Environment and Natural Resources Program

Harvard-Tsinghua Workshop on Market Mechanisms to Achieve a Low-Carbon Future for China

Summary of a Workshop at Tsinghua University, Beijing, June 3-4, 2014

Henry Lee, Sabrina Howell, Scott Moore, and Alice Xia

HARVARD Kennedy School
Belfer Center for Science and International Affairs

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Preface

The Harvard-Tsinghua Workshop on Market Mechanisms to Achieve a Low-Carbon Future for China explored both the opportunities and challenges for market-oriented climate, technology, and water resources policy in China. A collaboration between the Environment and Natural Resources Program and the Sustainability Science Program at the Harvard Kennedy School and the Center for Science, Technology and Education Policy at Tsinghua University, the workshop convened prominent members of the academic and policy communities from China, the United States, and Europe at Tsinghua University in Beijing, China, on June 3-4, 2014. In addition to off-the-record discussion among the participants, the workshop also included keynote addresses attended by students and the media.

The three closed sessions were on: 1) *Implementing a Carbon Tax or a Cap and Trade Program*, 2) *Incentivizing Low Carbon Technology Innovation through Policy*, and 3) *Designing Water Policies in an Era of Climate Change and Scarcity*. The discussion sessions followed Chatham House rules; that is nothing discussed can be attributed to individuals or organizations. The report represents a synthesis of the main points and arguments that emerged from the discussion. It is not a consensus document, since no effort was made at the workshop to arrive at a single consensus view. Rather, the report reviews the major themes discussed and where there was significant disagreement, we have tried to present both sides of the argument. Any errors or misrepresentations are the authors' responsibility.

Financial support for the workshop was provided by the Italian Ministry of Environment, Land & Sea and the Center for Science, Technology, and Education Policy at Tsinghua University.

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Introduction

In recent decades there has been a gradual transformation in environmental policy away from command-and-control policies and toward the use of more flexible, market-based mechanisms. This transformation is evident in the environmental policy of the United States, and the European Union where many scholars and policymakers have accepted the argument that, in comparison with more traditional regulatory approaches, market-centered solutions offer a cheaper and more efficient way to achieve many environmental policy objectives. While market mechanisms may work in certain economies and certain countries, whether they are appropriate for addressing the problem of climate change for countries without an institutionalized domestic market economy, such as china, is still an open question.

This report summarizes the discussions, conclusions, and questions posed during The Harvard-Tsinghua Workshop on Market Mechanisms to Achieve a Low-Carbon Future for China. As the report makes clear, most participants believe that market mechanisms have a powerful role to play in achieving a low-carbon future for China. However, considerable differences emerged among the participants regarding the proper design and implementation of market mechanisms, and significant questions remain concerning the proper role of market mechanisms in addressing climate change. This report, and the workshop it summarizes, does not attempt to resolve these differences, but aims to contribute to an ongoing discussion on the future of climate policy in China. The remainder of this Introduction describes the context for the workshop, its three thematic sessions, and outlines three over-arching themes that emerged. These themes are explored in the summaries of the three thematic sessions, while the Conclusion raises issues for further research.

The impetus for the workshop was laid out in three public keynote speeches that addressed, respectively, China's desire to achieve a low-carbon future, reasons to prefer market mechanisms over other potential solutions, and the importance of sustaining innovation in achieving climate policy objectives. China has adopted pilot cap-and-trade programs in five Provinces and two cities – together accounting for seven percent of the country's total carbon dioxide emissions. These pilots support a vision of achieving a "third industrial revolution" where economic growth and value-creation is de-coupled from carbon dioxide emissions. Second, market mechanisms are generally preferred by economists to regulation and subsidies as a means to reduce emissions because they achieve reductions at a lower overall cost, tend to direct emissions to their highest-value uses, and demand less institutional capacity since emitters rather than governments decide how to reduce emissions. Third, emissions reductions need to be linked to continual technological and policy innovation, as well as the need for proper design and implementation of market mechanisms. This point was emphasized with reference to the European Union Emissions Trading System (EUETS), where initial carbon permit prices were too low to incentivize low-carbon research and development. The low initial price of the EUETS made it more palatable to industry, but too low to send a significant market signal due to institutional weaknesses and the economic downturn.

The keynote addresses framed the discussion for the remainder of the workshop, which consisted of three off-the-record thematic sessions. Each thematic session focused on a different set of market mechanisms to address different facets of the climate policy challenge. The first session examined instruments designed to limit and reduce emissions of carbon dioxide, either by imposition of a tax designed to internalize the external cost of climate disruption or through establishment of a

cap-and-trade system whereby permits to emit carbon dioxide are issued under an overall cap set by government, and which can then be traded as some emitters make efficiency improvements. The second session examined the use of subsidies and other incentives to encourage clean technology innovation, and the third session examined the potential for a water-rights trading system to allocate water resources under conditions of increasing scarcity triggered by disruption in precipitation and increased evaporation rates.

The workshop concluded with a session devoted to developing a framework for further research and debate on the use of market mechanisms to refine and advance China's climate policy. The framework centered on three over-arching issues concerning market mechanisms: policy mix, innovation systems, and governance. The first of these issues concerns the inclusion of market mechanisms in a broader mix of policy responses, including command-and-control, which may be combined to achieve specific policy objectives. The second concerns the use of market mechanisms to develop, sustain, and enhance innovation systems that continually create new solutions and technologies to achieve a low-carbon future. The third concerns the importance of institutional design and governance systems to ensure the proper functioning of market mechanisms.

Session 1: Implementing a Carbon Tax or a Cap and Trade Program

China has established ambitious goals for reducing the carbon dioxide (CO_2) intensity of its economy. Specifically, in 2009 the State Council announced a targeted reduction of 40-45% in 2020 relative to 2005 levels. In order to achieve this, China's central government has adopted something that no other emerging economy has (and something that has eluded the United States): it has mandated the establishment of a national price on carbon, which will take the form either of a carbon cap-and-trade system or a carbon tax.[1]

The policy is also unique in that it is being initiated in an experimental manner with a set of seven pilots in five provinces and two cities. This experimental approach – which Deng Xiaoping called moving from "point to surface," or specific locations/industries to the whole country – is uniquely Chinese, and has been employed in nearly all important economic reform policies.

However, establishing seven independent carbon trading systems generates significant challenges when, over the next few years, China tries to design a national system. Further, China faces enforcement, data collection, and allocation challenges. More broadly, any market mechanism originally conceptualized for OECD economies must be redesigned for China's unique characteristics, particularly the higher degree of government intervention and the dominance of state-owned enterprises in the energy sector. The workshop focused on addressing these challenges, while recognizing the global importance of China's intention to transition to more sustainable development.

[1] This was also in the 12th Five-Year Plan. In August 2014, NDRC officials announced that China would implement a national carbon trading scheme in 2016.

1.1. Instrument Choice

In the context of general agreement that market mechanisms can be very useful in solving climate and other market failures, participants emphasized the continued important role of command-and-control regulation. Many participants pointed out that the efficacy of mandates, such as requiring certain amounts of renewable energy installation, should not be discounted in China. These command-and-control regulations can, as in the United States, co-exist with market-based mechanisms. One problem is conflicting policies; for example, certain command-and-control regulations (such as for power plant desulphurization), may conflict with carbon emission reduction goals. How China resolves these conflicts will impact its pursuit of market mechanisms.

At the time of the workshop, China had yet to determine whether the national carbon price system will be a cap-and-trade system or a carbon tax. In the former, the government sets an overall quota for total emissions and then allocates permits to entities such as firms, who can then trade these permits, allowing a market (and market price) to form for carbon. In a tax, the government determines the price, and the market determines the amount of reduction. Participants noted that in the past there has been disagreement among ministries about which option is preferable.

In general, China's governance system requires consensus among powerful ministries in order to enact any major energy policy. The key players are the National Development and Reform Commission (NDRC), which sets and allocates energy prices and targets, and approves major projects. The National Energy Administration (part of the NDRC) oversees energy production, and targets for renewable energy, as well as the renewable energy feed-in-tariffs. The Ministry of Environmental Protection is in charge of pollution regulation, and the Ministry of Science and Technology (MOST) manages research and development (R&D) funds, energy saving policies, and subsidies. The Ministry of Finance (MOF) is responsible for taxation policies and allocation of earmarked funds. Finally, the Ministry of Foreign Affairs conducts international climate negotiations. The State Council Leading Group on Energy, Conservation and Climate Change is tasked with coordinating relations between these ministries (and central-local relations).

Some participants argued that some government ministries prefer a cap-and-trade system and seek to orient the system around allocation to firms. Cap-and-trade proponents believe that a carbon tax would be too indirect, particularly because energy prices are not fully transparent and are primarily set by the government. MOF, on the other hand, prefers a carbon tax. Other agencies would rather focus on subsidies for industrial R&D. Nonetheless, consensus is required among these agencies in order to move forward with a national scheme.

One participant noted that there is substantial economic theory identifying when a price versus a quantity instrument should be employed under conditions of imperfect information. The basics of this theory suggest that a carbon tax would be preferable, because the damage function from emissions is flatter than the cost abatement function. However, most participants seemed to believe that there is a growing consensus in China in favor of a trading scheme. As in other countries, it is perhaps more politically palatable, and also provides certainty about the quantity of emission reduction.

1.2. The Pilot Programs

The seven pilot programs were planned in 2011 and 2012, and six were launched in the second half of 2013. The six are Shenzhen, Shanghai, Beijing, Guangdong, Tianjin, and Hubei. Chongqing is set to launch in June, 2014.[2] The pilot region local governments have essentially total autonomy in designing their frameworks, including emissions reduction targets, the area of coverage, quota allocation, monitoring, verification, and reporting (MVR), and compliance mechanisms.

As a result, each system is quite different from the others. In Shanghai, for instance, the program covers both industrial and non-industrial enterprises such as aviation and construction. Hubei, on the other hand, only covers a set of specific industries such as steel, chemical, and cement. Although all the cities seek to comply with the 12th Five-Year Plan calling for a reduction of carbon intensity by 17%-21% between 2010 and 2015, each has a different specific goal, such as 17% for Chongqing and 19.5% for Guangdong.

Thus far, the participants agreed that the pilots are functioning, and some participants suggested that they are working quite well. Through the end of April 2014, three million tons of carbon had been auctioned and traded on the exchange platforms, totaling 96 million RMB. Guangdong and Hubei seem to have the most active markets with the highest volume of trades. In Guangdong's five auctions, the average price has been 60 RMB per ton. In Hubei, the price has averaged only 20 RMB.

1.3. Integrating the Pilot Programs

Participants noted that on the positive side, the very differentiated pilots allow alternative systems to be tested in the Chinese context. Problems can be identified early and subsequently best practices disseminated nationally. This may be much less costly than learning from mistakes in a national system, as happened in the EU Emissions Trading Scheme.

Participants established that the seven pilots are independent, with different prices for the same ton of carbon, and that there are no plans for linking them. They noted that horizontal connections in China can be challenging, and that hard work has already been done to avoid this by disaggregating carbon targets to the participating provinces. Several participants stressed that a functional carbon market must be truly national, and asked what will happen to the pilot programs; will they disappear, or be grandfathered in, or incorporated in some way? The realization that it will be difficult to corral the pilot programs into a common regime has motivated the central government not to establish additional pilots, or expand the existing ones.

Another challenge to establishing a national program, participants noted, is the nascent nature of China's financial and economic market compared to the European Union and the United States. Would prices drive change on a national level, and how can incentives be established for both controlled and non-controlled firms?

[2] Chongqing launched on June 19, 2014.

1.4. Permit Allocation and Trading

In a cap and trade program, the allocation of permits will shape the incentives for both state and private enterprises. Hence both private enterprises and government need to be involved in the construction of the cap-and-trade system. At the same time, the issue of capture was raised, and the possibility that politically-connected firms might end up with more permits than they deserve. In general, fairness and equity concerns can be expected to rise to the fore. Who should bear the greatest burden of carbon mitigation will undoubtedly be contentious.

Several participants suggested that it might be more effective to initially focus on one or two large industries, ameliorating some of the equity concerns, assuming the government has sufficient political leverage over those industries. For example, the government could start with just the electricity sector, which is essentially what the new Obama Administration plan proposes for the U.S. power sector.

One or two participants raised the issue of futures trading in the event that China adopts a cap-and-trade scheme. Futures markets play a critical role in most well developed commodity markets by allocating risk and resources efficiently over time. Others argued that futures markets might be too risky. In an initial analysis for the pilot programs, the State Council and the China Securities Regulation Commission did not support futures. However, other participants thought it was worth allowing futures in certain pilots, and assessing the results to see if they could be effective. Currently, experts from Tsinghua and CSRC are doing a feasibility study of using Futures markets.

More generally, participants pointed out that China's market, particularly in the energy industry, is imperfect and still developing. There was concern that a "market mechanism" for allocating pollution rights may not work well in sectors where a "market" does not truly exist in the first place.

1.5. Data and Reporting

Adequate emissions monitoring, data management, and analysis is critical to a functional carbon market. China has long experienced problems in data integrity, accuracy, and consistency. One problem has been that reporting is not done directly from enterprises to central government ministries, but rather goes through a long chain of local governments that leaves ample opportunities for manipulation or error.

To try to counter this, the NDRC implemented a rule requiring all enterprises producing more than 13,000 tons of CO_2e in 2010 to report emissions of six greenhouse gas pollutants to the government. Further work has been done to expand China's statistical capacity, but this remains an area in which much progress can be made, and where scholars can potentially help the government identify best practices.

1.6. Enforcement

A central question in any carbon price scheme is enforcement. Some participants noted that in China there is thus far a weak legal basis for carbon emissions trading; that is, no law has been passed

requiring a carbon market or tax. In particular, although pilot projects have been established, their legal basis remains unclear: carbon trading has not been written into the Environmental Protection Law or other relevant regulations.

Participants also asked how enforcement is working in the trials – that is, what happens when a company has insufficient permits to cover its emissions? Some of the pilot programs have heavier fines than others, but in all programs compliance is mandatory and companies do pay fines. A goal of the trial period is to assess whether firms are following the rules. There was concern among participants that current penalties are not adequate and that caps on penalties may have distorting impacts. Once a firm reaches its maximum penalty, it has no incentive to mitigate at all.

On a positive note, there is strong evidence from Europe that merely setting a price on carbon captures companies' attention, and causes them to develop low carbon strategies. On the flip side, if the carbon price crashes, companies may interpret the fall as indicating a weakening of government commitment. Participants suggested that China should try to avoid this scenario. Setting expectations by sending credible signals to companies is important and can have significant impacts that go beyond the specific price, so long as the price is above zero.

1.7. Additional Issues

In general, participants agreed on the power of market mechanisms to solve market failures. There is strong evidence from the U.S. Acid Rain program that cap-and-trade systems can provide huge cost savings and deliver environmental results. Some participants, however, noted that the United States has not implemented a carbon trading system, and asked why this is the case.

The plethora of "slogans" used in China to promote sustainable development – green development, resource conservation, environmentally friendly society, ecological society construction, etc. – have the same general spirit. But the "Low Carbon Society" slogan is subtly different, and perhaps more challenging because it involves a global problem and a global responsibility.

Finally, participants deliberated on the difficult fact that China's ambitions to mitigate its carbon emissions may be in conflict with continued economic growth, resource requirements, and environmental protection needs. Participants from both Europe and China noted the potential impact of higher energy prices on GDP and, crucially, employment. How to balance these imperatives is a question that will shape the design and stringency of the future carbon price-setting program.

Session 2: Incentivizing Low Carbon Technology Innovation through Policy

Mitigating climate change requires rapid development of renewable energy and energy-efficiency technologies. China has made tremendous progress developing a renewable energy industry in a very short period. It ranks first in the world in total renewable energy capacity installed, both including and excluding hydropower. In 1996-2012, China has built a powerful domestic renewable energy industry that now supplies much of the world's solar panels and wind turbines.

China's renewable energy policy is closely intertwined with the larger national strategy to create "indigenous innovation" capacity. Since 2005, renewable energy has been explicitly identified as a strategic industry for China's pivot towards high-tech industry. Many of the new low-carbon companies are quite innovative, but participants observed that Chinese companies remain primarily engaged in low-margin sectors of the renewable energy industry, doing process or incremental innovation rather than product, or breakthrough innovation. A central discussion question was should China encourage the development of a high-tech, world-class low-carbon innovation ecosystem.

In this endeavor, China faces substantial challenges – many of which exist in the United States as well. Participants noted that the public goods-nature of innovation, government inefficiency and internal conflict, imperfect energy industry competition, and insufficient understanding about the imperatives of sustainable development all lead to inadequate R&D investment. In general, participants emphasized the role of the government in driving innovation through procurement, demonstration, subsidies, and mandates.

2.1. Governance

As in the other sessions, the question of command-and-control versus market mechanisms loomed large in the innovation policy discussion. Participants noted that in innovation policy there is a clear dichotomy between policies aimed at incentivizing private actors to work toward a general goal, and policies centered on government discretion to determine exactly which R&D projects should go forward.

China has, roughly, four policy mechanisms guiding innovation in the energy sector. First, the development plans, including the Five-Year Plans and the various Medium- and Long-term Plans provide overall guidance and aspirational targets. Second, energy-related laws, such as the Renewable Energy Law of 2006, mandate renewable energy capacity installation. Third, the State Council issues industry-specific Five-Year Plans with administrative guidance and local government instructions. Fourth, the individual Ministries issue their own more detailed regulations. Science and technology policy is primarily carried out at MOST, which funds research, development, and demonstration projects with dedicated funding streams.

Participants emphasized that China's innovation ecosystem is evolving, and the right policy tool depends in part on the technology's stage of maturity. In wind, for example, the government began with R&D subsidies to specific firms and then shifted in the late 1990s to joint ventures with foreign firms and manufacturing localization requirements. In the 2000s, support came primarily in

the form of procurement policies supplemented with localization requirements. Finally, the government partially liberalized the market in 2009 with feed-in-tariffs to drive investment.

The government, particularly in the recent 3rd Plenum Resolution, appears to be advocating that the market (private firms) should play the leading role in innovation. Some participants suggested that the allocation of resources has perhaps not kept up with this new perception. However, participants also emphasized that in China there is no zero sum game between command-and-control and the market. Instead it is, and will remain, a fuzzy and mixed system.

More specifically, some participants described the need to further reduce R&D regulation of firms while simultaneously strengthening and increasing regulation in "social" areas such as health and local environmental pollution. Increasing regulation in these areas would, it was thought, induce innovation in and adoption of energy saving technology. This is because regulation would increase incentives for firms to innovate in providing social goods where market incentives are lacking.

Local governments need to be part of a more innovative industrial base. Participants noted that trade barriers between provinces together with local subsidies to favored enterprises and local government procurement of local technologies inhibit innovation. The 10 Cities 1,000 Vehicles program, which aimed to deploy electric vehicles in pilot regions, was given as an example in which poor central-local coordination created distorted incentives and undermined the intent of the program.

2.2. Industrial Policy

Participants emphasized the importance of industrial policy in shaping China's innovation. The Chinese government has taken an active role in nurturing and protecting its high-tech industries throughout the Opening and Reform period. Solar, wind, nuclear, and other low-carbon industries have been characterized by a gradual shift towards greater international competitiveness and the development of internal R&D capability.

Participants noted that despite concerns that industrial policy distorts domestic and international competition, "green" industrial policy would play an important role in China's sustainable development, allowing China as well as other developing countries to overcome technology barriers.

Participants discussed the issue of short-term versus long-term technology and industrial planning. It was noted that in the past, China, in contrast to some Western countries, has benefited from long-term energy policymaking. However, some participants were concerned that increasing responsiveness by China's government to public sentiment is leading to short-termism, rather than efforts to solve the underlying problem sustainably. Sometimes the quickest response is not the best policy.

2.3. Incentivizing Low-Carbon Technology Deployment

Economists think about a frontier of technology, in which output is maximized with minimal carbon input. Innovation policy, in theory, asks how to shift the frontier outwards. However, what is often ignored is that in the real world, firms and households do not optimize and do not locate themselves on the frontier. In fact, research suggests they are often far from the frontier. Part of

the discussion focused how to induce large firms, such as steel mills or manufacturers, to deploy existing energy-saving technology. This is essentially a problem of inducing energy-saving investment and process innovation. Making energy costs higher and more salient is one way to change behavior. Standards, mandates, and education can also affect behavior.

Participants noted that despite major government efforts to stimulate energy-saving firm-level innovation, they have not yet seen the desired response. Manufacturers face different markets. Some are too competitive, others insufficiently competitive, and some are characterized by unfair or biased government practices. Some industries dominated by a few state-owned enterprises, such as power generation, are perhaps not competitive enough. Others, like low-end equipment manufacturing, are ultra-competitive and provide no margins for R&D or even energy-saving capital investments. Local governments sometimes protect certain firms, allowing them to benefit from especially low wages or low taxes. The firms' competitors argue that they can barely keep up, and have no room to innovate. Participants argued that closing these "loopholes" is critical. Other participants went further, suggesting that China has so far used too many carrots and not enough sticks.

A strand of the discussion focused on the *negative* side of innovation: China should avoid the uptake of technologies with potentially negative side effects. New low-carbon technologies may have unintended consequences. Participants discussed the example of a new waste incineration technology deployed in Hangzhou that turned out not to comply with basic pollution regulations. Similarly, the nuclear power build-out in China has created a public backlash in certain localities. Some participants argued that evaluating the potential risks of new technologies should be a larger part of China's innovation program. Others stressed the role of minimizing mistakes; that to encourage innovation the state must be "entrepreneurial," identifying wasteful R&D programs and then directing that money elsewhere. This approach requires constant evaluation of R&D program outcomes.

Participants agreed that China should avoid innovation for sake of innovation; rather it should seek useful innovation. This can be difficult to achieve. For example, the Netherlands issues a list each year of environmentally friendly technologies that deserve support. The list is very difficult to write and generates opportunities for capture by private interests. In general, in order to ensure a solid technological basis for policy *and* in order to avoid capture, some participants suggested that extensive involvement of the science and technology community, especially academics, is important in crafting good policy.

2.4. Supply-side vs. Demand-side Policies

China's innovation policy has thus far relied primarily on subsidies for R&D activities at universities and large companies. The three main programs are the National High Tech R&D Program (863), National Basic Research Program (973), and National Key Technology R&D Program (previously known as Gongguan). Together, in 2009 they channeled roughly $1.83 billion (at the contemporaneous exchange rate) into research, development, and demonstration projects. And while 863 and Key Technology support small and medium enterprises in the private sector, much of the

funds directed to applied R&D goes almost entirely to large, often state-owned companies.[3] For example, this is true in the New Energy Vehicle subsidy programs.

Supply-side policies, especially subsidies, are relatively simple to administer and are appealing to policymakers. However, they are not always effective. For example, the Golden Sun solar subsidy program, which promised 50% subsidies for all new solar installations starting in 2009, was abandoned when it became clear that there was rampant fraud and a failure to connect systems to the grid. In addition to the possibility of waste, corruption and capture, there is also worry that sometimes subsidies can substitute for private funds that would have done the same R&D in the absence of the government funds.

China has relied primarily on subsidies. One participant asked, "If you wanted to become the most innovative low carbon economy in world and couldn't use subsidies or grants, what would you do?" This question was never clearly answered.

Some participants advocated developing an environment in which it was profitable for companies to conduct low-carbon R&D work, and minimize the extent to which the government subsidizes specific projects. This goal is achieved through policies that generate a market for clean energy systems, such as a carbon price, feed-in-tariff, or renewable portfolio standards. Such "demand-side" policies lead to increased private R&D that targets cost-effective low-carbon solutions.

Recently, China has implemented feed-in-tariffs for wind and solar power. Participants were generally in favor of feed-in-tariffs as a mechanism for encouraging private companies to advance technology by making it profitable to produce new kinds of energy.

Some participants noted the importance of demonstration programs in China. The ability of the central government to fund large demonstration programs has given China an advantage in jump-starting new technologies. Other participants emphasized that subsidies are still and should be China's primary innovation support tool. The issue is who to give them to.

2.5. Allocation of Resources

A central question is how to best allocate R&D funds to promote more innovative outcomes than have thus far been achieved. Participants noted that subsidies to large, established firms and those to startups have fundamentally different aims. The former should be focused on reducing energy consumption through applying practical, existing technology, as described in section 2.3. The latter should go to high-risk, highly innovative small firms.

Participants emphasized that China's next step in its innovation development is removing barriers to entry by high-tech entrepreneurs, who have extreme difficulty in accessing external financing in China. Therefore, more of the R&D money should be directed to encouraging the establishment of high-tech small businesses, or startups.

[3] This is separate from the demonstration projects such as the 10 Cities 1,000 Vehicles program, and is also separate from subsidies directly supporting renewable energy capacity installation.

2.6. International Cooperation

The workshop participants agreed that international low-carbon technology cooperation is critical in the fight to mitigate climate disruption. On the positive side, despite volatile country-level policy, the global market for renewable energy has resulted in relatively stable demand for certain technologies. This allows firms to survive bad years, without losing the expertise that it has built over time. In the future, participants suggested that closer international coordination is critical to support nascent low-carbon industries. Although each country's government considers only its own targets, companies often market its goods and services globally and consider the sum of the targets. Therefore, strategically setting targets to promote innovation at a global scale will be helpful.

Participants noted that pressure from global trading partners might help drive transition in China's S&T policy. In particular, recent anti-dumping and countervailing duties imposed by the United States and Europe are forcing China to confront whether it still needs to subsidize its "infant" industries. Not only can subsidies lead to international trade disputes, but internally there is evidence that Chinese renewable energy manufacturers often face no penalties for their own pollution. Ignoring environmental externalities in order to compete with international rivals is not in China's long-term interest as it seeks to create a more sustainable economy.

On a positive note, despite nationalism inherent in most countries' S&T policy, there is evidence that sometimes the greatest progress comes from global interaction. For example, when Germany tried to create a solar industry with only its domestic market and local manufacturers, it was simply too expensive. Only when Chinese firms entered did prices fall. Participants suggested that collaboration exploiting different countries' strategic advantages should be encouraged.

Session 3: Designing Water Policies in an Era of Climate Change and Scarcity

The third and final section of the workshop concerned the design of water resource policies in an era of climate change and scarcity. For China, this is a pressing issue. Long-term shifts in precipitation already appear to be inducing regular drought in parts of northern, central, and southwestern China. These shifts in the availability and timing of precipitation add further stress to water scarcity created as a result of rapid economic development. A special dimension of this stress comes from increasing competition for water between existing uses, especially for agriculture, and emerging energy-related uses, such as for shale gas production. Although several market mechanisms were discussed, including China's use of price increases in urban water supply to encourage water conservation, the discussion centered on the agricultural water sector because it accounts for the vast majority of water use in China.

The discussion began with the example of Australia, which has established perhaps the world's most comprehensive and sophisticated market-based mechanism to address water scarcity. The chosen instrument, Water Rights Trading (WRT), allocates usage rights to users, who can then buy and sell water shares. WRT now covers the entire Murray-Darling River Basin, Australia's largest. The session focused on how this system might be applicable to China, and in particular how the establishment of the system was achieved in the face of initial resistance from a variety of water users. Although participants were generally impressed with the Australian example, some important challenges were raised regarding the application of a similar system in China.

3.1. Lessons and Experiences from Australia's Water Trading System

The session's principal presentation concerned the Australian WRT system. This system was put in place and slowly evolved in response to the challenge of allocating increasingly scarce water resources. The presentation's key message was two-fold. First, that markets represent the preferred instrument to respond to water scarcity, and secondly that water markets arise from "excellence in institutional design." Hence, government's role is to create the conditions to allow markets to emerge, rather than to be directly involved in water resource allocation. Over the course of a long evolutionary process of policy reform, Australia began to issue shares of river water to individual water users in perpetuity, which created secure property rights to water and drove water use efficiency improvements. These rights could be sold to higher-value water uses.

The key issue in the Australian example was how to create the proper institutional framework to allow markets to flourish. The gradual evolution of the Australian system was emphasized, which overcame numerous difficulties in the process. Many of these were political; substantial resistance to marketization was mounted by farmers and state governments, who initially were hesitant to allow water rights to be traded across state lines. However, sustained political commitment by the federal government and protracted negotiations allowed these issues to be overcome, gradually and incrementally strengthening the institutional foundation. This long process of adaptation, and its reliance on particular institutions, provided the foundation for vibrant debate among participants about how readily the Australian example could be followed in China.

3.2. China's Water Rights Trading System

Participants noted that China's response to water scarcity has been significantly different from that of Australia's. China has emphasized regulatory, as opposed to market measures. The Chinese government has proposed a general objective for the water shortage challenge and to control the gross utilization of water resources. Improvements in water use efficiency and effectiveness within the margin of total quantity control are the core components of the central government strategy. The Chinese government promised that total national water use up to 2020 will not surpass 670 billion cubic meters and will not surpass 700 billion cubic meters up to 2030. These figures account for nearly one fourth of China's total water resources, and represent one of the world's most ambitious water resource regulatory policy measures.

In light of this, much of the discussion revolved around the applicability of WRT in China. There appear to be some relevant indigenous cases of water rights: for example, a Chinese military commander of the Qing Dynasty, Nian Gengyao, implemented timed water rights in Western China where the time of collecting water upstream was strictly limited. In the joint project founded by Australian and Chinese governments in 2006, water rights reforms were the topic of heated discussions. China proposed a construction framework for a water rights system, including long-term water rights on the national level, the river basin level to the regional level, and then to the farmers, and lastly, specific household users. According to this plan, the management of annual water utilization is a point of focus as well as the differences between water rights and carbon emissions, land rights trading, and forest rights trading. Within this framework, the Chinese government is incrementally pushing forward water rights system reform.[4]

3.4. Discussion and Linkages with Carbon Trading

The discussion emphasized several key differences between China's WRT system and the model followed by Australia. First, in order to make full use of the potential of water markets, Australia moved from a regime where water rights where defined primarily at the irrigation district level to one that defined them at the individual level. China has yet to make this transition and may not be prepared to allow it to happen, as it can make it more difficult to control use at the regional level. In China rights are typically granted to larger units such as irrigation districts. This allocation limits incentives for individual users to invest in efficiency improvements and for others to pursue opportunities to trade among regions. Second, there are strong political concerns about equity in China. In particular, there is concern that WRT may increase water prices too much for poor farmers that aspire to have access to more water. Third, the size of individual farms in China is small compared with Australia, making it more difficult for water management agencies to administer the allocation systems.

Participants raised several key points for the future of WRT in China. Perhaps the most salient was whether the market has as strong a role in the case of water as in other issues related to climate change. Several participants voiced concern that there should be more deliberation on how to determine water rights, and once implemented, how to mitigate conflict among special interests. There should also be related discussions on how to deal with market failure and how to ensure credible transactions in a strong market, etc. Another key issue is monitoring and enforcement, and how to ensure that water use is kept below the limit set by the initial WRT allocation. A suggestion brought up by participants is that prior to setting a blueprint for a water trading system in China,

[4] In July 2014, the Ministry of Water Resources announced that seven provinces will carry out pilot projects on different types of waters rights systems, taking a definite step towards the creation of a water rights trading market.

water resources should be divided into different categories, such as drinking water, agricultural water, industrial water, etc. Australia started with this approach but decided to move to a regime that established a priority sharing regime that leaves each municipality, business, farm, etc. the opportunity to decide how much supply risk they wish to expose themselves to.

A final notable issue explored by participants was linkages and lessons between markets for water and for carbon. Some participants noted that China has proposed creating an integrated national natural resource rights system that includes water, forests, energy reserves, and other resources. Others suggested that granting entitlements to such resources in perpetuity, as Australia has with water, would help to drive innovation and, thorough this, long-run efficiency improvements. However, the idea of linking these markets for diverse natural resource rights was not explored in detail.

In sum, there was agreement that there is much to emulate in Australia's water trading system, but its judicial and legal system have played a significant role in forming the water trading market, a feature which other countries should pay particular attention to. A few participants also stressed that Australia attaches great importance to public participation and input from citizens in designing water resources management policy, which may be beneficial for China to consider. There is a greater need to listen to the views of the public and water users and not only pay attention to environmental protection experts and scholars who are often informed through narrow channels.

Conclusion

The final segment of the workshop was devoted to building on the three thematic sessions to outline questions for future research and study, as well as to summarize issues raised during the course of the thematic sessions. Three major issues were raised: 1) how to integrate markets with regulation; 2) how to properly adapt market mechanisms to the Chinese context, especially given the size of its population and economy, and its distinctive economic model of state-led capitalism; and 3) how to ensure proper monitoring, enforcement, and verification of emissions reductions and water use efficiencies achieved through the use of market mechanisms.

Workshop participants also posed three research questions in response to these issues. The first proposed to use a within-country comparative case study to answer the question, "Given that market mechanisms will likely be more appropriate in some parts of China than others due to differences in economic development and other factors, where will market mechanisms work best?" The second question asked, "How can market mechanisms be best integrated with regulatory approaches?" A third proposed research question attempted to address the issue of the Chinese context by asking, "What can we learn from traditional, indigenous approaches to water and other resource scarcity, both in China and elsewhere in the world?"

These questions point to several different directions for future research and discussion. However, workshop participants expressed consensus on the desirability of focusing future work on how to best employ market mechanisms, rather than whether or not to apply them. One participant posed a final research question which encapsulates both this consensus and the issues which must be addressed to properly use market mechanisms to achieve a low-carbon future in China: "Well-designed and implemented market mechanisms can play an important role in helping China meeting its energy and environmental goals, but what are the lingering challenges and problems?" The workshop thus concluded by affirming the promise of market mechanisms in furthering China's sustainable development, while recognizing that significant challenges remain to be addressed in future research and discussion, which workshop participants hope will be catalyzed by the experience of convening at Tsinghua. The Environment and Natural Resources Program and the Sustainability Science Program at the Harvard Kennedy School and the Center for Science, Technology and Education Policy at Tsinghua University will convene another workshop on energy technology innovation in June 2015.

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