and Taiwan (TW).

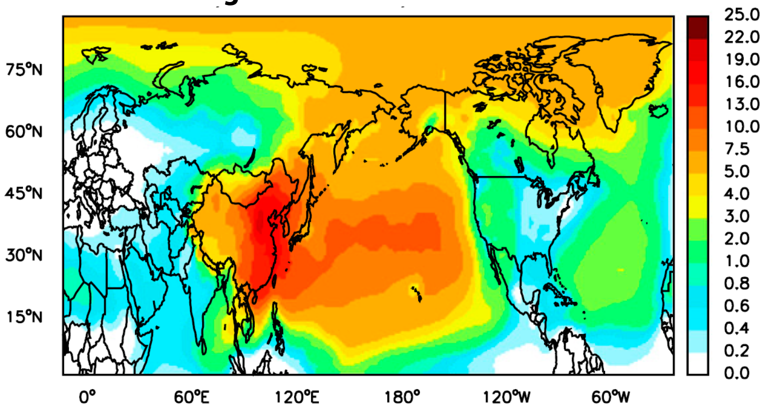
Figure 5. China-based Pollution Flows

Panel A: Satellite Image of West-to-East Flows of Yellow Dust



■ Source: http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=37544, photo acquired March 16, 2009.

Panel B: Percentage and Distribution of Black Carbon in 2006 from Chinese Export Industries



■ Source: Lin et al. (2014).

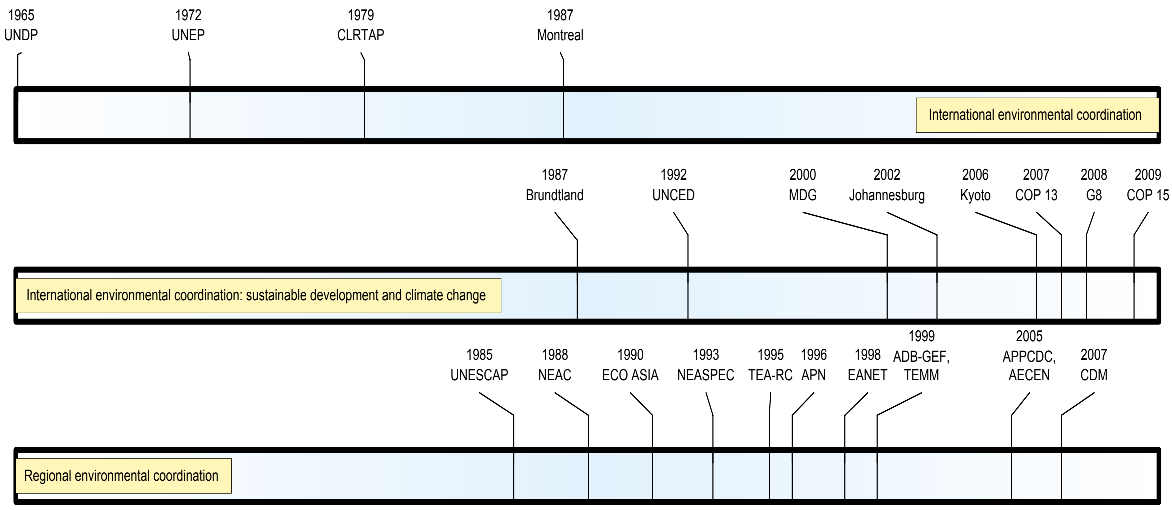
self-loops. Based on all four categories of alternative energy, energy conservation, agriculture efficiency, and environmental purification and protection, we observe in Figure 4, from the 12 o'clock position and moving clockwise, a German (DE)-centric cluster, a Japan (JP)-centric cluster, a US-centric cluster, a West European-centric cluster, and a North/East European-centric cluster. Korea is positioned within the German-centric cluster, and China and Taiwan are in the Japan-centric cluster; however, Korea is positioned on the right-hand side of the German-centric cluster, thus closest to the Japan-centric cluster. This offers initial evidence that, on the whole, green R&D is produced within a Northeast Asian cluster.

Interview analysis revealed that yellow dust and nuclear power are the dominant issues around which the Northeast Asian countries focus. Much of the discussion surrounds the fact that the prevailing winds blow west-to-east and thus that airborne pollution generated in China will extend far beyond the country's political borders. Consider, for example, China- originating yellow dust and soot, shown in Panels A and B of Figure 5, respectively. The effects of the latter are felt even in the U.S., where cities like Los Angeles receive one extra day of pollution per year from China's production of goods for export (Lin et al., 2014). Correspondingly, given the

Figure 6. Existing and Planned Nuclear Power Reactors in China

■ Source: http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/China–Nuclear-Power/

Figure 7. Key Cross-national Environmental Policies, 1965-2010



■ Source: Shapiro (2014).

prevailing winds, nuclear disasters are a focal point for China's neighbors, as the presence of nuclear plant sites on China's coast, shown in Figure 6, continues to grow. It is also consistent with the rise of region-based efforts in recent years to address cross-national environmental and technological concerns, shown at the bottom of Figure 7.

On the basis of these findings, a more focused examination of green patent data can identify associations between green R&D in specific areas — e.g., nuclear energy, yellow dust-based pollution, and manufacturing pollution — and a Northeast Asia R&D cluster. In light of the four categories of green R&D already identified — alternative energy, energy conservation, agriculture efficiency, and environmental purification and protection — two additional network graphs are presented in Figures 8 and 9. With regard to alternative energy patents, clusters in Figure 8 can be defined by whether they are US-centric, German-centric, Japan-centric, and Western/North-European-centric. China, Korea, and Taiwan all reside within the Japan-centric cluster; i.e., the strong regional focus on alternative energy R&D is a possible reflection of concerns about, among other things, nuclear power. For example, rather than installing one or both of the proposed nuclear power plants at Weihai, the installation of tidal or wind power could lessen the risk for both Chinese residents and its surrounding neighbors to the east, northeast, and southeast. On the other hand, environmental purification and protection patents, presented in Figure 9, reveal a division within Northeast Asia, as Japan and Korea are based in the German-centric cluster while China and Taiwan are in the US-centric cluster. Thus, the Northeast Asian countries do not

Figure 8. Green R&D Clusters Based on Alternative Energy Patents Only

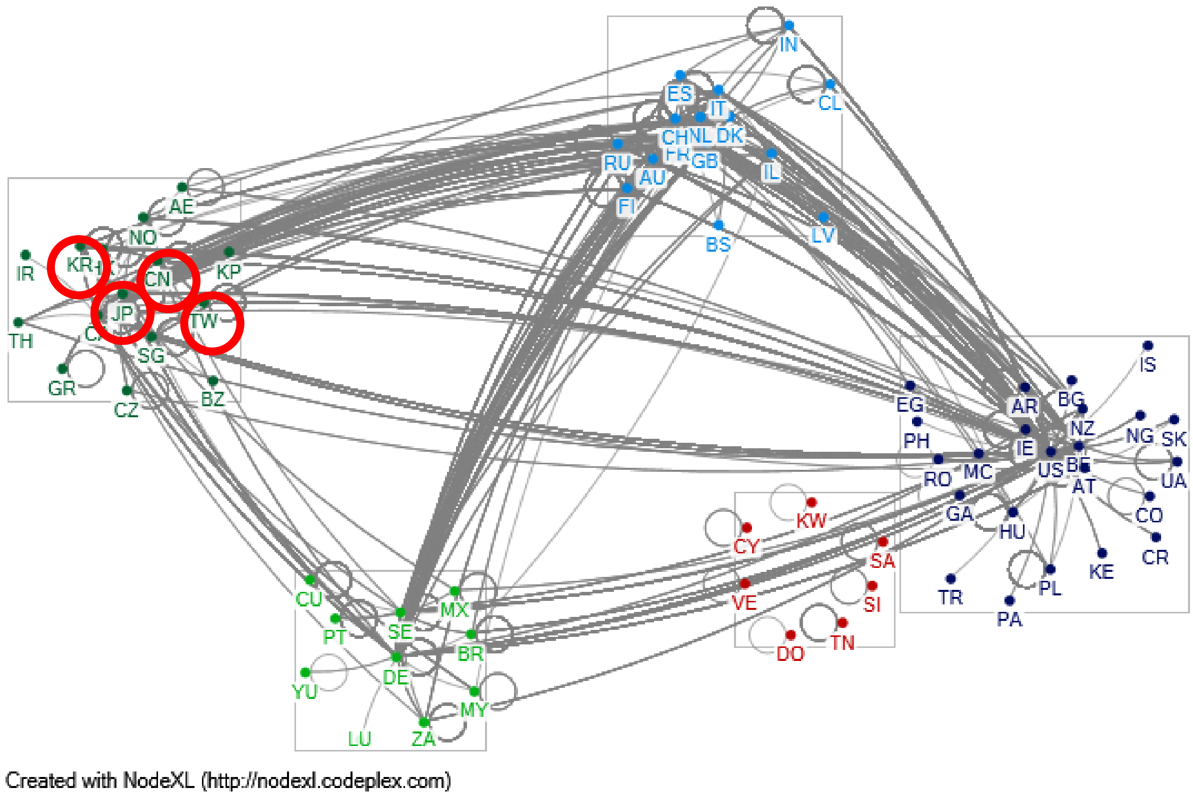
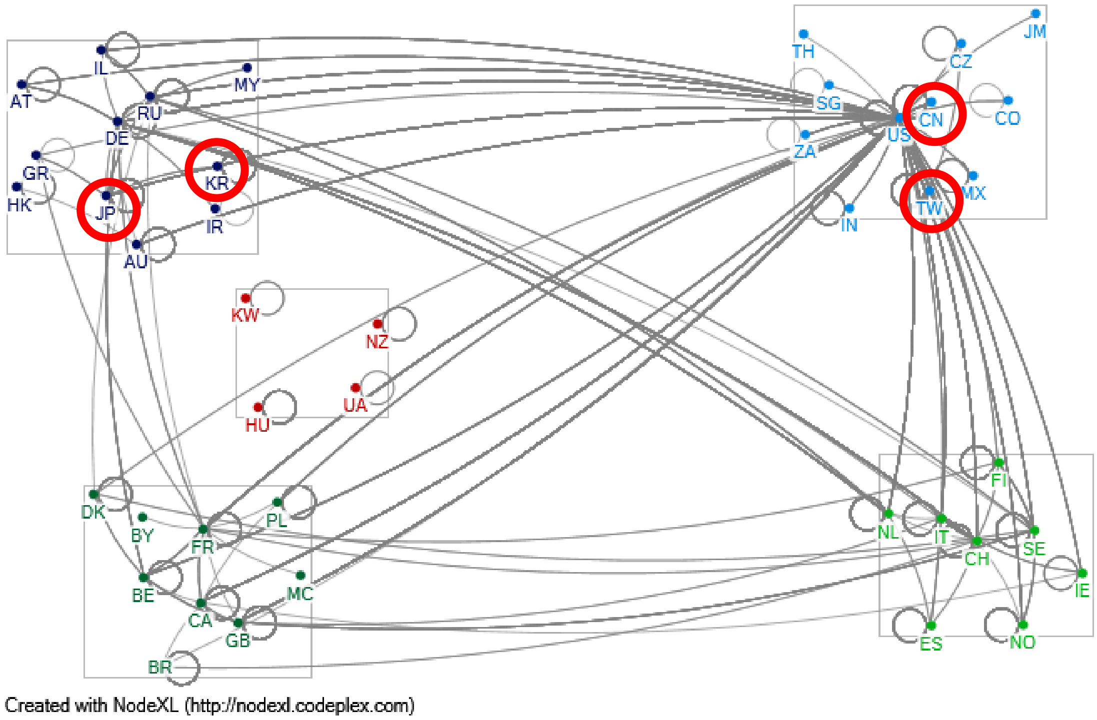


Figure 9. Green R&D Clusters Based on Environmental Purification and Protection Patents Only



collaborate to target pollution mitigating technologies to address the externalities of China's anthropogenic desertification and export-oriented manufacturing-related pollution. In a similar way, energy conservation patents and agriculture efficiency patents revealed no indication of a region-oriented approach. For Northeast Asia, cross-national R&D collaboration at the regional level is present only for an alternative energy focus.

Discussion

While it is obvious that all four Northeast Asian countries are active contributors to the world's cache of green R&D, there is a possible division of labor within the region itself. The descriptive and network analyses above have shown definitively that Japan is the green R&D leader in Northeast Asia as well as a hub for a global cluster. Japan may lead in terms of R&D funding and output, but China leads in terms of its broader financial authority, investing and contributing billions of dollars to the World Bank, the Asian Development Bank, and even newer versions of them ("Why China is creating a new 'World Bank' for Asia," 2014).[14] At the same time, Korea is most affected by pollutants from mainland China and has served as a necessary bridge between the other countries in terms of coordinating efforts across the region, such as those identified in the bottom section of Figure 7. Korea's geographic centrality and its pattern of middle power

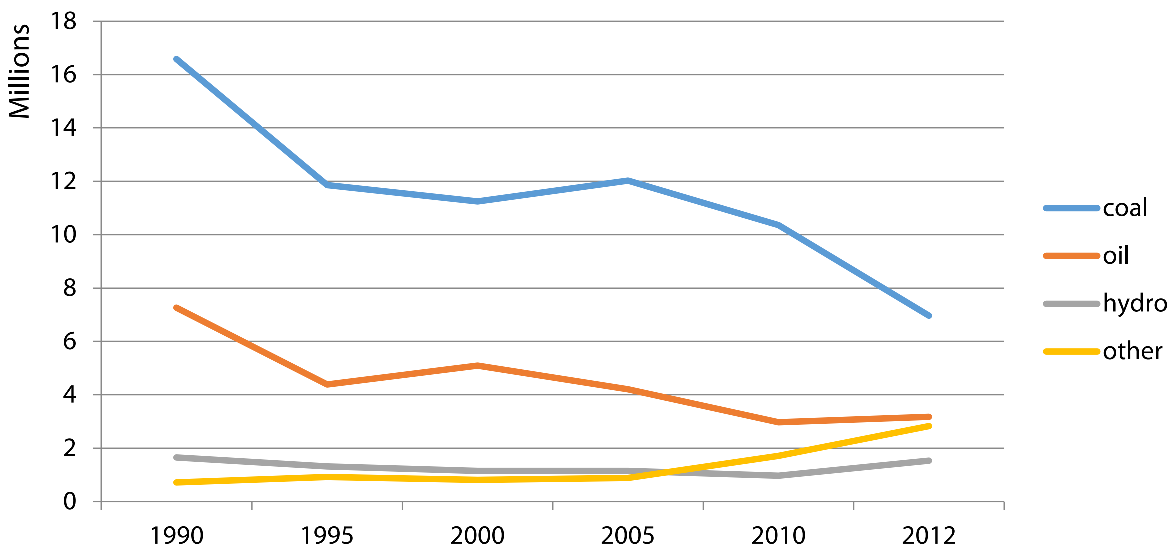
[14] Ironically, Japan has wanted a Northeast Asia Bank for 20 years, but historical concerns raised by its neighbors have prevented it from advancing.

diplomacy could make it a prime location for the headquarters for a Northeast Asia Bank which can fund cross-national, region-based green projects. A balancing act is required here, though, as country-level representation will be a function less of formal processes (outside of R&D-related processes) and more a function of the size of a country's investment. The implication is that those countries with minimal investment in green R&D are less likely to have a voice in the generation and thus possible implementation of new technologies. In addition, countries without a stake in the implementation of new technologies are likely to make efforts to keep existing technology at the forefront, blocking new green R&D output (A. C. Keller, 2009). This is by no means ideal and invokes hazards such as Schumpeter's "creative destruction" as well as the earlier discussion about competitiveness and disincentives to share information across countries (Schumpeter, 2008).

In terms of Northeast Asia's potential to increase its global cachet in green R&D and beyond, there are two possible worldviews. Optimists may invoke the standard argument that basic research cannot be done by a single country in the region but requires expertise, funding, and long-term horizons from multiple sources. Of course, Northeast Asia does not need to engage in cross-national R&D coordination on the level of the European Union's Future and Emerging Technologies Flagships projects, requiring funding in the billions of dollars, but it can engage in specific projects which advance, for example, carbon capture and storage or new energy storage systems, both of which are in the early stages of cross national coordination according to USPTO data. On this point, Korea already has the "Jeju Smart Grid Test Bed Project." With a population of 584,000 and 8.74 million annual tourists, primarily from China, Jeju Island has been identified as an ideal place for development of a smart grid. Total power demand is 600 MW, but the island is connected to the mainland by just two 400 MW HVDC systems (Moon, 2014b), so the development of new energy storage systems are crucial for the project's success, given the use of intermittent, renewable energy sources. While the success of this project is still undetermined, its forward-looking approach may in fact enable Jeju Island to become a "carbon free island" by 2030 ("Jeju to be carbon free by 2030," 2012). At the same time, pessimists of Northeast Asia's prospects to become a global leader highlight the role that competition for technological leadership plays in countering environmental coordination (Fankhauser et al., 2013), directly challenging the assumptions made earlier with regard to complex interdependence and the rise of epistemic communities. Pessimists also highlight a pattern of countries within the region eschewing multilateral coordination for bilateral discussion, as the latter can be accomplished with greater ease and efficiency but at the cost of excluding, perhaps symbolically, other countries.

One must also acknowledge green R&D coordination in the presence of a potentially volatile neighbor such as North Korea. North Korea represents a potentially destabilizing force for regional status quo if it engages in brinksmanship in its international relations, if it successfully attempts leverages particular countries to work against other countries in the region, or if it experiences its own internal destabilization. There are a number of reasons and examples showing why these might occur, including its ongoing energy crisis. Shown in Figure 10, there has been a nearly 50 percent reduction in the overall energy supply from 1990 to 2012, dropping from 23.9 million to 12.3 million tonnes of oil equivalent (TOE). Yet, engagement of North Korea is possible through an analog to the Cold War's détente: establishing relations on the less sensitive issues in order to minimize conflicts and/or their escalation. This has already occurred in the form of engineering students' exchange between Syracuse University in the U.S. and North Korea's Kim Chaek University of Technology, described in Seo and Thorson (2009). Specifically referenced here, though, is "green détente," meaning that other countries — but especially those in Northeast Asia — engage North Korea with a focus on increasing its alternative energy options and improving its energy infrastructure. Specifically proposed are improvements in North Korea's supply of high-voltage direct current, its regional supply network (via the installation of microgrids), and through the creation of a Northeast Asian "super grid," in which Russia is also engaged to improve North Korea's energy supply (Moon, 2014a). The fact that Northeast Asia is already a defined cluster for alternative energy-related R&D is certainly a necessary precursor to effective green détente with North Korea.

Figure 10. North Korea's Energy Supply (TOE) and Distribution, 1990-2012



■ Source: Moon (2014a)

Conclusion

This study has employed a mixed methods approach to understand a crucial but often overlooked component of international relations and coordination: scientific collaboration. A focus on actors that are tangentially related to institutions of international relations and environmental policies, i.e., scientists and researchers, helps minimize the omitted variable bias plaguing macro-level studies. It is confirmed here, thus, that the presence of the Northeast Asian environmental regime is strongly associated with the development of green R&D among countries in the region. It can be further confirmed that Northeast Asia is on the cusp of becoming a genuine counterweight to the existing dominance of the U.S. and Western Europe.

While not necessarily robust across all categories of green R&D, the fact that there is clear evidence of coordination across the region with regard to alternative energy provides confirmation that epistemic community building, or at least an analog of such behavior, is occurring across Northeast Asia. Further, it can be argued that the focus on alternative energy addresses both economic concerns about high energy costs as well as the expected positive externalities of shifting to cleaner producing energy sources. In other words, one can argue that targets across the region on alternative energy are emblematic of both environmental and economic concerns. The lack of clear coordination across the region for the other areas of green R&D may not reflect so much a lack of attention to issues such as improved farming techniques, energy conservation, or pollution remediation as it reflects a complete regional focus on alternative energy.

While the connections among scientists and researchers as a primary source for international connectedness have been highlighted in this study, the focus is potentially limiting. A more comprehensive model can account for, among other things, R&D funding levels, national research projects, procurements, tax incentives, export facilitation, trade barriers, and legal institutions.[15] It can also account for alternative measures of green R&D, such as research publications, which would help establish the origin of knowledge spillovers from academia to industry, as described in Jaffe (1989). Research on this topic has found that, for example, Chinese scientists co-author extensively with the U.S. (Wagner et al., 2014), so future studies would be remiss to not triangulate both patent and publications data. In the wake of existing research which does account for dynamics among FDI, pollution flows, knowledge transfer, and domestic R&D budgets, the present study has provided specific insights into the nature of connections among scientists and related researchers engaging in green R&D. These individuals may behave in an environment relatively free of institutional interference; yet, their contributions to the field of green R&D are consistent with the stated, multilateral goals of the existing Northeast Asian environmental regime. ■

[15] Intellectual property rights matter a lot for green patenting (Dechezleprêtre, Glachant, & Ménière, 2013), and there are implications for the licensing of such technology, given more generalized findings in Yang and Maskus (2001, 2003).

References

Abbott, K. W. (2012). The transnational regime complex for climate change. *Environment and Planning C: Government and Policy*, *30*(4), 571–590.

Abbott, K. W., Green, J. F., & Keohane, R. O. (2013). Organizational ecology and organizational strategies in world politics. *Harvard Projecton Climate Agreements*, *Discussion*.

Aghion, P., & Howitt, P. (1992). A Model of Growth through Creative Destruction. *Econometrica*, *60*, 323–351.

Anderson, M. S., & Liefferink, D. (1997). European Environmental Policy: The pioneers. Manchester: Manchester University Press.

Andonova, L. B., Betsill, M. M., & Bulkeley, H. (2009). Transnational climate governance. *Global Environmental Politics*, *9*(2), 52–73.

Barkdull, J., & Harris, P. G. (2002). Environmental change and foreign policy: a survey of theory. *Global Environmental Politics*, *2*(2), 63–91.

Brettell, A. (2007). Security, energy, and the environment: the atmospheric link. In I.-T. Hyun & M. A. Schreurs (Eds.), *The Environmental Dimension of Asian Security: Conflict and cooperation over energy, resources, and pollution*. Washington, D.C.: United States Institute of Peace.

Bulkeley, H., Andonova, L., Backstrand, K., Betsill, M. M., Compagnon, D., Duffy, R., … VanDeveer, S. (2012). Governing climate change transnationally: assessing the evidence from a database of sixty initiatives. *Environment and Planning C: Government and Policy*, *30*(4), 591–612.

Cainelli, G., Mazzanti, M., & Montresor, S. (2012). Environmental innovations, local networks and internationalization. *Industry and Innovation*, *19*(8), 697–734.

Cheng, T.-J., Haggard, S., & Kang, D. (1998). Institutions and growth in Korea and Taiwan: the bureaucracy. *Journal of Development Studies*, *34*(6), 87–111.

De Coninck, H., Fischer, C., Newell, R. G., & Ueno, T. (2008). International Technology-Oriented Agreements to Address Climate Change. *Energy Policy*, *36*(1), 335–356.

Dechezleprêtre, A., Glachant, M., Haščič, I., Johnstone, N., & Ménière, Y. (2011). Invention and Transfer of Climate Change Mitigation Technologies: A Global Analysis. *Review of Environmental Economic Policy*, *5*(1), 109–130.

Dechezleprêtre, A., Glachant, M., & Ménière, Y. (2013). What drives the international transfer of climate change mitigation technologies? Empirical evidence from patent data. *Environmental and Resource Economics*, *54*(2), 161–178.

Fankhauser, S., Bowen, A., Calel, R., Dechezleprêtre, A., Grover, D., Rydge, J., & Sato, M. (2013). Who will win the green race? In search of environmental competitiveness and innovation. *Global Environmental Change*, *23*(5), 902–913.

Fowler, J. H., Heaney, M. T., Nickerson, D. W., Padgett, J. F., & Sinclair, B. (2011). Causality in political networks. *American Politics Research*, *39*(2), 437–480.

Frantzen, D. (2002). Intersectoral and International R&D Knowledge Spillovers and Total Factor Productivity. *Scottish Journal of Political Economy*, *49*(3), 280–303.

Gallagher, K. P. (2009). Economic globalization and the environment. *Annual Review of Environment and Resources*, *34*, 279–304.

Gerber, E. R., Henry, A. D., & Lubell, M. (2013). Political homophily and collaboration in regional planning networks. *American Journal of Political Science*, *57*(3), 598–610.

Gong, G., & Keller, W. (2003). Convergence and polarization in global income levels: a review of recent results on the role of international technology diffusion. *Research Policy*, *32*(6), 1055–1079.

Griliches, Z. (1990). Patent statistics as economic indicators: a survey. *Journal of Economic Literature*, *28*(4), 1661–1707.

Grossman, G. M., & Helpman, E. (1991). *Innovation and growth in the global economy*. Cambridge: MIT Press.

Haas, P. M. (1990). Obtaining international environmental protection through epistemic consensus. *Millennium: Journal of International Studies*, *19*(3), 347–363.

Haggard, S. (2013). The organizational architecture of the Asia-Pacific: insights from the New Institutionalism. In M. Kahler & A. MacIntyre (Eds.), *Integrating Regions: Asia in Comparative Context*. Stanford: Stanford University Press.

Hall, B. H., Jaffe, A. B., & Trajtenberg, M. (2002). The NBER patent citations data file: lessons, insights and methodological tools. In A. B. Jaffe & M. Trajtenberg (Eds.), *Patents, citations and innovations*. Cambridge: MIT Press.

Helm, C., & Sprinz, D. (2000). Measuring the effectiveness of international environmental regimes. *Journal of Conflict Resolution*, *44*(5), 630–652.

Helpman, E. (1993). Innovation, Imitation, and Intellectual Property Rights. *Econometrica*, *61*(6), 1247–1280.

Ingold, K. (2011). Network structures within policy processes: coalitions, power, and brokerage in Swiss climate poilcy. *Policy Studies Journal*, *39*(3), 435–459.

Jaffe, A. B. (1989). Real Effects of Academic Research. *American Economic Review*, *79*(5), 957–970.

Jaffe, A. B. (1998). The Importance of "Spillovers" in the Policy Mission of the Advanced Technology Program. *Journal of Technology Transfer*, *23*(2), 11–19.

Jaffe, A. B., Fogarty, M. S., & Banks, B. A. (1998). Evidence from Patents and Patent Citations on the Impact of NASA and other Federal Labs on Commercial Innovation. *Journal Of Industrial Economics*, *46*(2), 183–205.

Jaffe, A. B., Trajtenberg, M., & Fogarty, M. S. (2000). Knowledge spillovers and patent citations: evidence from a survey of inventors. *American Economic Review*, *90*(2), 215–218.

Jeju to be carbon free by 2030. (2012, June 25). *The Jeju Weekly*.

Jervis, R. (1982). Security regimes. *International Organization*, *36*(2), 357–378.

Jost, G. F., & Jacob, K. (2004). The climate change policy network in Germany. *Environmental Policy and Governance*, *14*(1), 1–15.

Keller, A. C. (2009). *Science in Environmental Policy: The politics of objective advice*. Cambridge: MIT Press.

Keller, W. (2002a). Geographic localization of international technology diffusion. *American Economic Review*, *92*(1), 120–142.

Keller, W. (2002b). Trade and the transmission of technology. *Journal of Economic Growth*, *7*(1), 5–24.

Kelley, J. G. (2013). The potential for organizational membership rules to enhance regional cooperation? In M. Kahler & A. MacIntyre (Eds.), *Integrating regions: Asia in comparative context*. Stanford: Stanford University Press.

Keohane, R. O., & Nye, J. S. (1989). *Power and Interdependence: World politics in transition*. Boston: Little-Brown.

Keohane, R. O., & Victor, D. G. (2011). The regime complex for climate change. *Perspectives on Politics*, *9*(1), 7–22.

Kim, L. (1999). *Learning and Innovation in Economic Development*. Cheltenham: Edward Elgar.

Kim, L. (2001). The Dynamics of Technological Learning in Industrialisation. *International Social Science Journal*, *53*(168), 297–308.

Kim, L., & Nelson, R. R. (2000). Technology, Learning and Innovation: Experiences of Newly Industrializing Economies. Cambridge: Cambridge University Press.

Kim, S. (2014). South Korea's climate change diplomacy: Analysis based on the perspective of "middle power diplomacy." *EAI MPDI Working Paper*.

Kinne, B. J. (2013). Network dynamics and the evolution of international cooperation. *American Political Science Review*, *107*(4), 766–785.

Lin, J., Pan, D., Davis, S. J., Zhang, Q., He, K., Wang, C., … Guan, D. (2014). China's international trade and air pollution in the United States. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(5), 1736–1741.

Link, A. N. (2006). Entrepreneurship and Technology Policy. Cheltenham: Edward Elgar.

Link, A. N., Siegel, D. S., & Bozeman, B. (2007). An Empirical Analysis of the Propensity of Academics to Engage in Formal University Technology Transfer. *Industrial and Corporate Change*, *16*(4), 641–655.

Lubell, M., Scholz, J., Robins, G., & Berardo, R. (2012). Testing policy theory with statistical models of networks. *Policy Studies Journal*, *40*(3), 351–374.

Miyazaki, A. (2013). Emerging loose system in regional institutions: networked cooperation on transboundary air pollution in East Asia. In *ESG*.

Moon, S. Il. (2014a). *Reunification of North and South Korea through electricity*. Seoul.

Moon, S. Il. (2014b). *Road to smart grid: case of Korea*.

Nemet, G. F. (2012). Inter-technology knowledge spillovers for energy technologies. *Energy Economics*, *34*(5), 1259–1270.

O'Toole, L. J. (1997). Treating networks seriously: practical and research-based agendas in public administration. *Public Administration Review*, *57*(1), 45–52.

Park, J. (2004). International and Intersectoral R&D Spillovers in the OECD and East Asian Economies. *Economic Inquiry*, *42*(4), 739–757.

Perkins, R., & Neumayer, E. (2008). Fostering environment-efficiency through transnational linkages? Trajectories of CO2 and SO2, 1980-2000. *Environment and Planning A*, *40*(12), 2970–2989.

Robins, G., Lewis, J. M., & Wang, P. (2012). Statistical network analysis for analyzing policy networks. *Policy Studies Journal*, *40*(3), 375–401.

Romer, P. (1990). Endogenous Technological Change. *Journal of Political Economy*, *98*(5), S71–S102.

Salter, A. J., & Martin, B. R. (2001). The economic benefits of publicly funded basic research: a critical review. *Research Policy*, *30*(3), 509–532. Retrieved from <Go to ISI>://000167193800009

Schmookler, J. (1966). *Invention and economic growth*. Cambridge: Harvard University Press.

Schumpeter, J. A. (2008). *Capitalism, socialism and democracy*. New York: Harper Perennial Modern Thought.

Seo, H., & Thorson, S. (2009). Academic science engagement with North Korea. *Korea Economic Institute Academic Paper Series*, *4*(4), 1–11.

Shapiro, M. A. (2012). Environmental legislation in East Asia: rationale and significance. In Z. Zhu (Ed.), *New Dynamics in East Asian Politics*. New York: Continuum.

Shapiro, M. A. (2014). Regionalism's challenge to the Pollution Haven Hypothesis: A study of Northeast Asia and China. *The Pacific Review*, *27*(1), 27–47.

Shapiro, M. A., & Gottschall, K. (2011). Northeast Asian environmentalism: policies as a function of ENGOs. *Asian Politics and Policy*, *3*(4), 551–567.

Shapiro, M. A., & Nugent, J. B. (2012). Institutions and the sources of innovation: the determinants and effects of international R&D collaboration. *International Journal of Public Policy*, *8*(4-6), 230–250.

Sohn, I. (2012). Toward normative fragmentation: An East Asian financial architecture in the post-global crisis world. *Review of International Political Economy*, *19*(4), 586–608.

Solomon, R. H. (2007). Foreword. In I.-T. Hyun & M. A. Schreurs (Eds.), *The Environmental Dimension of Asian Security: Conflict and cooperation over energy, resources, and pollution*. Washington, D.C.: United States Institute of Peace.

Stein, A. A. (1982). Coordination and collaboration: regimes in an anarchic world. *International Organization*, *36*(2), 299–324.

Trefler, D. (1995). The case of the missing trade and other mysteries. *American Economic Review*, *85*(5), 1029–1046.

Underdal, A. (1998). Explaining compliance and defection: three models. *European Journal of International Relations*, *4*(1), 5–30.

Victor, D. G. (2011). *Global warming gridlock*. Cambridge: Cambridge University Press.

Wagner, C. S. (2005). Six case studies of international collaboration in science. *Scientometrics*, *62*(1), 3–26.

Wagner, C. S., Bornmann, L., & Leydesdorff, L. (2014). Recent developments in China-US cooperation in science. In *Conference on China's International S&T Relations*.

Why China is creating a new "World Bank" for Asia. (2014, November 11). *The Economist*.

Yang, G. F., & Maskus, K. E. (2001). Intellectual property rights and licensing: an econometric investigation. *Weltwirtschaftliches Archiv-Review of World Economics*, *137*(1), 58–79.

Yang, G. F., & Maskus, K. E. (2003). Intellectual Property Rights, Licensing, and Innovation. World Bank Policy Research Working Paper, No. 2973.

Young, O. R. (1990). Global environmental change and international governance. *Millennium: Journal of International Studies*, *19*(3), 337–346.

Yun, S.-J., Ku, D., & Han, J.-Y. (2014). Climate policy networks in South Korea: alliances and conflicts. *Climate Policy*, *14*(2), 283–301.

Author's Biography

Matthew A. Shapiro
Illinois Institute of Technology

Matthew A. Shapiro is an Associate Professor of Political Science, Lewis College of Human Sciences, Illinois Institute of Technology. He was trained in political science, economics, and public policy at the University of California at San Diego (B.A.) and the University of Southern California (M.A. & Ph.D). He also earned an M.A. in Korean Studies at Yonsei University's Graduate School of International Studies in Seoul, having won a Woojung Scholarship to study there.

Dr. Shapiro's published and ongoing research lies at the intersection between economics and public policy. More specifically, he attempts to understand how national innovation systems are formed and contribute to sustainable development, how climate change is addressed and impacted by relevant policies and political forces, and how communications from politicians, scientists, and the media impact both of these areas. In political science, these concerns fall under the purview of science, technology, and environmental politics (STEP), information technology and politics (ITP), and East Asian politics.

Dr. Shapiro's work has been published in *The Pacific Review, American Politics Research, Environment & Planning, International Journal of Public Policy*, and *Scientometrics* among others. He teaches courses in research methods, public policy, political economy, and Asian politics for the Department of Social Sciences. More information can be found at www.understandgreen.com.

Publications include:

Matthew A. Shapiro (2014) "Recycling: The Politics, the Science, and the Technology," in Brent S. Steel's (Ed.) *Science and Politics: An A-to-Z Guide to Issues and Controversies*, Thousand Oaks, CA: Sage.

Matthew A. Shapiro (2014) "Regionalism's Challenge to the Pollution Haven Hypothesis: A Study of Northeast Asia and China," *The Pacific Review*, 27(1): 27-47.

Toby Bolsen, Thomas J. Leeper, and Matthew A. Shapiro (2014) "Doing What Others Do: Norms, Science, and Collective Action on Global Warming," *American Politics Research*, 42(1): 65-89.

Matthew Haigh and Matthew A. Shapiro (2013) "Do Environmental Policy Instruments Influence Fiduciaries' Decisions?" *Environment & Planning A*, 45(4): 853-871.

Jahna Otterbacher, Matthew A. Shapiro, and Libby Hemphill (2013) "Interacting or Just Acting? A Case Study of European, Korean, and American Politicians' Interactions with the Public on Twitter," *Journal of Contemporary Eastern Asia*, 12(1): 5-20.

— *From the website of Illinois Institute of Technology*

Knowledge-Net for a Better World

- This working paper is the result of the EAI's main academic and educational activity, the *EAI Fellows Program on Peace, Governance, and Development in East Asia*, which is granted by the Chiang Ching-kuo Foundation for International Scholarly Exchange of Taiwan, the Japan Foundation, and the YBM/Korea International School. It is presented at the seminars and lectures hosted by partner institutions of the program. Subsequently it is distributed to those audiences. The PDF document of this article can also be viewed via the EAI website by the wider public. Any citation or quotation is prohibited without prior permission of the author and the EAI.

- The EAI Fellows Program is a scholarly exchange program, for the purpose of promoting East Asian studies and educating students in East Asian universities. For the information about the program, please visit our website, [EAI Fellows Program].

- This paper and other EAI reports can be found on our website, [EAI Working Papers].
The contents of this article do not necessarily reflect the views of the East Asia Institute.

- Young-Hwan Shin, the Executive Director of EAI Fellows Program
Tel. 82 2 2277 1683 (ext. 112) fellowships@eai.or.kr

- Typeset by Young-Hwan Shin