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Green Growth (for China): A Literature Review

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Abstract

This paper has two purposes. The first is to review the emerging literature on green growth, with a focus on the origin and meaning of the concept, as well as the justifications for and criticisms of the concept. The general idea of taking into account the impact of economic growth policies on the environment is not very controversial, but the possibility of simultaneously achieving conventional GDP growth and environmental protection is debated. The second purpose is to consider how China might move on to a green growth path. We summarize a sizable literature that traces China's rapid economic growth and the associated environmental problems to its unique and fundamental institutions, and discuss the implications of this on how China might grow more sustainably.

Key Words: green growth, economic development, environmental protection, China

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Mun S. Ho and Zhongmin Wang*

1. Introduction

The primary purpose of this report is to review the emerging but still limited literature on green growth, with a focus on the origin and meaning of the concept, as well as the justifications for pursuing it. Our review suggests that there is not yet a consensus definition for green growth, but most stakeholders take it to mean economic growth that is environmentally sustainable. Consistent with this definition, green growth was proposed, and is being promoted by some countries and international organizations, as a strategy to achieve sustainable development. This term is politically attractive because it focuses on the synergies, rather than the trade-offs, between economic growth and environmental protection.

In spite of its attractiveness, the evidence for successful green growth is limited—a fact acknowledged by some of the international organizations promoting green growth. The evidence of narrow green growth (win-win) projects is voluminous. But for an entire country, there are few examples of such success. Indeed, developed countries, during their industrialization stage, experienced environmental degradation instead of environmental improvement. Nonetheless, to help readers see the potential synergies between economic growth and environmental protection, we offer a brief overview of the relationship between economic growth and the environment, examining how environmental policies might affect economic growth and how economic growth may affect the environment. The perceived trade-off between environmental policy and economic growth is more likely to exist when economic growth is narrowly defined as gross domestic product (GDP) growth in the short run. Such trade-offs may be attenuated when economic growth refers to long run growth, or to growth in a broader definition of social welfare (or "green GDP").

The second purpose of this paper is to consider briefly how China might move to a green growth path. The *China 2030* report by the World Bank and Development Research Center of the State Council (2012) provides excellent discussions of green development in China and we thus do not offer a comprehensive discussion of green growth in China or review the large

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literature on China's environmental issues and policies.[1] We summarize a sizable literature that traces China's rapid economic growth and the associated environmental problems to its unique and fundamental institutions, and discuss the lessons from this literature on designing policies and institutions for China to grow "greenly," or sustainably.

2. The Concept of Green Growth

2.1. Origins of the Green Growth Concept

According to the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) and Korea International Cooperation Agency (KOICA), green growth "was not born out of economic theory. Rather, it is a vision put forward by policymakers in an attempt to find practical ways of reconciling economic growth and environmental sustainability" (2012, xxi). Green growth, as a policy concept, originated from the Asian and Pacific region.[2] It first appeared in the ministerial declaration adopted by the Fifth Ministerial Conference of Environment and Development (MCED), which was convened by UNESCAP in the Republic of Korea in 2005. This conference focused on the synergy between environmental sustainability and economic growth and labeled environmentally sustainable economic growth as "green growth" (IISD 2005). In May 2010, UNESCAP countries further expressed in the Incheon Declaration their intent to "strengthen [their] efforts to pursue green growth strategies as part of [their] response to the current [global financial] crisis and beyond."[3]

In 2012, UNESCAP and KOICA elaborated their views on green growth in a report titled *Low Carbon Green Growth Roadmap for Asia and the Pacific: Turning Resource Constraints and the Climate Crisis into Economic Growth Opportunities*. That same year, UNESCAP, Asian Development Bank (ADB), and United Nations Environment Programme (UNEP) jointly released a report on green growth in the Asia and Pacific region, *Green Growth, Resources, and Resilience: Environmental Sustainability in Asia and the Pacific*. In 2013, ADB and Asian

[1] Zheng and Kahn (2013), for example, review the literature that studies the causes and consequences of China's urban pollution challenges.

[2] See Blaxekjær (2012), who offers a more detailed account of the emergence and spreading of green growth as a policy concept.

[3] See descriptions at http://climate-l.iisd.org/news/unescap-66th-commission-session-adopts-incheon-declaration/ and at the UN web page http://sustainabledevelopment.un.org/index.php?menu=1447.

Development Bank Institute (ADBI) jointly released yet another green growth report, *Low-Carbon Green Growth in Asia: Policies and Practices*.

The Republic of Korea played a key role in promoting the concept of green growth. In 2008, Korea adopted "low carbon green growth" as the country's new development vision. The next year, it released its National Strategy for Green Growth and Five-Year Plan for Green Growth, followed by the enactment of the Framework Act on Low Carbon Green Growth in 2010. Korea has since been promoting the green growth concept more broadly. Korea was instrumental in establishing the Global Green Growth Institute (GGGI), which is headquartered in Seoul and "is dedicated to pioneering and diffusing a new model of economic growth in developing and emerging countries, known as 'green growth,' that simultaneously targets key aspects of economic performance, such as poverty reduction, job creation and social inclusion, and those of environmental sustainability, such as mitigation of climate change and biodiversity loss and security of access to clean energy and water."[4]

Beyond the Asia and Pacific region, other international organizations have also contributed to the diffusion of the green growth concept. At the Organization for Economic Co-operation and Development (OECD) Ministerial Council Meeting in June 2009, 30 OECD countries and 5 prospective member countries approved the Declaration on Green Growth, which states that green and growth can go hand in hand, and commissioned the OECD to develop a green growth strategy. Since then, the OECD has become a major proponent of green growth and has issued a number of studies,[5] in particular, a 144-page report, *Towards Green Growth* (OECD 2011), discussing a policy framework and measurement issues.

The Group of Eight (G8) and the Group of Twenty Finance Ministers and Central Bank Governors (G20) have also declared their support for green growth. The G8 2009 declaration (paragraph 60) states that "the interlinked challenges of climate change, energy security and the sustainable and efficient use of natural resources are amongst the most important issues to be tackled in the strategic perspective of ensuring global sustainability. A shift towards green growth will provide an important contribution to the economic and financial crisis recovery."[6] The G20 2010 Seoul Summit Leaders' Declaration states that leaders of the G20 "recognize that

[4] http://gggi.org/about-gggi/background/organizational-overview/.

[5] The OECD documents are given at http://www.oecd.org/greengrowth/oecdworkongreengrowth.htm.

[6] "Responsible Leadership for a Sustainable Future," available at http://www.g8italia2009.it/static/G8_Allegato/G8_Declaration_08_07_09_final,0.pdf.

sustainable green growth, as it is inherently a part of sustainable development, is a strategy of quality development, enabling countries to leapfrog old technologies in many sectors, including through the use of energy efficiency and clean technology."[7]

In 2011, the United Nations Environment Programme (UNEP) issued a 631-page report, *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication.* A green economy in the context of sustainable development and poverty eradication was one of the two themes for the 2012 United Nations Conference on Sustainable Development (Rio+20). In 2012, the World Bank issued its report on green growth, *Inclusive Green Growth: The Pathway to Sustainable Development*. In 2012, GGGI, UNEP, OECD, and the World Bank jointly launched the Green Growth Knowledge Platform (GGKP), "a global network of international organizations and experts that identifies and addresses major knowledge gaps in green growth theory and practice … [and that] offers practitioners and policymakers the policy guidance, good practices, tools, and data necessary to support the transition to a green economy."[8]

2.2. The Meaning of the Green Growth Concept

While there is no exact consensus definition for green growth in the literature, it is generally thought to be economic growth that is environmentally sustainable, and is considered a vital strategy to achieve sustainable development. Green growth not only is a normative ideal but also carries with it the claim that environmental protection is, at a minimum, compatible with economic growth.

To compare the various definitions, it is useful to recall the concept of sustainable development first. The Brundtland report (WCED 1987) coined the term "sustainable development" and defined it as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs." The report describes three pillars of sustainable development. Besides economic development (the economic pillar), the report emphasizes the environment's ability to meet present and future needs (the environmental pillar) and the needs of the world's poor (the social pillar). In academic discussions of sustainable development, weak sustainability requires that the total capital stock, which is the sum of natural capital, physical capital, and human capital, does not decline, while

[7] Paragraph 68 of the declaration, which is available at http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/er/117705.pdf.

[8] http://www.greengrowthknowledge.org/about-us.

strong sustainability requires that the value of natural capital (e.g., minerals, fisheries, ecosystems) does not decline (Tietenberg 2003).

According to the OECD, "Green growth … is about fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies" (2011, 9). OECD's definition of green growth emphasizes the strong version of sustainability, and it does not mention the social pillar of sustainable development. Therefore, it is not surprising that OECD writes that "green growth has not been conceived as a replacement for sustainable development, but rather should be considered a subset of it. It is narrower in scope, entailing an operational policy agenda that can help achieve concrete, measurable progress at the interface between the economy and the environment" (p 11).

The World Bank says that green growth "can be thought of as economic growth that is environmentally sustainable, … [and] that is efficient in its use of natural resources, clean in that it minimizes pollution and environmental impacts, and resilient in that it accounts for natural hazards and the role of environmental management and natural capital in preventing physical disasters" (2012, 30). Like the OECD's definition, that of the World Bank does not include the social pillar either. The World Bank report emphasizes that green growth is no substitute for inclusive green growth, and that inclusive green growth is the pathway to sustainable development. Dercon (2011) offers detailed and thoughtful arguments on why green growth, if defined as economic growth that is environmentally sustainable, may not be good for the poor. For example, eliminating fuel subsidies is widely considered a growth-enhancing, environment-improving, win-win policy, but it affects the poor disproportionately if not accompanied by a compensation mechanism.

UNEP uses the term "green economy" instead of green growth, and its definition is much wider than those of OECD and World Bank: a green economy is "one that results in 'improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities.' … In its simplest expression, a green economy is low carbon, resource efficient, and socially inclusive. … The development path should maintain, enhance and, where necessary, rebuild natural capital as a critical economic asset and as a source of public benefits. This is especially important for poor people whose livelihoods and security depend on nature. The key aim for a transition to a green economy is to enable economic growth and investment while increasing environmental quality and social inclusiveness" (2011, 16). The statement that one should "maintain, enhance and, where necessary, rebuild natural capital" emphasizes the strong version of sustainability, while the reference to "socially inclusive" recognizes the social

pillar of sustainability. For UNEP, "moving towards a green economy must become a strategic economic policy agenda for achieving sustainable development" (p 19).

"Low carbon" is mentioned explicitly in UNEP's definition of green economy, but not in the definitions of green growth by OECD or the World Bank.[9] However, both the OECD and the World Bank reports recognize that climate change is a crucial part of environmental sustainability and that low-carbon development is part of the green growth agenda. Low carbon is featured much more prominently in the green growth reports by UNESCAP and KOICA (2012) and by ADB and ADBI (2013). These two reports use the term "low-carbon green growth" instead of green growth only. For example, ADB and ADBI state that "low-carbon green growth is an avenue toward development that decouples economic growth from carbon emissions, pollution, and resource use, and promotes growth through the creation of new environment-friendly products, industries, and business models that also improve quality of life. Thus, low-carbon green growth entails: (i) using less energy, improving the efficiency with which resources are used, and moving to low-carbon energy sources, (ii) protecting and promoting the sustainable use of natural resources such as forests and peat lands, (iii) designing and disseminating low-carbon technologies and business models to reinvigorate local economies, and (iv) implementing policies and incentives that discourage carbon intensive practices" (2013, xi).

Although the OECD, UNEP, the World Bank, and other international organizations define green growth differently, they all appear to view green growth as a vital strategy to achieve sustainable development. For green growth to be a vital strategy, it must be at least feasible and doable. The World Bank report states that "greening growth is necessary, efficient, and affordable" (2012, xi). The OECD report says that "green growth has the potential to address economic and environmental challenges and open up new sources of growth through [a number of] channels" (2011, 9). The OECD emphasizes that the perceived trade-off between environmental protection and economic growth is attenuated or eliminated when economic growth is represented by new measures that better capture well-being instead of conventional GDP, and when policies are evaluated over a longer time horizon.

[9] Some early writings defined green growth as low carbon growth only. For example, Huberty et al. (2011) defines green growth as "job creation or GDP growth compatible with or driven by actions to reduce greenhouse gases."

The UNEP report makes even stronger claims about green growth. It terms as a prevalent myth the view that "there is an inescapable trade-off between environmental sustainability and economic progress," and states that "the greening of economies need not be a drag on growth. On the contrary, the greening of economies has the potential to be a new engine of growth, a net generator of decent jobs and a vital strategy to eliminate persistent poverty" (2011, 16). However, the UNEP report argues only that green economy policy can deliver higher growth than traditional growth policies when measured over the long run. A key element of the UNEP report is a global model, which predicts that investing two percent of global GDP in natural capital and in energy and resources efficiency, compared with business-as-usual investment, would make GDP growth slower in the short to medium term, but faster in the long run (about a decade). GDP growth under the business-as-usual scenario is slower in the long run because of the depletion of natural resources, resulting in lower soil quality, higher water stress, and higher fossil fuel prices.

Green growth is a politically attractive term because it speaks simultaneously to the two key challenges the world is currently facing: economic growth needed to improve the living standards of the world's growing population, and measures needed to address the issues of environmental sustainability and climate change. Some commentators (e.g., Bowen and Fankhauser 2011; Jacobs 2012) see the concept of green growth as an attempt to shift the environmental discourse from a negative and politically unattractive focus on the costs of environmental protection and climate mitigation to something more positive. Bowen and Fankhauser, for example, write that "green growth allows environmental protection to be cast as a question of opportunity and reward, rather than costly restraint" (2011, 1157). This point is somewhat acknowledged by UNESCAP and KOICA when they state that "there is an urgent need to translate [the sustainable development] vision into implementing strategies and to find a positive agenda for pursuing the integration of the three pillars of sustainable development—economic growth, environment protection and social inclusiveness—by seeking to develop synergies instead of focusing on the current trade-offs and trying to balance them" (2012, 18).

We would be remiss if we did not note that some of the international organizations that are promoting green growth policies themselves acknowledge that there is little systematic evidence for green growth. For example, when addressing the question of whether higher growth under a green economy is really possible, UNESCAP and KOICA state that "green growth is a fairly new concept, it does not have decades of empirical evidence to support it; so far, there are limited examples and mainly from industrialized countries" (2012, 20). The Global Green Growth Institute also acknowledges on its website that "there is a lack of practical experience in

planning and implementing green growth strategies, and in generating demonstrated results. … There is not yet a convincing economic theory and policy agenda to explain the fundamentals of green growth and guide its pursuit."[10]

3. The Relationship between Economic Growth and the Environment

In this section, we discuss two different perspectives on the relationship between economic growth and the environment: the impact of environmental policy on GDP growth and the impact of GDP growth on the environment.

3.1. Impact of Environmental Policy on GDP Growth: The World Bank Framework

Hallegatte et al. (2011) provide a useful framework for thinking about how environmental policy might affect conventional GDP growth. This framework was adopted by the World Bank (2012) report and may be a useful guide for analysis of proposed policies. We draw on it to summarize the various channels through which green policies might affect economic growth and social welfare.

In this framework, aggregate output (i.e., GDP) is produced by physical capital, labor, natural capital, and "technology." Natural capital would include mineral resources, forests, fisheries, mangroves (as protection against flooding), clean air, and so on. Some of these resources clearly provide useful goods. For example, forests provide wood and recreational amenities. The contamination of other natural capital hurts production. For example, air pollution can make workers sick, and acid rain can kill fish. Physical capital includes both private capital and public capital such as roads and sewage treatment plants. "Technology" is a catch-all term to refer to the intangibles such as organizational knowledge, scientific knowledge, network effects, economies of agglomeration, and scale economies. These intangible factors are often referred to as total factor productivity (TFP). Growth in GDP may come from increases in each of the three production factors and technology.[11]

[10] http://gggi.org/about-gggi/background/organizational-overview/.

[11] We should note that in the latest System of National Accounts, it is recommended that R&D expenditures be regarded as investment and be part of final demand (i.e., GDP) instead of being treated as intermediate inputs as in the old system. This is implemented in the latest version of the U.S. National Accounts. In the simple framework above, one should include this intangible capital with the physical capital. A more complex treatment would regard knowledge capital as a distinct input.

Economists find it useful to distinguish between maximum possible output given a set of production factors (the "production possibility frontier") and the actual level of output. Actual production may be lower than the maximum possible output; in other words, production efficiency is less than 100 percent.[12] Production inefficiency may be due to cyclical causes: during the downturn part of the business cycle, unemployment rises and output falls (workers who are willing and able to work are not fully used). Production inefficiency may also be due to structural causes, such as market failures, governance failures, missing insurance markets, or undeveloped financial markets. Hallegatte et al. (2011) also mention how externalities may lead to underinvestment in R&D and how behavioral biases, such as people's inability to make decisions concerning low-probability events, lead to suboptimal decisions.

Environmental policies can affect each of the three factors of production, as well as technology and production efficiency, thus changing GDP. Policies aiming at protecting the environment may increase natural capital (cleaner air, reforestation, fisheries management). Such policies may also indirectly affect the other two factors (physical capital and labor). Cleaner air increases labor supply and reduces damages to buildings and equipment, and flood control reduces damages to structures. The World Bank (2012) report refers to these impacts as the "input effect."

Environmental policies may also change technology (e.g., the much debated Porter hypothesis, which we discuss below). Energy efficiency policies may trigger innovations that lower both energy use and costs, causing an improvement in TFP. Direct government investments in research and development (R&D) may lead to higher productivity in the private sector. Government subsidies for private sector research may also lead to improvements in technology.[13] The World Bank (2012) report uses the term "innovation effect" to refer to the positive effect environmental policies may have on innovations.

Environmental policies may affect production efficiency through many channels. An environmental infrastructure project can be a critical part of a well-designed stimulus package

[12] The maximum output may be written as $Y^m = f(K,L,E,T)$, a function of capital, labor, environment/natural capital, and technology. The actual output, $Y = \psi f(K,L,E,T)$, is the maximum output, Y^m, multiplied by the efficiency factor, ψ, which is less than one.

[13] We should note that such green investments and subsidies need to be carefully justified. Green investments have opportunity costs. That is, green investments crowd out investment in other technology areas. One has to be sure that the return from green investments is higher than the alternatives, at least in the long run.

during a recession when capacity is not fully utilized. Such green stimulus policies benefit the environment and increase aggregate demand and thus overall output. World Bank (2012) calls this the "stimulus effect." Subsidies for R&D in renewable technologies or energy efficiency may help overcome the lack of such investments due to knowledge spillovers; private firms underinvest in research and development because they cannot capture all the returns of their new knowledge. Such R&D policies may move the economy closer to the optimal level. Organizing a fishing community to avoid overfishing is another example of a policy that reduces inefficiencies. The World Bank uses the term "efficiency effect" to refer to the positive effect environmental policies may have on production efficiency.

Environmental policies may also have negative impacts on factor inputs and production efficiency. Removing sulfur dioxide from coal boilers requires flue gas desulfurization (FGD) equipment that is costly to install and operate.[14] That is, resources that may be used elsewhere are required to reduce SO_2 emissions. In this particular example, FGD equipment requires electricity to run, meaning that more coal may be burned (and more CO_2 emitted) to maintain the same net output of usable electricity. Environmental regulations may also lead to short-run adjustment costs. For example, if a steel factory reduces output and employment because of higher pollution control costs, the laid-off workers may need some time before finding another job. Environmental policies such as those requiring low-carbon technologies may lead to forced early retirement of existing physical capital if not implemented optimally.

3.2. Examples of Environmental Regulations

The above framework is very useful for thinking about the impacts of environmental policies. However, it might be easier to see both the benefits and costs if we consider specific types of environmental regulations. For this purpose, we separate environmental policies into the following three categories: (1) policies designed to correct nonenvironmental market failures and governance failures; (2) environmental regulations (e.g., environmental taxes, cap-and-trade programs, technology standards, and command-and-control measures) that apply to manufacturing, transportation, agriculture, and other industries; and (3) green innovation and industrial policies.

[14] Nielsen and Ho (2013a) estimate the cost of operating FGD in China at about 2.4% of total operating costs.

3.2.1. Policies That Correct Nonenvironmental Market Failures or Government Failures

Policies designed to correct some nonenvironmental market failures that have environmental consequences are most likely to be win-win. One example is congestion pricing, charging motorists to use busy roads during peak hours. Congestion pricing reduces traffic congestion, thus increasing commuters' leisure and productivity. By improving traffic flow and reducing gasoline used per trip, congestion pricing also reduces air pollution. Moreover, revenue from congestion pricing could be used to build transportation infrastructure, further benefiting the economy. Despite being a win-win policy, congestion pricing is controversial because of distributional concerns: critics say that it hurts those motorists who are poor but must drive.

Another example is the individual transferable quota (ITQ) system used to protect fisheries. Open-access resources such as ocean fisheries suffer from the problem of the commons and are prone to overexploitation. In an ITQ system, a government agency sets an annual limit for the catch and allocates quotas to each fisherman, who can then decide whether to use it to fish or sell it. The choice of catch technology and timing is left to the individual fisherman. Newell et al. (2005) describe some successful examples of ITQs used in several countries to protect fisheries. In the case of an ITQ system, the trade-off is that fishermen may be worse off in the short run even though they, as well as the ecosystem, are better off in the long run.[15]

Eliminating some government failures would significantly benefit the environment at little cost to the economy, though government failures are hard to correct. One example of government failure is subsidies that lead to an overuse of fuels, water, fisheries, and other natural capital. World Bank (2012) cites estimates that the global subsidy for the use of natural capital is in the range of US$1 trillion to $1.2 trillion, with fuel subsidies amounting to more than $450 billion. Lin and Jiang (2011) estimate China's energy subsidies at 1.4 percent of GDP. Eliminating fossil fuel subsidies will lead to higher fuel prices and lower fuel consumption (and thus lower pollution emissions). In addition, governments can save large sums of expenditures that can be used for more efficient programs. Consumers of fuels will be hurt, however, and thus it is recommended that a comprehensive policy reform use some of the saved subsidies to compensate the poorest households.

[15] We note that not all policy responses to the problem of the commons are effective. For example, some governments have tried to limit annual catches by closing particular areas for particular times or by imposing restrictions on fishing technologies. As Stavins (2011) notes, these traditional types of regulations are not effective partly because they have led to changes in fishermen's behavior, such as the use of expensive, capital-intensive methods of fishing or more boats, given the time limits.

Another example is the price cap regulation in the natural gas sector in some countries (including China). A price cap leads to excess demand at the regulated price. Eliminating it will give the natural gas firms incentives to produce more, so the impact on the regulated sector is positive. Although the higher price will cut off some desired consumption, higher domestic output of natural gas will allow it to replace coal and thus benefit the local environment as well as reduce GHG emissions. Consumers faced with higher prices may be opposed to such policy reforms, and World Bank (2012) emphasizes the need to manage the political economy of reform, citing the successful example in Iran where energy prices were raised more than 20 times in 2010.

3.2.2. Environmental Regulations Affecting Costs in Particular Industries

Pollution emissions regulations are an example of the second category of environmental regulations. One wishes to set policies by comparing costs and benefits. Consider first the benefit of emissions reduction. Better environmental quality improves welfare by improving people's health and life expectancy. Emissions reduction may also benefit GDP growth through two channels. First, it can benefit the economy in general through the input effect by increasing the availability and productivity of natural capital (e.g., better water and soil quality increases the productivity of agriculture, and better health increases labor productivity).

Second, emissions regulations may lead firms to innovate more. Porter (1991) and Porter and van der Linde (1995) challenged the conventional wisdom that environmental regulation imposes additional costs to firms that may erode their global competitiveness. Porter and van der Linde (1995, p 98) argue that "properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them". Researchers have empirically tested two versions of the Porter hypothesis, a weak version and a strong one. The weak version is that properly designed environmental regulation (flexible regulations as opposed to rigid ones) can spur innovation, and the empirical evidence for this version, according to Ambec et al. (2013), is well established. The strong version is that the benefits of innovations triggered by environmental regulations can more than offset the costs of complying with environmental regulations. Ambec et al. conclude that the evidence for the strong version is mixed. Note that the strong version of the Porter hypothesis is still weaker than the claim that innovations spurred by environmental regulations can increase GDP growth. In addition, most of the empirical papers in this area study environmental regulations in developed countries. Developing countries are less likely to have properly designed environmental regulations, and firms in developing countries have less capacity to innovate. Many may take these considerations

as suggesting that it is difficult to make the case that environmental regulation can increase developing countries' GDP growth through firm innovations.

Consider, next, the cost of emissions regulations. For such regulations, economists often suggest the "polluter pays" principle. The impact of SO_2 reduction by power plants, whether via technology requirements (e.g., requiring FGD equipment), an SO_2 emissions tax, or an SO_2 cap-and-trade program, is to raise costs for firms, which would normally pass on such costs to customers as higher prices. Affected customers, paying higher prices, would likely use less electricity. Regulated power generators thus lose some sales even if they can pass on the higher costs. Some of their workers, and even some workers in the coal mines that sell to them, may be laid off. In some cases of severe emissions, firms may have to shut down completely because of high compliance costs. The other industries that buy the more expensive electricity would try to pass on their higher costs. These outcomes are efficient in a normally functioning market; companies and other institutions whose electricity consumption led to the pollution emissions are ultimately paying for maintaining healthy air. When labor markets are not functioning well, the adjustment costs for the laid-off workers would have to be taken into account. Furthermore, in most countries, the electricity sector is a highly regulated one where the regulatory agency decides the price, and perhaps quantity, of electricity. The final accounting of costs and benefits of SO_2 control thus depends on complementary actions by the regulators.

While the overall benefits of this type of environmental regulations in the long run may far exceed their costs, it may be difficult politically to implement such policies. First, such regulations may be incompatible with conventionally measured GDP growth in the short run; costs to the regulated industries are immediate, but benefits may take a longer time to materialize. Second, the costs of such regulations may be borne by a small number of firms and a small portion of the population, while the benefits are diffused among a much larger population. The few affected firms have a strong incentive to lobby against environmental regulations. Third, some environmental policies, such as building water treatment facilities or public transportation infrastructure, provide benefits not just to the current generation but to future ones as well. Greenhouse gas control is an extreme case in which mitigation costs are high for the current generation but benefits are large for future generations. An effective policy that is widely supported, and thus enforceable, may require a cost-sharing or redistributive component.

To see clearly the benefits and costs of this type of environmental regulations, consider air quality regulations in the United States, the United Kingdom, and the European Union. The United States suffered from badly polluted air during its industrialization period in the first half of the 20th century. As late as the 1940s, levels of total suspended particles (TSP) above 300

$\mu g/m^3$ were recorded in Pittsburgh. The first federal air pollution law was passed in 1955, followed by the Clean Air Act (CAA) in 1963. The CAA of 1970 required comprehensive federal and state regulations and expanded enforcement and led to substantial improvements in air quality, Amendments passed in 1990 addressed the issue of acid rain and set up a permits program for stationary sources. The well-known pioneering sulfur dioxide cap-and-trade program was started in 1995.

The 1990 amendments required the Environmental Protection Agency (EPA) to periodically assess the benefits and costs of the CAA, and to do so in consultation with outside experts. The first assessment was given in EPA (1997), which estimates that by 1990, due to the CAA, SO_2 emissions were 40 percent lower, NO_x emissions were 30 percent lower, and CO emissions were 50 percent lower. As a result of the lower emissions, air quality was improved: ozone concentration was 15 percent lower, and $PM_{2.5}$ concentrations were 45 percent lower. By 1990, improved air quality is estimated to have reduced premature mortality by 205,000 cases per year and chronic bronchitis by 674,000 cases. The EPA report values these reduced health damages and other material benefits at $22 trillion (of which $23 billion was for higher agriculture output) over the period 1970–1990. These figures are for the central estimate, and the report emphasizes the large degree of uncertainty about these estimates.

The direct cost of complying with the CAA over the same 1970–1990 period is estimated at $0.5 trillion, which includes the costs of installing and operating desulfurization equipment in power plants and catalytic converters in motor vehicles, and the costs of monitoring and reporting. These direct costs are relatively easy to measure, but there are other indirect costs on other firms that are not directly observed. For example, desulfurization equipment increases the cost of electricity, which affects electricity users, and catalytic converters increased the cost of manufacturing motor vehicles. EPA (1997) uses an economic model of the entire economy to simulate these indirect (general equilibrium) impacts. It estimates that the CAA reduced the rate of gross national product (GNP) growth by 0.05 percent on average from 1973 to 1990, so that by 1990 GNP was about 1 percent lower than it would have been in the absence of the policy.

Another report, EPA (2011), estimates the potential future benefits and costs of the 1990 Clean Air Act Amendments by comparing with a base case that includes the 1970 CAA but not the 1990 changes. For the year 2020, the direct annual costs are estimated at $65 billion and benefits at $2.0 trillion. An economy-wide model analysis of the direct and indirect impacts suggests that the gross GDP loss is about $110 billion (0.54 percent of GDP) in 2020; when the benefits of having more healthy workers and lower medical expenses are included, the net GDP impact for 2020 is a small positive 0.02 percent of GDP.

These enormous benefits are mainly driven by valuing the mortality cases by a value of statistical life (VSL) of about $5 million. The VSL methodology has been vigorously debated, with some arguing that it is not applied appropriately (e.g., NERA 2011). However, even if we ignore the mortality cases, the tangible benefits of reduced sick hours and lower medical costs are comparable to the costs of pollution reduction, and the impact on GDP nets out to about zero in 2020.

Britain has also analyzed the costs and benefits of its Air Quality policies. The Department of Environment, Food and Rural Affairs (DEFRA 2001) analyzes various policy packages. For an illustrative package, DEFRA estimates the "cost of added life year" to be between £65 thousand and £243 thousand. An alternative, more limited, package has an implied cost of added life year of only £23 thousand to £61 thousand. This report does not put a value on the benefits, stating, "Due to a lack of agreed estimates of the willingness to pay to avoid the risk … health benefits have not been expressed in monetary terms." A later study, DEFRA (2007), however, does put a valuation on the health benefits: for a set of air quality measures, the costs are in the range of £400 million to £1,000 million, while benefits are in the range of £500 million to £1,500 million. DEFRA also recognizes a great deal of uncertainty in these estimates. Based on this 2007 study, the British government concludes that "after many years of significant improvement, air quality benefits are increasingly costly to achieve, making action difficult to justify on this basis alone." However, it further notes that "the measure was also estimated to realize climate change benefits valued at £91 million (compared to the local benefits of 72 million)" (DEFRA 2010, p 12,).

The European Commission has also estimated the prospective costs and benefits of air pollution control measures for a group of 25 EU countries. The Commission of the European Communities Staff (2005) analyzes three scenarios out to 2020. The least ambitious case is estimated to cost €5.9 billion and save 0.5 million life years, which the report values at €37 billion to €120 billion for the EU-25. The impact on GDP of this weakest scenario is –0.03 percent. That is, the EU also estimates a high benefit–cost ratio, with an admittedly large range of uncertainty about benefit values and a small negative impact on GDP.

3.2.3. Green Industrial and Innovation Policies

Private enterprises have the incentive to choose highly polluting simple coal boilers to generate electricity, given their low cost. As a response, many governments have adopted such green industrial and innovation policies as subsidies, feed-in tariffs, tax breaks, and investment grants to private companies to encourage the development of more expensive renewable sources

or high-efficiency combined-cycle systems. Many governments have also financed R&D in green technologies. On the demand side, many governments have promoted energy efficiency and low-pollution production processes by subsidizing equipment (e.g., fluorescent lamps, electric cars) and instituting other policies.

The motivations for these green industrial and innovation policies are fairly straightforward. If coal is not priced properly to take into account the full externalities, then one tries to adjust the price for renewables. If the private sector underinvests in R&D because of knowledge spillovers, then governments can use certain policies to correct this market failure. If information barriers or other market failures are hindering the adoption of energy-efficient technologies, governments might use certain policies to overcome them.

However, to determine the optimal level of such interventions, one needs to estimate the costs and benefits of proposed interventions. Although it is not hard to estimate the number of light bulbs replaced and thus the electricity saved, or the amount of heating and cooling saved by renovating an old house, it is difficult to estimate the benefits of subsidizing wind or solar electricity, as it impacts the whole electricity grid and one has to account for the costs of backup systems and grid extension costs (NREL 2013 is an example of such analysis). Similarly, subsidies or direct spending on R&D are also difficult to evaluate, partly because of the existence of opportunity costs; if a particular subsidy is not given or some green investment is not made, then some other projects may be subsidized or promoted. The National Research Council (NRC 2001) evaluates the benefits and costs of R&D programs sponsored by the US Department of Energy, and notes a large range of successes and failures. NRC (2005) follows up with a proposal for a more systematic evaluation of proposed R&D projects.

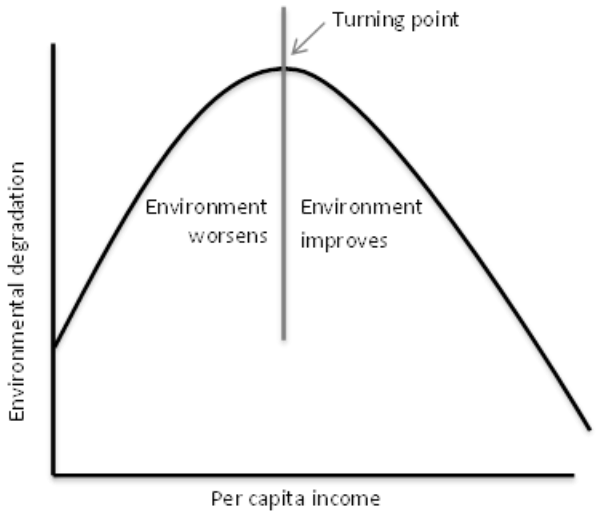
Devoting an entire chapter to green innovation and industrial policies, the World Bank (2012) report concludes that such policies are potentially useful tools to promote green growth but warns that such policies should be carefully designed to minimize the risks from capture and rent-seeking behaviors. The report notes that such policies have a mixed record and are rife with both successes and failures.

3.3. The Impact of GDP Growth on the Environment

When economists think about the relationship between GDP growth and the environment, they often point to the environmental Kuznets curve. As income rises over time, some indicators of local environmental quality (e.g., drinking water quality, SO_2 emissions) first become worse (or environmental pollution first becomes more serious), but then they become better after the

GDP per capita in the country or region reaches certain levels. This stylized fact is called the environmental Kuznets curve, as shown in Figure 1, where the vertical axis is environmental degradation instead of environmental quality. Many observers have noted, however, that this curve does not fit many other indicators of environmental quality, such as soil fertility and fisheries, as well as GHGs. While the richer countries today are indeed reducing the levels of pollutants such as sulfur dioxide, ozone, or DDT, most are still raising their level of CO_2 emissions per capita.

Figure 1. An Environmental Kuznets Curve



We note that the environmental Kuznets curve is the subject of vigorous debate in the economics literature (e.g., Levinson 2001). Nonetheless, it is useful to invoke this phenomenon to think about the driving force behind the decoupling of most pollutants and GDP growth in developed countries and the meaning of green growth.

GDP growth affects the environment through the scale effect, composition effect, and technology effect (Grossman and Krueger 1995). The scale effect refers to the observation that more pollutants are produced as more goods are produced. The composition effect refers to the fact that some sectors (e.g., service) are cleaner than some other sectors (e.g., manufacturing), and that a shift in the structure of the economy will lead to a change in the environmental indicator. The technology effect refers to the fact that better technology produces less pollutants per unit of product. Developed countries are consuming more goods over time, and thus the scale effect alone would have worsened the environment, so why is it that most pollutants exhibit a declining trend in developed countries? Unfortunately, the economics literature has not provided rigorous evidence to address this important question. We offer a few thoughts below.

One important factor in the decoupling of GDP growth from most pollutants in developed countries is the composition effect. The European Commission, for example, states that "the change in the relative importance of the three sectors [of] agriculture, industry and services over the last centuries—the change itself driven by changing factor endowments, technological progress, market saturation and changing needs of the population—is definitely the most important force behind the changing pollution intensity of economies: with the emergence and rapid growth of dirty heavy industries and industrialization, the pollution intensity typically skyrockets, and the emergence and rapid growth of the cleaner service sector then reverses this trend" (2004, 322). We note that some of the change in structure of economic activity is due to the increasing imports of manufactured goods into developed countries from developing ones. Some of the reduced pollution in the rich countries is really offset by the increased pollution in other countries. These changes in composition are due in part to natural effects of development and in part to policy choices.

Another important factor is technological progress, which could have resulted from innovations in general or innovations generated by environmental regulations.

3.4. Some Criticisms of Green Growth

In this section, we want to note the doubts expressed by various prominent economists about the practical significance of the various channels through which environmental policy might positively affect GDP growth. For example, Schmalensee (2012) is highly critical of the claim that the greening of economies can be a new engine of growth in the world today, saying, "The main arguments that have been offered in support of that assertion and of policies based upon it do not stand up to close scrutiny" (2012, S4). Toman writes that the "synergy between economic growth and environmental sustainability might be more extensive than implied by standard economic theory. However, it is not possible to address their practical significance without more empirical research than is currently available. Consequently, some claims of substantial win-win opportunities between growth and the environment may be premature" (2012, abstract).

Resnick et al. (2012) note that proponents of green growth provide many win-win examples to justify green growth, but such examples are typically at the household or project levels. They emphasize that green growth, as a national development strategy, poses more trade-offs than are actually acknowledged for two reasons. First, to be on a green growth path, countries often need to deviate from the prescriptions of conventional development theory and their comparative advantage. This change of development strategies may generate sizable

benefits in the long run, but it is extremely costly in the short run. Second, the short-term costs of the green growth strategies, they argue, will generate substantial antireform coalitions that may include both the poor and the powerful, making green growth strategies politically difficult to implement. The authors use the cases of Malawi, Mozambique, and South Africa to illustrate their arguments. These three African countries are engaged in development strategies that involve chemical fertilizers, biofuel production, and coal-based energy, respectively. These strategies are not green, but they address critical development needs (e.g., food security, fuel, and electricity) and allow each of the three countries to pursue its comparative advantage in terms of resource availability. Resnick et al. argue that green growth "would not only be economically costly but also generate substantial domestic resistance, especially among the poor" (2012, 215).

4. Green Growth in China

4.1. Major Energy and Environmental Issues in China

China's GDP grew from 3.43 percent of global GDP in 2000 to 11.35 percent in 2012.[16] Its per capita income of US$6,100 in 2012, or US$11,000 when measured in purchasing power parity (PPP), puts China in the category of middle-income countries along with South Africa (US$12,200), Egypt (US$10,900), and Thailand (US$13,800). Along with the spectacular economic growth, China also has been experiencing rapid growth in energy consumption and overtook the United States to become the world's largest energy consumer in 2010. China accounted for only 10.5 percent of global energy consumption in 2000 but 21.9 percent in 2012 (BP 2013). According to the National Bureau of Statistics of the People's Republic of China (NBS 2013), coal has been China's dominant source of energy, accounting for 66.6 percent of the country's total primary energy consumption in 2012.[17] The US Energy Information Administration reports that China accounted for 46 percent of global coal production and 49 percent of global coal consumption in 2012.[18]

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[16] Gross domestic product by country in 2012 and 2000 from http://databank.worldbank.org/data/download/GDP.pdf and http://www.pdwb.de/archiv/weltbank/gdp00.pdf.

[17] The shares of oil and natural gas are, respectively, 18.8% and 5.2%, and the share of hydropower and nuclear together is 9.4%. NBS (2013) reports the percentage of energy sources by two methods: calorific value calculation and coal equivalent calculation. We are reporting percentages calculated from the second method.

[18] http://www.eia.gov/todayinenergy/detail.cfm?id=16271&src=email.

With its heavy reliance on coal for energy, China has become the world's largest CO_2 emitter, starting in 2006 (PBL n.d.).[19] In 2012, China's total CO_2 emissions were about 9.9 billion tons, accounting for 29 percent of global CO_2 emissions. This is larger than the combined emissions from the United States (16 percent) and EU-27 (11 percent). China's CO_2 emissions per capita, at 7.1 tons, is now close to the EU-27's (7.4 tons), although still less than half of the US rate (16.4 tons) (Olivier et al. 2013).

China's air, water, and soil have been polluted to alarming degrees. Many Chinese cities have suffered from heavy smog in the past two years. In March 2014, China's Ministry of Environmental Protection (MEP) announced that only 3 out of the 74 large Chinese cities it monitored met official standards for air quality in 2013. The following month, China's Ministry of Land and Resources (MLR) reported that the quality of groundwater was "poor" in 43.9 percent of the 203 prefectures in China and "very poor" in 15.7 percent of the prefectures. In the same month, MEP and MLR (2014) jointly announced that 19.4 percent of the farmland in China was contaminated.

The Chinese government has made substantial efforts to control pollution through the MEP and its predecessors, the State Environmental Protection Administration (SEPA) and National Environmental Protection Agency (NEPA) (see, e.g., Vennemo et al. 2009). Nielsen and Ho (2013a, 2013b) point out that the country's SO_2 emissions fell sharply between 2006 and 2010, with an estimated benefit of 74,000 fewer cases of premature mortality.[20] They also note China's enormous efforts to decarbonize the energy system: in less than 10 years, the country has achieved the world's largest wind power capacity, with plans to triple this by 2020, and it also plans to multiply nuclear capacity six fold between 2005 and 2020. These current efforts, however, have not matched the scale and complexity of the pollution problem.

[19] See also World Bank World Development Indicators database, CO_2 Emissions (kt), http://data.worldbank.org/indicator/EN.ATM.CO2E.KT?page=1. These figures refer to CO_2 emissions from fossil fuel use and cement production.

[20] The reduction in SO_2 emissions during the 11th five-year plan (2006–2010) is attributed partly to the successful implementation of the policies to require FGD equipment and to shut down small, inefficient plants. The US-China Joint Economic Study (JES 2007) estimates that the FGD policy has a benefit-to-cost ratio of 5 to 1.

4.2. What Led to China's Rapid Economic Growth and Environmental Degradation?

To understand China's spectacular economic growth and its environmental failures, as well as determine how the country can begin to grow more sustainably, it is necessary to understand China's institutional reward system. According to Xu (2011), who offers an overview of a large body of literature on this topic, China's governance structure can be characterized by economic decentralization and political centralization. Economic decentralization refers to a governance structure in which subnational (or regional) governments are directly responsible for, and deeply involved in, developing the economies within their jurisdiction, and subnational governments carry out most of the government functions. Political centralization refers to a governance structure in which the national government controls not only ideology and the media, but also the personnel matters of subnational governments through its cadre evaluation system. Using this system, the central government directly appoints, evaluates, and dismisses key provincial leaders, and each tier of subnational government appoints and evaluates lower-level government officials.

This economically decentralized and politically centralized system provides government officials, who are motivated by career concerns, powerful incentives to perform by promoting those with better performance. This system promotes regional competition in economic development and regional experiments in economic reforms, and this is a major reason why China experienced rapid economic growth in the past, even though many consider the country as having poor legal protection of property rights, poor corporate governance, and weak rule of law.

In the past, however, the cadre evaluation system has put far more emphasis on GDP growth than on environmental protection (Wang 2013). In this system, performance targets are separated into targets with veto power, hard/binding targets, and soft/guidance targets. Social stability and the one-child policy had long been targets with veto power, the most important type of targets. Failure to meet these veto targets results automatically in punishment, and poor performance on these targets cannot be compensated by good performance on other targets. Economic growth has long been a hard/binding target, while environmental goals have been soft targets in the past.

To increase their chance of promotion, government officials respond to this evaluation system by focusing more on economic growth than on environmental protection. There is empirical evidence to suggest that provincial leaders' economic performance (i.e., GDP growth rate) relative to the national average had a significant impact on the probability of their promotions (e.g., Li and Zhou 2005; Chen et al. 2005). There is also some evidence that

spending on environmental amenities negatively affects city-level officials' odds of promotion (e.g., Wu et al. 2013).

Many observers hold the view that the coverage and enforcement of environmental laws in China have been weak in the past. A major underlying reason is simply that, in the words of Xu, "the central government, subnational governments, and citizens [all agree] that economic growth was the most important objective of China's economic reform. Under that consensus, other objectives can be overlooked so long as the economy grows rapidly" (2011, 1129).

There are other policies that motivate government officials to focus on the growth of GDP, especially the growth of energy-intensive and high-emissions industries, instead of environmental protection. One such policy is China's fiscal system. About half of the tax revenue in China comes from value-added tax, which is directly related to the growth of industry. In addition, subnational governments' tax revenue is not commensurate with local government expenditure responsibilities. According to the World Bank (2012), subnational governments are responsible for 80 percent of government expenditure responsibilities but receive only slightly more than 40 percent of tax revenue. Local governments thus have a strong incentive to find additional revenue to finance their expenditures and a very weak incentive to invest in environmental protection.

Another such policy is the below-market prices of natural resources, including energy, land, and water, and of capital (e.g., interest rates). The low prices of natural resources and capital lead to economic growth that is intensive in resources and capital.

4.3. Implications for China's Green Growth Strategies

For China to be on a green growth path, it is thus not sufficient to simply introduce environmental and resource policies at the national level; environmental protection has to be emphasized more in the cadre evaluation system. Indeed, the consensus in the past that economic growth was more important than environmental protection has gradually broken down as China's economy continues to grow and many indicators of its environment continue to worsen. As a result, environmental protection has gradually become more important in cadre evaluation.

In the 11th five-year plan (2006–2010), several environmental targets became hard/binding targets for the first time, including a 10 percent reduction in sulfur dioxide emissions and in chemical oxygen demand releases and a 20 percent reduction in energy intensity. Subnational governments took substantial action to meet these hard/binding targets. For example, by the end of 2010, subnational governments had shut down about 70 gigawatts of

small, "backward" thermal power plant capacity (Wang 2013). The 12th five-year plan contains more binding environmental targets, including a 17 percent reduction of carbon intensity. See Hu (2012) for a more detailed comparison of the environmental targets in the 11th and 12th five-year plans.

In December 2013, the Organization Department of the Communist Party of China announced that it would modify the cadre evaluation system.[21] The announcement states that GDP growth should not be the only main criterion in evaluating government officials, and that more weight should be given to environmental protection, resource efficiency, overcapacity elimination, and a number of other social and economic considerations.

A more nuanced cadre evaluation system would certainly help protect the environment, but this system, as with other multitask principal-agent problems, has weaknesses. For example, it is difficult and controversial to measure nonmarket activities due to incentive and technical problems. China's failed green GDP experiment during 2004–2006 was an attempt to take into account environmental costs when evaluating the performance of government officials, but unfortunately, that initiative faced strong opposition and quickly failed (Li and Lang 2009). The binding environmental targets in the 11th five-year plan were met, but they led some local government officials to fake data and take highly inefficient measures (Wang 2013). Xu (2011) offers a number of suggestions on how to improve the cadre evaluation system, including that responsibilities for activities with strong cross-region externalities should be centralized and regulated by specialized ministries and that many monitoring and law enforcement functions should be separated from subnational governments.

The cadre evaluation system has inherent weaknesses, so it is also important to strengthen environmental laws and law enforcement. Indeed, environmental laws are being strengthened in China. In April 2014, the Standing Committee of the National People's Congress approved major amendments to its Environmental Protection Law, the first since the law was enacted in December 1989. One of the critical revisions is to replace the previous one-off limited fine system with a new fine penalty system in which the amount of the fine continues to accumulate for each day the pollution violation continues. Another is that nongovernmental organizations (NGOs) can take legal actions against polluters on behalf of the public interest.

[21] http://news.xinhuanet.com/politics/2013-12/09/c_118484309.htm.

As to the choice of green strategies, we have noted above that while the current efforts have been substantial, they have not matched the scale and complexity of the pollution problem generated by rapid economic growth. Many proposals have been put forward to address particular aspects of the air, water, and solid waste pollution problem. Goulder (2005) discusses how fiscal instruments and "technology-push" policies are important components of the policy toolkit in addition to direct emission controls. Ho and Jorgenson (2007) discuss the use of fuel and Pigovian taxes based on environmental damages in China and the modest impact on GDP.

One strand of the pollution policy literature emphasizes that reducing coal use will reduce both local pollutant emissions and CO_2 emissions. Aunan et al. (2007) estimate that a carbon tax that aims to reduce CO_2 emissions by up to 17 percent may have negative costs. That is, the ancillary benefits to reduced health and agriculture damages are greater than the costs of lower GDP and consumption. Nielsen and Ho (2013a) estimate that a carbon tax of about 27 yuan/ton would reduce CO_2 emissions by 12 percent and premature mortality by 19,000 to 100,000 cases per year. Such a modest tax is estimated to reduce GDP by a small 0.2 percent. These two studies are only representatives of a large number of studies on how a carbon price policy may contribute to a low-carbon green path in China.

The green exploitation of natural resources such as forests and fisheries is another important strand of literature. Xu et al. (2010), for example, describe China's bold new forest policy and provide recommendations for improvement. They point out the need to improve the participation of households in the collective decision-making process, and the need to establish a regulatory environment which clearly guides land allocations. CCICED (2010) discusses policy changes to strengthen ecosystem protection, including sustainable ocean development.

4.4. A Summary of Green Growth Policy Issues in China

We highlight here what we believe are the implications of the literature reviewed in this section.

i. China followed a development path that is similar in many respects to the experience of the developed countries: the initial emphasis was on raising incomes over environmental protection.

ii. China is now a middle-income country with severe degradation of air and water quality in many parts of the country. The earlier consensus of focusing on economic growth over environmental protection has broken down. While environmental protection efforts have been substantial and officials make frequent references to the

need for further action, these actions have not matched the immense scale of the problems.

iii. The costs and benefits of environmental policies are often difficult to estimate; however, there are some obvious areas where the benefits are likely to be much larger than the costs. Current levels of air pollution in China are comparable to the worst levels in the earlier period of the developed countries' experience. These richer countries have reduced air pollution and found that such policies brought huge net benefits: the improved health is clearly worth the costs of emissions reduction. Many studies have also reached such a conclusion for Chinese air pollution reduction.

iv. Higher production costs and product prices as a result of reducing pollutant emissions are the appropriate outcomes under an efficient "polluter pays" principle. The costs of adjustments (e.g., the costs of relocating workers) may be reduced by an active assistance program. While these costs do imply a smaller share of output going to consumption, the impacts on GDP growth and employment are likely to be small.

v. Other policy changes are often recommended as having large environmental (and net) benefits—"getting the prices right"—such as the elimination of energy price subsidies. Such policy changes have big distributional impacts and need a well-designed system of parallel compensation policies to gain support among the people, as shown by the experience of other countries. Lessons also can be learned from other countries about designing policies to prevent unsustainable overexploitation of forests, fisheries, and other natural capital. Technology-push policies (e.g. R&D subsidies) are often noted as important complements to traditional command-and-control policies.

vi. The efficacy of energy efficiency and renewable energy policies intended to lower use of coal, and thus lower local pollutant and CO_2 emissions, are less obvious and more widely debated, pointing to the need for a system of continual evaluation and adjustment.

vii. The implementation of any of the above policies, or other green growth policies, requires a suitable regulatory structure. Various recommendations for reforming the governance institutions to avoid the previous lack of incentives for local officials to protect the environment—revising the criteria for promotion, centralizing some regulatory and monitoring functions, reforming the financing of environmental protection bureaus—should be carefully studied and debated.

viii. Many international development organizations have emphasized the need to consider the social pillar of sustainable development, an *inclusive* green growth definition. This emphasis on simultaneous attention to improving the lives of the poor, in addition to making growth green, is in line with the Chinese government's stated goals of "social fairness and justice." The actual implementable policies to achieve such inclusive green growth are, however, still to be developed. Studies have noted that green development strategies that require a deviation from the traditionally recommended path of exploiting a country's comparative advantage could impose severe short-run costs, particularly on the poor.

5. Conclusion

There is a growing realization among governments, including China's, that the traditional sole focus on economic growth is unsustainable. International development organizations and NGOs are advocating a strategy that emphasizes efficient use of resources and protection of the environment and natural capital. Many argue that it is both possible and imperative to develop strategies that both promote material well-being and protect the environment. Even those who are skeptical of finding such policies advocate good environmental and resource policy design that efficiently balances material consumption with the maintenance of healthy air, water, and other ecosystems. China's rapid growth in real incomes gives it much more leeway in making such trade-offs than is possible for other developing countries.

While the idea that there are no trade-offs between growth and the environment may be controversial, the ideas that specific projects can be win-win and that certain types of policies, such as removing energy subsidies, can be win-win with a proper set of supplementary redistributive policies are well accepted.

For China's leaders, green growth, meaning sustainable growth with less polluted air and water, is now a necessity. To make this happen, changes in China's institutional rewards system and governance structures are seen as key. China's leaders seem to have started down this path of reform, however, the scale of the problems requires greater efforts and some fresh thinking and experimentation.

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