Are There Limits to Green Growth?

Edward B. Barbier

Key Points

- Of US$3.3 trillion allocated globally worldwide to fiscal stimulus in response to the 2008-9 Great Recession, US$522 billion was devoted to green expenditures or tax breaks.
- Environmentally motivated subsidies could become an obstacle to green economic development over the long term if they lead to distortionary incentives and inefficiencies, lack of competitiveness and over-use.
- It is estimated that phasing out all fossil fuel consumption and production subsidies by 2020 could result in a 5.8% reduction in global primary energy demand and a 6.9% fall in greenhouse gas emissions.
- Revenues from eliminating subsidies and implementing market-based incentives for green innovation could be used to establish a Green Economy Innovation and Investment Fund (GEIIF) to foster a structural transformation.

Introduction

In recent years, there is an emerging view that the risks, instabilities and recent crises faced by the world economy, most notably the 2008-9 Great Recession, can stimulate a transition to a "greener" economy. For example, according to UNEP (2011, p. 8):

> *"This recent traction for a green economy concept has no doubt been aided by widespread disillusionment with our prevailing economic paradigm, a sense of fatigue emanating from the many concurrent crises and market failures experienced during the very first decade of the new millennium, including especially the financial*

> *and economic crisis of 2008. But at the same time, we have seen increasing evidence of a way forward, a new economic paradigm – one in which material wealth is not delivered perforce at the expense of growing environmental risks, ecological scarcities and social disparities."*

According to this view, a *green economy* results in "improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP 2011, p. 9). Consequently, the transition from the economy today to a green economy is often referred to as *green growth*, which means "fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies" (OECD 2011). [1]

Proponents of green growth suggest that the transition is already on the way, and point to the use of green fiscal measures during the Great Recession and the emergence and expansion of green sectors as evidence. Although such progress is encouraging, a review of the impacts of the green stimulus policies, their aftermath and the current challenges facing the expansion of green sectors suggests that we are still a long way from an economy-wide green growth transition. In other words, in the current policy climate, there are still significant limits to green growth that will prevent it from ushering in a new wave of sustainable industrial innovation, R&D and employment that ultimately replaces the brown economy.

However, identifying the current limits to green growth is important, as it helps us address a critical policy question: What should the policy agenda be, beyond the green stimulus measures of the 2008-9 Great Recession, if we are to foster economy-wide green growth?

To address this question, this paper first briefly reviews the scope and impact of the green stimulus policies enacted during the Great Recession. The paper then provides an overview of the current state of the emerging green economy in key countries. The paper next discusses the key limits to green growth. The biggest obstacles are major market disincentives,

[1]See also the various documents and reports available at the Green Growth Knowledge Platform http://www.greengrowthknowledge.org/.

especially the under-pricing of fossil fuels and market failures to spur green innovation. Whether these limits can be overcome will depend crucially on the policy choices made in the coming years and decades. A three-part strategy to sustain green growth would involve, first, removing fossil fuel subsidies, second, employing market-based instruments to further reduce the social costs of fossil fuel use, and third, allocating any resulting revenue to public support for green innovation and investments. Such a strategy would ensure that green growth is not just about promoting niche green sectors, but instigating economy-wide innovation and structural transformation.

Green stimulus during the Great Recession

A unique feature of the global policy response to the 2008-9 recession is that, as part of efforts to boost aggregate demand and growth, some governments adopted expansionary policies that also incorporated a sizable "green fiscal" component. Such measures were wide ranging, including support for renewable energy, carbon capture and sequestration, energy efficiency, public transport and rail, and improving electrical grid transmission, as well as other public investments and incentives aimed at environmental protection.

Table 1 indicates the total green stimulus worldwide and by 10 major economies that adopted these measures plus the European Union, which implemented its own package separately from its member countries. Of the US$3.3 trillion allocated worldwide to fiscal stimulus over 2008-9, US$522 billion was devoted to such green expenditures or tax breaks. Almost the entire global green stimulus was by the Group of 20 (G20), which comprise the world's twenty largest and richest countries.[2] In fact, just four economies – China, the United States, South Korea and Japan - accounted for around 85% of the global green stimulus over 2008-9. China (42%) and the United States (23%) contributed nearly two thirds of the global expenditure on green fiscal stimulus, followed by South Korea (12%) and

[2] The members of the Group of 20 include 19 countries (Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, the UK and the US), plus the European Union.

Japan (8%). In comparison, the European Union contributed just over 4%, and Germany almost 3%, which was the most by any individual European economy.

Only a handful of economies devoted much of their total fiscal spending to green stimulus (see Table 1). South Korea earmarked nearly 80% of its total fiscal stimulus toward green measures, whereas China allocated around one third and Australia almost a quarter. In contrast, only 6% of the fiscal stimulus in Japan was for green expenditures and tax breaks. The North American economies spent approximately the same amount of their total stimulus on green measures: 12% for the United States, 10% for Mexico and 9% for Canada. In comparison, the proportion of fiscal stimulus allocated by European economies to green expenditures and tax break appears impressive (see Table 1), but only because their total fiscal spending was much lower. For example, although low-carbon investments accounted for the majority of fiscal spending by the European Union, total EU fiscal spending in general was small (US$22.8 billion), only 0.2% of GDP (Barbier 2010a).

Economies also differed substantially in terms of the share of gross domestic product (GDP) devoted to green stimulus (see Table 1). South Korea spent 5% of its GDP on its Green New Deal, and China just over 3% on its variety of green measures.[3] This is considerably higher than the global share across all countries of 0.7%. In contrast, Australia spent 1.3% of it GDP on green stimulus, and the United States and Japan spent around 1%. Finally, Canada allocated a much more modest 0.2% of GDP, and Mexico just 0.1%. European economies also spent only 0.1% to 0.3% of their GDP on green expenditures and tax breaks.

To summarize, most the world's green stimulus during the 2008-2009 Great Recession was realised in North America and East Asia. However, in North America, it was really only the United States that spent a significant amount on green stimulus; Canada and Mexico allocated much smaller amounts to these measures. Even in the three East Asian countries there were some important differences. Whereas South Korea and China devoted

[3] South Korea's Green New Deal included around US$19 billion for the Four Rivers Project, which includes plans to dam and dredge four major rivers, which could have some negative environmental impacts (Nubile 2010).

a large share of their total fiscal stimulus and GDP to green tax breaks and expenditures, Japan was much more conservative.

Table 1: Green stimulus during the Great Recession, 2008-9

	Green stimulus ($US billion)				Share (%) of green stimulus in:		
Economies	Low carbon power[a]	Energy efficiency[b]	Waste and water[c]	Total	Global total	Fiscal stimulus	GDP[d]
China	1.6	182.4	34	218	41.8%	33.6%	3.1%
United States	39.3	58.3	20	117.7	22.5%	12.0%	0.9%
South Korea	30.9	15.2	13.8	59.9	11.5%	78.7%	5.0%
Japan	14	29.1	0.2	43.3	8.3%	6.1%	1.0%
European Union[e]	13.1	9.6	0	22.8	4.4%	58.7%	0.2%
Germany	0	13.8	0	13.8	2.6%	13.2%	0.5%
Australia	3.5	6.5	0	9.9	1.9%	22.7%	1.3%
France	0.9	5.1	0.2	6.2	1.2%	18.2%	0.3%
United Kingdom	0.9	4.9	0.1	5.8	1.1%	16.3%	0.3%
Canada	1.1	1.4	0.3	2.8	0.5%	8.7%	0.2%
Italy	0	1.3	0	1.3	0.3%	1.3%	0.1%
Total G20	**105.3**	**330.1**	**78.1**	**513.5**	**98.3%**	**17.1%**	**0.8%**
Global total	**107.6**	**335.4**	**79.1**	**522.1**	**100.0%**	**15.7%**	**0.7%**

[a] Support for renewable energy (geothermal, hydro, wind and solar), nuclear power, and carbon capture and sequestration.
[b] Support for energy conservation in buildings; fuel efficient vehicles; public transport and rail; and improving electrical grid transmission.
[c] Support for water, waste and pollution control, including water conservation, treatment and supply.
[d] Based on 2007 estimated Gross Domestic Product (GDP) in terms of purchasing power parity, from the US Central Intelligence Agency The World Factbook, available at https://www.cia.gov/library/publications/the-world-factbook/rankorder/2001rank.htmle Only the direct contribution by the European Union is included.
The members of the Group of 20 (G20) include 19 countries (Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, the UK and the US), plus the European Union.

The emerging green economy

Over the past decade, progress in green growth for some economies has been promising, especially North America, East Asia and Western Europe. This may be due, at least in part, to the green stimulus enacted during 2008-9. However, even before the recession, nascent green sectors were emerging.

Today, there are five key sectors that are considered part of the burgeoning green economy:

- energy from renewable resources,
- energy efficiency,
- pollution abatement and materials recycling,
- natural resources conservation and ecological restoration, and
- environmental compliance, education, training and public awareness.

The first sector comprises electricity, heat, or fuel generated from renewable sources, such as wind, biomass, geothermal, solar, ocean, hydropower, and landfill gas and municipal solid waste. The second sector includes energy-efficient equipment, appliances, buildings, and vehicles, as well as products and services that improve the efficiency of energy storage and distribution. In the third sector, pollution abatement involves the reduction or elimination of pollution and hazardous wastes, whereas recycling materials involves the collection, reuse, remanufacturing or recycling of waste materials and water. In the fourth sector, natural resources conservation includes organic agriculture and sustainable forestry, land management, soil, water, or wildlife conservation, and storm water management, whereas ecological restoration is the practice of renewing and restoring degraded, damaged, or destroyed ecosystems and habitats in the environment by active human intervention and action. Finally, the fifth sector comprises products and services that enforce environmental regulations, provide education and training related to green technologies and practices, or increase public awareness of environmental issues.

In North America, the United States was an early leader in these green five sectors. Pew (2009) found that, between 1998 and 2007, jobs in the clean energy sector grew more quickly than overall US employment growth, and by 2007, accounted for over 770,000 jobs, or approximately 0.5% of employment in the United States.[4] The green sectors in the United States may now employ more than three million workers (ca. 3 percent of US

4 In comparison, Pew (2009) found that the biotechnology sector employed fewer than 200,000 workers, or approximately 0.1% of total US jobs in 2007, and the fossil fuel sector, including utilities, coal mining, and oil and gas extraction, employed 1.27 million workers in 2007, or about 1% of total US jobs.

employment), produce around 3 percent of gross domestic product (GDP), and have exceeded economy-wide GDP growth every year since 2000. [5]

In Canada, between 2007 and 2009, clean technology investments boomed by 47%, and by 2010 this sector employed 45,000 jobs (Sustainable Prosperity 2012). In 2013, there were over 730,000 environmental professionals in Canada, just over 4 percent of the labor force (ECO Canada 2013). The number of jobs in this area have grown ten-fold since 1993 and nearly tripled in the past ten years; in comparison, total Canadian employment from 2003 to 2013 grew only 13 percent (ECO Canada 2013).

Even before it adopted green fiscal measures, China viewed the promotion of green sectors as sound industrial policy, aiming to be the world market leader in solar panels, wind turbines, fuel-efficient cars, and other clean energy industries (Aizawa and Yang 2010; Ho and Wang 2015; Mathews 2012; Ping et al. 2013). By 2008, its renewable energy sector already had a value of nearly US$17 billion and employed close to 1 million workers (Barbier 2010a). From 2006 to 2010, the expansion of renewable energy in China may have resulted in a further 472,000 net employment gains, and in 2010, for every 1% increase in the share of solar photovoltaic generation there could be a 0.68% increase in total employment, larger than any other power generation technology in China (Cai et al. 2011). In December 2013, China announced that it would modify further the 12th Five-Year Plan (2011–2015), which already contains binding environmental targets such as a 17% reduction in carbon intensity, to give even more weight to environmental protection, resource efficiency, and other goals compatible with supporting green sectors (Ho and Wang 2015).

South Korea also sees its industrial strategy tied to green growth (Barbier 2010a; Hwang et al. 2014; Mathews 2012). In addition to the Green New Deal adopted during the Great Recession, the South Korean government established a US$72.2 million renewable energy fund to attract private investment in solar, wind and hydroelectric power projects. In July 2009, South Korea launched a five-year Green Growth Investment Plan, spending

[5] See the Green Goods and Services Survey of the U.S. Bureau of Labor Statistics. http://www.bls.gov/ggs/news.htm. Accessed on 2 February 2015, and Environmental Business International http://ebionline.org/ebj-archives/1944-ebj-v26n07-08. Accessed on 2 February 2015.

an additional US$60 billion on reducing carbon dependency and environmental improvements, with the aim of creating 1.5-1.8 million jobs and boosting economic growth through 2020 (Barbier 2010a).

Despite its relatively modest green stimulus during the Great Recession compared to China and South Korea, as early as the 1990s Japan developed a lead position in green manufacturing, especially for consumer durables, motor vehicles, parts and accessories, electrical equipment and other special purposes machinery (Fankhauser et al. 2013). This has allowed Japan to maintain a leading edge in these industries, and in green innovation overall.

In Europe, manufacturing in Germany appears to have benefited from green innovation, whereas other economies, notably Italy, may be lagging behind (Fankhauser et al. 2013). For example, Germany has used its existing capacity and innovations in high-precision machining to develop an early comparative advantage in wind turbines. After Japan, Germany has the strongest international record in green innovation, and continues to be well ahead of other European countries (Fankhauser et al. 2013). Germany is also well-known for adopting a feed-in-tariff system to promote electricity production from renewables, especially the adoption of solar power by homeowners (Böhringer et al. 2014).

To summarize, there is considerable progress in developing certain green sectors in North America, East Asia and Western Europe. These sectors are providing significant employment opportunities and contributing to overall GDP. However, whether these sectors can become the fulcrum for widespread green transformation and innovation in economies will depend critically on overcoming key policy challenges, which are becoming limits to green growth.

Limits to green growth

Perhaps one of the most limiting features of green growth policies is that, to be successful, they must eventually foster a degree of structural transformation and industrial development that is well-beyond simple expansion of the five green sectors identified above. For example, Fankhauser et al. (2013, p. 903) "interpret green growth as an economy-wide

transformation, rather than the expansion of the environmental goods and services sectors." The authors argue that there are several strategic sectors whose transformation is central to the creation of a green economy. These areas include industrial processes, which need to become cleaner and more resource efficient (e.g. iron and steel); sectors that are important for energy efficiency on the supply side (electricity distribution systems) and the demand side (domestic appliances); the energy supply chain for electricity generation and other industrial processes (steam generators; engines and turbines; electric motors and transformers); and car manufacturing (low-emission and electric vehicles) and key components (accumulators, primary cells and batteries).

Fankhauser et al. (2013) find that the "green race" to become global competitive leaders in these industries is between eight high-income or large emerging market economies – China, France, Germany, Italy, Japan, South Korea, the United Kingdom and the United States. Of the North American and East Asian economies, only Japan has a large number of sectors (61) with above-average green innovation, which accounts for two-thirds of the country's manufacturing output. In contrast, in the other seven economies, green innovation is occurring in at most of 20-40% of manufacturing. Japan also has the highest green innovation in its 15 largest manufacturing sectors. However, China has significant green innovation in its fabricated metal products, and Fankhauser et al. (2013, p. 906) maintain "that we should expect China's performance to improve as the objective of the five-year plan are implemented." South Korea has a competitive advantage and green innovation in basic chemical industries (excluding fertilizer) and special purpose machinery; the United States leads in electronic equipment manufacturing, basic chemicals, automobile parts and accessories, measuring/testing/navigating appliances, and aircraft manufacture.

Overall, Fankhauser et al. (2013, p. 911) conclude that, in developing a competitive advantage in green transformation and innovation, "public policy is important. A key challenge for the green economy is to overcome persistent market failures (e.g. on innovation) and externalities (e.g. pricing the environment), which requires well-designed and consistent public policy

intervention. Business decisions on investment and R&D in particular respond to such policy signals."

Similarly, the Asian Development Bank (ADB and ADBI 2013, p. 18) identifies "low-carbon green growth" in Asia as "a process of structural change", which envision patterns of industrial development, specialization and innovation, "thereby defining low-carbon development as the capacity of an economy to generate new dynamic activities". Thus, a major component of this strategy is to ensure the dissemination of low-carbon and energy-saving technologies, the adaption and dissemination of these technologies throughout the economy, support for infant green firms, government procurement policies to achieve mainstream emission reduction targets, and public sector investments to support these industrial developments. In other words, the approach advocated is to enhance economy-wide "green" structural transformation through a combination of "public investment and industrial as well as trade policies, aiming at encouraging in both cases a strong private sector response" (ADB and ADBI 2013, p. 19).

With the exception of China and South Korea, a major obstacle to green structural transformation in North America and East Asia is the "policy void" since the green stimulus policies enacted during the Great Recession. In North America especially, the expansion of the green economy could remain confined to a few niche sectors rather than lead to sustained, economy-wide green growth. Key difficulties include outdated utility business models, inadequate transmission infrastructure for renewables, and complications caused by decreasing energy and resource prices.[6] The clean technology industry in Canada is also under-funded by venture capitalism and public research and development (R&D) financing (Sustainable Prosperity 2012). China also faces unique obstacles, such as overcoming the reluctance of some provincial policy-makers to meet key environmental and green sector targets (Ho and Wang 2015). In addition, there is concern that, in the absence of implementing an economy-wide carbon tax and other complementary policies, China may have difficulty to achieving its ambitious green industrial

[6] See http://beforeitsnews.com/environment/2014/01/top-u-s-green-economy-trends-and-predictions-for-2014-2489240.html. Accessed on 2 February 2015.

strategy and greenhouse gas reduction targets (Lu et al. 2010). South Korea may also incur significant economic costs, if it tries to achieve its mid-term green growth targets without introducing policies that support economy-wide green innovation and technological change (Hwang et al. 2014).

These policy challenges are significant impediments to green structural economic transformation. This is due to two principal reasons (Barbier 2010b).

First, the boost to green sectors provided by the green stimulus measures enacted during the 2008-9 Great Recession is waning quickly. Almost two thirds of the global green stimulus was devoted to energy efficiency (see Table 1), much of which was aimed at boosting short-term employment and not promotion long-term structural transformation. In the major European economies, virtually all the green stimulus was for energy efficiency; in China over 80%; in Japan and Australia around two thirds; and in the U.S. and Canada, around half of green stimulus spending. Although very important to reduce overall energy use, energy efficiency investments not only have short-lived impacts on the economy but also are one-time investments. Once they have occurred and impacted productivity and jobs, these benefits are not repeated, and there is little subsequent generation of sustained and complementary green developments and innovations in the economy.

Second, major market disincentives to long-term development of the green economy exist in the form of distortionary policies. These include environmentally harmful subsidies, the absence of pollution taxes and other market-based incentives, and the lack of public investments to support private green R&D. Unless a greater effort is made to remove these major market disincentives, then the long-term prospects for green innovation and transformation in North America and East Asia may be severely hindered.

To summarize, the key challenge facing the expansion of economy-wide green innovation and structural change is the absence of relevant policy follow-up to the green stimulus enacted during the Great Recession. The boost to green sectors provided by the latter measures is fading, given that so much of the green stimulus focused on energy efficiency. But perhaps the most serious obstacles are major market disincentives, such as environmentally harmful subsidies, the absence of pollution taxes and other

market-based incentives, and persistent market failures to spur green innovation.

Under-pricing of fossil fuels

The most important market disincentive that is a significant deterrent to green structural transformation and innovation is the persistent under-pricing of fossil fuels. Current markets for coal, oil and natural gas, as well as for their key products – electricity generation, diesel and gasoline – not only exclude these environmental damages and other impacts, but the prices in these markets are frequently subsidized.

Barbier (2011) has documented how cheap and accessible fossil fuels – first coal and then oil and natural gas – were essential to the two phases of innovation that characterized the long process of industrialization that began around 1750. It was during this process, approximately around the middle of the 19th century, that the global spread of industrialization and the growing dependence of virtually every economy on the new sources of energy ushered in the fossil fuel era, which persists to this day. Thus, in the modern era, all economies have become entirely dependent on fossil fuels, and access to inexpensive supplies of these natural assets is considered strategically essential to economic development globally. Carbon-dependent development, mainly through the consumption of fossil-fuel energy, is the model of successful economic development to which all economies aspire.

The persistent under-pricing of fossil fuels is therefore a major market disincentive to green structural transformation and innovation. As noted in the introduction, a green economy aims to reduce carbon emissions and pollution, as well as enhance energy and resource efficiency (UNEP 2011). As long as fossil fuel markets are heavily subsidized and fail to account for pollution and other social costs, clean energy and low carbon investments, energy efficiency, and pollution abatement are placed at a competitive disadvantage.

Perhaps because of the association of fossil fuel energy use and economic development, under-pricing of coal, oil and natural gas remains a significant and widespread practice in the world economy. Yet, the result is also

considerable impacts on the environment and human health, with considerable economic costs. For example, researchers from the International Monetary Fund (IMF) have estimated some of these impacts and costs (Parry et al. 2014, p. 1):

- Increased outdoor air pollution, which comes primarily from fossil fuel combustion, and causes more than 3 million premature deaths each year worldwide, costing about 1 percent of annual gross domestic product (GDP) in the United States and 4 percent in China.
- Increased motor vehicle use, which leads to crowded roads, accidental deaths and injuries; traffic accidents already account for 1.2 million deaths worldwide.
- Greater greenhouse gas emissions, which is causing global climate change.

Current markets for coal, oil and natural gas, as well as for their key products – electricity generation, diesel and gasoline – not only exclude these environmental damages and other impacts but also the prices in these markets are frequently subsidized. Subsidies to consumers lower the prices paid for fossil fuels used in transport (e.g., gasoline and diesel), kerosene and natural gas used in homes, or fuels used in electricity generation or by domestic industries. In recent years, these subsidies have ranged between US$480 billion and US$548 billion globally, or approximately 0.7% of global GDP and 2% of all government revenues. [7]

Subsidies to producers occur when suppliers of fossil fuels receive higher than market prices in domestic markets, and include tax breaks, allowances for accelerated depreciation, and reduced royalty payments. These producer subsidies have proven more difficult to measure, although estimates suggest that they may range from US$80 billion and US$285 billion annually in developing and emerging market economies (Bast et al. 2012;

[7] The US$480 billion estimate for global fossil fuel subsidies is from Clements et al. (2013). This estimate is for 172 countries in 2011, and include consumer subsidies for gasoline, diesel and kerosene, consumer natural gas and coal subsidies (for 56 countries) and producer subsidies for coal (for 16 countries). The US$550 billion estimate for fossil fuel subsidies is from (IEA 2014). This estimate is for 2013 and includes subsidies to fossil fuels that are consumed directly by end-users or consumed as inputs to electricity generation. The share of fossil fuel subsidies in GDP and government revenues is estimated by Clements et al. (2013).

Whitley 2013). Oil and gas production subsidies in Russia are around US$14.4 billion annually, in Norway US$4 billion, Canada US$2.8 billion and Indonesia US$1.8 billion (Whitley 2013). In the United States, fossil fuel production subsidies have grown from US$12.7 billion in 2009 to US$18.5 billion in 2014 (Makhi Jani et al. 2014).

Related to production subsidies is government-provided support for fossil fuel exploration, which aims to find new oil, natural gas and coal resources and reserves. Between 2010 and 2013, the Group of 20 (G20) countries provided each year US$49 billion for investment by state-owned enterprises in these activities, US$23 billion in subsidies of direct spending and tax breaks, and US$16 billion in other forms of public finance for exploration (Bast et al. 2014).

Table 2 summarizes estimates of subsidies and under-pricing of fossil fuels in the G20 countries. Support for exploration amounts to approximately US$88 billion per year in these economies, and annual fossil fuel subsidies are a further US$187 billion, or approximately 39% of the global total. However, when further under-pricing is accounted for – tax breaks and the failure to take into environmental damages such as such the costs of climate change, local pollution, traffic congestion, accidents, and road damage – the losses in G20 economies amount to nearly US$1.3 trillion, which is over two-thirds of the world total. The United States alone accounts for US$502 billion in under-pricing, or over a quarter of the world total, followed by China with US$257 billion, or 14% of the world total. Fossil fuel subsidies comprise just under 1% of the world's GDP, and for 0.5% of ANNI in the G20 (see Table 2). However, the effects of overall under-pricing of fossil fuels amounts to 3.5% of GDP per year in the world economy, and 3% of annual GDP in the G20. But the economic costs are even higher in large emerging market economies: around 18% in Saudi Arabia, 10% in Indonesia and Russia, 6% in China and India, and 5% in South Africa. As these economies strive to industrialize and develop, the under-pricing of fossil fuels is actually imposing significant hidden costs on their populations.

Table 2: Under-pricing of fossil fuels, Group of 20 economies

	Annual exploration subsidies (US$ billion) 2010-2013a	Annual fossil fuel subsidies (US$ billion) 2011b	Share (%) of world total	Annual fossil fuel subsidies, tax breaks and environmental costs (US$ billion) 2011b	Share (%) of world total	Annual fossil fuel subsidies share (%) of GDP 2011	Annual subsidies, tax breaks and environmental costs share (%) of GDP 2011
Argentina	6.5	3.4	0.7%	7.7	0.4%	1.1%	2.4%
Australia	3.6	38.1	7.9%	26.5	1.4%	4.7%	3.2%
Brazil	12	0	0.0%	5	0.3%	0.0%	0.4%
Canada	3.5	21.1	4.4%	26.4	1.4%	1.7%	2.1%
China	11.5	0	0.0%	257.4	13.5%	0.0%	6.1%
France	0.06	0	0.0%	4.7	0.2%	0.0%	0.2%
Germany	0.5	2.7	0.6%	21.6	1.1%	0.1%	0.7%
India	4.6	25.8	5.4%	74.8	3.9%	1.9%	5.6%
Indonesia	0.5	21.8	4.5%	39.2	2.1%	5.4%	9.7%
Italy	0.7	0	0.0%	7.5	0.4%	0.0%	0.4%
Japan	6	0	0.0%	46	2.4%	0.0%	1.0%
Mexico	3	0	0.0%	27.6	1.5%	0.0%	2.8%
Russia	6	20.2	4.2%	92.8	4.9%	2.1%	9.8%
Saudi Arabia	17	44.5	9.3%	83.2	4.4%	9.4%	17.6%
South Africa	0.004	0.1	0.0%	14.4	0.8%	0.0%	4.8%
South Korea	3.1	0.2	0.0%	16.7	0.9%	0.0%	1.5%
Turkey	1	0.2	0.0%	7.5	0.4%	0.0%	1.2%
United Kingdom	2	0	0.0%	10.9	0.6%	0.0%	0.4%
United States	6.5	8.8	1.8%	502.1	26.4%	0.1%	3.6%
G20 Total	**87.9**	**186.9**	**38.9%**	**1,272**	**66.9%**	**0.4%**	**3.0%**
World	--	**480**	**--**	**1,900**	**--**	**0.9%**	**3.5%**

G20 is the Group of 20 countries. The members of the G20 include 19 countries (Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, the UK and the US), plus the European Union. The G20 total excludes the European Union.

[a] Bast et al. (2014). Exploration subsidies include government subsidies for exploration, public investment on exploration through state-owned enterprises, and public finance from domestic and international sources for exploration.

[b] Clements et al. (2013). Energy Subsidy Reform: Lessons and Implications. International Monetary Fund (IMF), Washington, D.C. Annual fossil fuel subsidies plus tax breaks for fossil fuels and the failure to price (tax) negative externalities, such as the costs of climate change, local pollution, traffic congestion, accidents and road damage. Gross Domestic Product (GDP) in constant 2005 US$), from World Development Indicators, http://databank.worldbank.org/data/databases.aspx.

Environmentally motivated subsidies

The prevalence of under-pricing natural capital through these market distortions creates another problem for the transition to a green economy. They provide the rationale for implementing *environmentally motivated subsidies* as the main policy for fostering the green economy: First, to counter the price advantage that under-pricing of fossil fuels gives to the brown economy, and second, to promote expansion of and employment in the emerging sectors of the green economy. But as such environmentally motivated subsidies become more pervasive, they fail to establish the appropriate incentives for efficient and sustainable use of natural capital.

The use of environmentally motivated subsidies, in the form of tax discounts, grants and soft loans, and tariff subsidies, to promote various green sectors in major economies is already large and increasing in number as well as in coverage (Barbier and Markandya 2012, pp. 114-119). [8] Table 3 indicates the subsidies used to promote a variety of green sectors and activities in ten major economies. These economies are all G20 members; unfortunately, there is yet no available information on environmentally motivated subsidies for the other G20 countries. As indicated in Table 3, the United States employs the most such subsidies across a range of activities. Mexico has just begun introducing environmentally motivated subsidies, and although Japan and Germany have the next lowest amount, their use in these countries has increased in recent years.

Some of these subsidies could be relatively minor in their impact, and others may be necessary. However, it is also clear from that every major green sector in major economies has already benefited from some form of subsidy (see Table 3). Employing subsidies to foster temporarily the expansion of nascent green sectors and industries may seem like a reasonable policy. Unfortunately, as the persistence of both fossil fuels and environmentally harmful subsidies in illustrates, once any subsidy is implemented, it becomes difficult to remove and thus often remains in place indefinitely. The growing and widespread use of environmentally motivated subsidies may in turn become an obstacle to green economic development

[8] The Organization of Economic Cooperation and Development tracks environmentally motivated subsidies for a number of economies at http://www2.oecd.org/ecoinst/queries/#, which is frequently updated.

over the long term. Just like any other subsidy, they can lead to inefficiencies, lack of competitiveness and over-use.

Table 3: Environmentally motivated subsidies in selected economies

Type of subsidy and activities supported	Australia	Canada	France	Germany	Italy	Japan	Mexico	South Korea	UK	USA
Grant										
Clean-up of earlier pollution		X						X		X
Energy saving	X	X		X	X				X	X
Investment in physical capital	X	X	X	X	X	X		X	X	X
Market penetration of clean products	X	X		X	X	X		X	X	X
Operation of treatment facilities						X			X	X
Research and Development (R&D)	X	X	X	X	X			X	X	X
Training of employees	X			X						X
Other		X		X	X	X			X	X
Soft Loan										
Clean-up of earlier pollution								X		
Energy saving	X	X	X							X
Investment in physical capital	X					X		X	X	X
Market penetration of clean products	X		X					X		X
Operation of treatment facilities						X		X		X
Research and Development (R&D)								X	X	
Other									X	X
Tax Reduction										
Clean-up of earlier pollution	X						X			X
Energy saving		X	X		X				X	X
Investment in physical capital	X	X	X		X	X	X	X	X	X
Market penetration of clean products		X	X		X	X		X	X	X
Operation of treatment facilities								X	X	X
Research and Development (R&D)			X					X		X
Other	X	X	X		X		X		X	X
Other										
Clean-up of earlier pollution		X								
Energy saving	X	X	X	X	X			X	X	X
Investment in physical capital	X	X	X	X	X		X	X	X	X
Market penetration of clean products	X	X	X		X				X	X
Operation of treatment facilities	X							X		
Research and development (R&D)	X							X		
Other		X		X					X	X
Total	**16**	**16**	**12**	**9**	**12**	**8**	**4**	**17**	**18**	**24**

Source: Organization for Economic Cooperation and Development (OECD). Database on instruments used for environmental policy. Environmental subsidies: Activities supported. Available at http://www2.oecd.org/ecoinst/queries/#. Accessed on March 16, 2015.

Market failures in green innovation

As discussed above, even among the major economies involved in the "green race" to become competitive leaders globally, economy-wide green innovation falls well short of the level necessary to generate structural transformation (Fankhauser et al. 2013). That is, under-investment in research and development (R&D) leading to widespread technological change may be a serious obstacle to the development of the green economy.

An important impetus for rapid economy-wide innovation is "technology spillovers", which occur when the inventions, designs and technologies resulting from the research and development (R&D) activities by one firm or industry spread relatively cheaply and quickly to other firms and industries. However, such technology spillovers also undermine the incentives for a private firm or industry to invest in R&D activities. The private investor bears the full costs of financing R&D, and may improve its own technologies and products as a result, but the investor receives no returns from the subsequent spread of these innovations throughout the economy. The consequence is that private firms and industries routinely under-invest in R&D, and the result is less economy-wide innovation overall.

Moreover, overcoming this disincentive cannot be achieved solely by the use of market-based incentives to correct inefficient pricing but requires the simultaneous implementation of "technology-push policies", such as research and development (R&D) subsidies, public investments, protecting intellectual property, and other initiatives (Acemoglu et al. 2012; Goulder 2004). Market-based incentives may reduce pricing distortions that put green goods and services at a competitive advantage. However, only technology-push policies directly address the tendency of firms and industries to under-invest in green R&D.

Goulder (2004) finds that reducing the costs of low-carbon energy adoption in the United States stems both from the boost to private sector R&D and from learning-by-doing as firms gain familiarity with new low-carbon technologies, products and processes. He identifies both a set of technology-push policies and a set of direct emissions policies that consistently induce additional technological change by supporting private R&D and learning-by-doing (See Table 4). However, Goulder also finds that

the direct emissions policies on their own cannot induce sufficient private-sector investment in innovations and learning-by-doing; rather, there needs to be complementary technology-push policies implemented as well.

Table 4: Induced innovation and public policies for reducing carbon dependency

Public policies for reducing carbon dependency	
Market-based incentives	**Technology-push policies**
Carbon taxes	Subsidies to R&D in clean energy technologies
Carbon quotas	Public-sector R&D in clean energy technologies
Cap-and-trade for greenhouse gas (GHG) emissions	Government-financed technology competitions (with awards)
Subsidies to GHG emission abatement	Strengthened patent rules

Source: Goulder (2004).

Studies for reducing greenhouse gas emissions in the United States, Asia and Europe show that combining the two types of policies substantially lower the costs of meeting targets compared to relying just on regulations or one set of policies (Acemoglu et al. 2012; ADB and ADBI 2013; Blesl et al. 2010; Fischer and Newell 2008; Hwang et al. 2014; Lu et al. 2010; Popp 2010). The optimal portfolio of policies generally includes some form of subsidies and other public support for technology R&D and learning along with carbon pricing and other direct emissions policies. Such an outcome is likely to extend to other sectors of the green economy, especially when spillovers of knowledge make it difficult for private investors in R&D to reap the full social benefits of their innovations.

Public support and investments may also be critical for other bottlenecks to green growth in economies (Barbier 2010a). One obstacle is inadequate transmission infrastructure for renewables, which can only be overcome through public investments to design and construct a "smart" electrical grid transmission system that can integrate diffuse along with conventional sources of supply. Another is the development of green-growth policies in urban areas that combine municipal planning and transport policies to foster

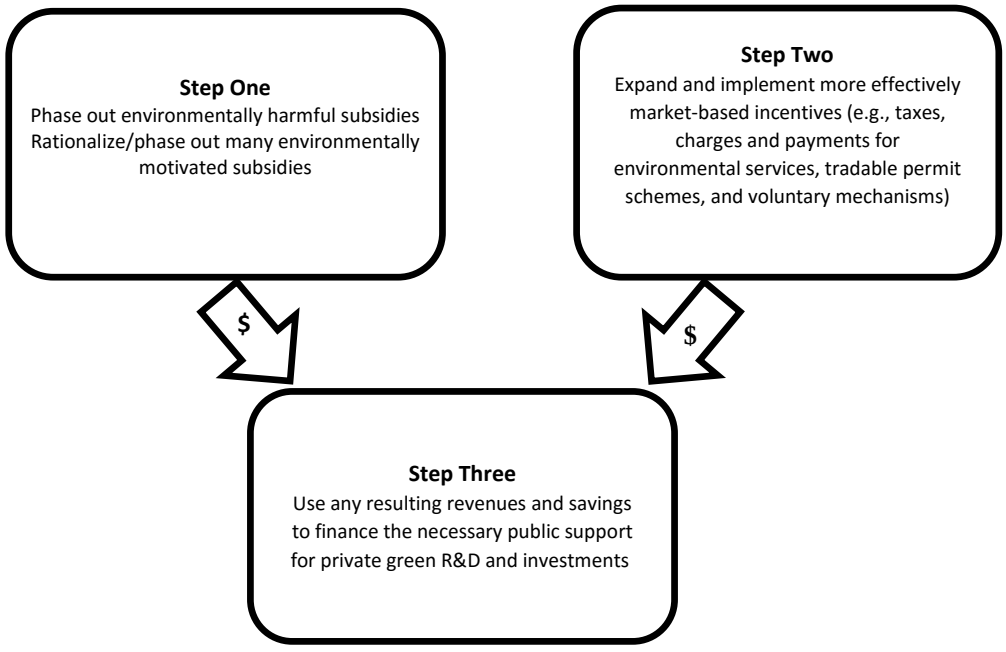
more sustainable cities. Finally, public investment in mass transit systems, both within urban areas and major routes connecting cities has been a long-neglected aspect of public infrastructure development throughout many economies.

A policy strategy to promote green growth

To summarize, the under-pricing of fossil fuels, the increasing use of environmentally motivated subsidies to promote green sectors, and the lack of public support for private green R&D and investments to overcome other obstacles to green growth are serious impediments that need to be addressed. Without comprehensive policies to eliminate these barriers to green structural transformation and innovation, the long-term prospects for developing more sustainable and green economies are bleak.

A comprehensive approach for promoting green innovation and structural transformation should be based on a three-part policy strategy to overcome these limits: phasing out fossil fuel and other environmentally harmful subsidies, and where possible, rationalizing or eliminating environmentally motivated subsidies; implementing various market-based incentives to correct any remaining under-pricing of fossil fuels; and finally, using any resulting financial savings and revenues to fund public support public for private green R&D and investments. This three-part strategy is outlined in Figure 1.

Figure 1: Policy strategy for green innovation and structural transformation



Step One: Phasing out environmentally harmful subsidies

The first-step requires phasing out environmentally harmful subsidies. As discussed above, with the case of fossil fuels, annual subsidies worldwide amount to just under US$500 billion annually, with around US$190 billion occurring in the Group of 20 (G20) comprising the twenty richest and large emerging market economies (see Table 2). Support for fossil fuel exploration amounts to an additional US$90 billion per year spent in the G20 economies. According to IEA/OPEC/OECD/World Bank (2010), phasing out all fossil fuel consumption and production subsidies by 2020 could result in a 5.8% reduction in global primary energy demand and a 6.9% fall in greenhouse gas emissions.

Environmentally harmful subsidies are also pervasive in other sectors, notably agriculture and fishing.

In 2013, support to agricultural producers amounted to US$258 billion in the countries of the Organization for Economic Cooperation and Development (OECD), which amounts to around 18% of gross farm receipts (OECD 2014).[9] In 2012, six other major agricultural producers – Brazil, China, Indonesia, Kazakhstan, Russia, South Africa and Ukraine – had farm subsidies totalling US$227 billion, with China alone accounting for US$165 billion in subsidies (Potter 2014). As these six countries plus the OECD members produce almost 80% of global agricultural value added, this suggests that agricultural output worldwide is heavily subsidized – with payments totalling around US$485 billion annually. In addition, it is the mainly rich and large emerging market economies in Asia, Europe and North America that account for 94% of global agricultural subsidies, with only 6% spent in the rest of the world (Potter 2014). Removal of such subsidies would improve the efficiency of agricultural production, boost the competitiveness of smaller producers and poor economies, and reduce environmental degradation, such as excessive conversion of forests, wetlands and other natural habitats to agriculture and pollution runoff from over-use of fertilizers, pesticides and other inputs.

Globally, marine fisheries receive around US$27 billion in subsidies annually, around 60% of which are considered environmentally harmful (UNEP 2011). One of the most damaging fishing activities globally is sea-bottom trawling, and it is estimated that fleets that engage in this activity receive about US$152 million per year, which constitutes around one quarter of the total landed value of the fleet (Sumaila et al. 2010).[10] As the the profit

[9] This means that for every dollar earned in revenues by OECD farms, 18 cents came from some kind of agricultural subsidy. The OECD member countries include: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, South Korea, Luxembourg, Mexico, The Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States. In fact, the agricultural subsidy rate for some individual countries is extremely high. According to OECD (2014), in the European Union, producer support is around 20% of gross farm receipts, and the share is even larger for Japan (56%), South Korea (53%), Norway (53%), Switzerland (49%), and Iceland (41%). The European Union (EU) estimate is for the 27 members; i.e., it excludes Croatia, which joined on July 1, 2013. The 27 EU members are: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and United Kingdom.

[10] As the authors estimate the profit earned by bottom trawl fleets is normally not more than 10% of landed value, removal of their subsidies will stop the activities of many of these fleets worldwide, thereby reducing the current threat to deep-sea and high seas fish stocks.

earned by bottom trawl fleets is normally not more than 10% of landed value, removal of their subsidies will stop the activities of many of these fleets worldwide, thereby reducing the current threat to deep-sea and high seas fish stocks.

As discussed previously, the use of environmentally motivated subsidies, in the form of tax discounts, grants and soft loans, and tariff subsidies, to promote various green sectors in major economies is already large and increasing in number as well as in coverage (see Table 3). Employing such subsidies to foster temporarily the expansion of nascent green sectors and industries may seem like a reasonable policy. Unfortunately, as the persistence and spread of subsidies for fossil fuels, agriculture and fishing illustrate, once any subsidy is implemented, it becomes difficult to remove and thus often remains in place indefinitely. Consequently, the growing and widespread use of environmentally motivated subsidies in many economies is worrisome, as they may become an obstacle to green economic development over the long term if they lead to distortionary incentives and inefficiencies, lack of competitiveness and over-use.

They may also, perversely, cause some environmental damages. For example, biofuel subsidies in the United States have been directly related to increased nitrate runoff, and energy efficient subsidies across North America, especially to households or for technology changes in transport, have sometimes led to increased energy use (Barbier and Markandya 2012, pp. 113-118). In other cases, subsidies might increase adoption rates of a green good or service, but without producing all the desired environmental and green development impacts. For example, a study of the German feed-in-tariff for renewable energy contributions to the electricity grid found that the subsidy did lead to growth in renewable electricity production; however, the policy did not reduce greenhouse gas emissions substantially, as renewable expansion led to too little abatement from other mitigation opportunities such as fuel switching, nor was there a significant boost to clean energy innovation (Böhringer et al. 2014). The equivalent subsidy used widely across North America – the Renewable Portfolio Standards (RPS) – could be producing similar outcomes.

Step Two: Implementing market-based incentives.

The second step in the strategy outlined in Figure 1 is to implement various market-based incentives to correct any remaining under-pricing of natural resources and resulting environmental damages. These include: taxes and charges for environmental services, tradable permit schemes, payments for environmental service (PES), and voluntary mechanisms.

A variety of environmental taxes and charges are currently employed in many high-income economies, including emissions charges, product charges (including deposit/refund schemes for recycling), and user fees for environmental services, natural resource use or waste disposal (Barbier and Markandya 2012, ch. 6).[11] However, most of these incentives are currently set at low rates or subject to many exemptions, so they do not reduce environmental damages significantly or provide sufficient incentives for economy-wide green investments. In addition, many taxes and charges are designed principally for raising revenues rather than for generating incentive effects. There are fewer cases of environmental taxes and charges in developing countries. Although taxes on petroleum products are the most common form of instrument, there is growing use of charges for pollution, solid waste and water supply use (Barbier and Markandya 2012, ch. 6).

The benefits to many economies of implementing more effectively taxes, charges and other environmental market-based incentives could be substantial. For example, as discussed previously, the environmental damages imposed by under-pricing fossil fuels are substantial, and include the costs of climate change, local pollution, traffic congestion, accidents and road damage. When these costs are added to fossil fuel subsidies, the overall global cost of under-pricing fossil fuels amounts to US$1.9 trillion annually, or 3.5% of global GDP (see Table 2).

Similar inefficient pricing exists in markets for key goods and services throughout many economies, including agriculture, water supply and use, natural resources and transport. To take one example – inefficient water pricing – this problem may be best be tackled by a variety of market-based

[11] The Organization of Economic Cooperation and Development (OECD) tracks a variety of environmental market-based instruments for a number of high-income and emerging market economies at http://www2.oecd.org/ecoinst/queries/#, which is frequently updated.

incentives, such as establishing water markets, tradable permit schemes, taxes and charges for water use and pollution, and payments for watershed services. Although the use of water markets and market-based reforms for a wide range of water sector applications is growing, there remain fundamental barriers to instigating such market-based incentives in many countries. Nevertheless, water pricing and institutional reforms, especially in agriculture, will be essential to controlling the growing problem of freshwater availability in many developing economies (Dinar and Saleth 2005; Dosi and Easter 2003; Easter and Archibald 2002; Schoengold and Zilberman 2007). In addition, greater efforts need to be made in all economies on developing and implementing water pollution charges, including permit fees, discharge levies and fines, as a means to discouraging excessive effluent discharges from point and non-point sources. The use of water quality trading schemes is occurring in some river basins in Canada and the United States, but the geographic coverage remains small (Horan and Shortle 2011).

Payments for environmental services (PES) are also emerging worldwide, but are still underutilized. PES are agreements whereby a user or beneficiary of an environmental service provides payments to individuals or communities whose management decisions influence the provision of that service. The main purpose of introducing payments for environmental services is to influence land-use decisions by enabling landholders to capture more of the value of these services than they would have done in the absence of the mechanism. However, existing PES schemes have largely focused on four services: carbon sequestration, watershed protection, biodiversity benefits and landscape beauty. Hydrological services from watershed protection tend to predominate, although land use and geological carbon sequestration schemes have expanded in recent years (OECD 2010).

Step Three: Using financial savings and revenues to support green innovation

The final step in fostering green innovation and structural transformation is to allocate the revenues saved or generated from eliminating or reducing subsidies and implementing various market-based incentives to overcome under-investment in green innovation (see Figure 1). Phasing out

environmentally harmful subsidies, and rationalizing or removing many environmentally motivated subsidies should provide funds to finance the necessary public support for private sector green R&D and investments as well other public infrastructure and programs necessary for green innovation and structural transformation. In addition, many market-based incentives, notably taxes, fees, charges, levies and auctioned permits, would raise revenues that could also be used to support green R&D and investments. For example, just based on the estimates for fossil fuels, agricultural and fisheries discussed here, removal of subsidies and employing market based incentives would raise globally:

- o US$1.9 trillion annually from ending the under-pricing of fossil fuels,
- o US$485 billion annually from eliminating agricultural subsidies, and
- o US$27 billion annually from eliminating subsidies to marine fisheries.

The revenues saved or generated from the phasing out of environmentally harmful subsidies, the rationalization or phasing out of many environmentally motivated subsidies, and the use of various market-based incentives could be used to establish a Green Economy Innovation and Investment Fund (GEIIF). The purpose of the GEIIF should be to finance the public support for private sector green R&D and investments as well other public infrastructure and programs necessary for green growth. For example, the GEIFF could fund a number of important technology-push policies, such as subsidies to green R&D by the private sector as well as complementary public-sector R&D, government-financed green technology competitions, and stronger patent rules (see Table 4). Important public investments to support the green economy would include development of a "smart" electrical grid transmission system that can integrate diffuse along with conventional sources of supply, municipal planning and transport infrastructure to foster more sustainable cities, and expanding of mass transit systems both within urban areas and major routes connecting cities.

Conclusion

Ultimately, whether green sectors remain just one small niche within an overall brown economy, or green growth ushers in a new wave of industrial innovation, R&D, and employment, requires ending the current "policy void" that has emerged since the Great Recession. As long as this void persists, harmful subsidies, inadequate pollution taxes and other market-based incentives, and the dwindling public support of private green R&D and investments, will continue to hinder economy-wide green development. Another concern is that green sectors are becoming overly reliant on environmentally motivated subsidies, which could be detrimental to green growth over the long run.

The three policy steps proposed in this paper aim to foster a more economy-wide effort at fostering green innovation and structural transformation. All three policies are essential to an integrated strategy, and as outlined and summarized in Figure 1, they are also interdependent: Step one involves phasing out fossil fuel subsidies, not only because this policy is relatively straightforward to implement but also because determining which additional market-based incentives to employ to end the chronic under-pricing of fossil fuels requires first assessing the environmental and economic consequences of subsidy removal. This pricing policy should be step two in the strategy. Finally, establishing a Green Economy Innovation and Investment Fund (GEIIF) to finance the necessary public support for private sector green R&D and investments should be the subsequent policy, because the Fund's financing should come from any revenues saved from subsidy removal or generated from market-based incentives.

As argued in this paper, green growth is not about promoting niche green sectors; it involves economy-wide innovation and structural transformation. Some economies have proven to be among the leaders in promoting certain green sectors and industries. Whether they can sustain, build on and expand this competitive edge in the near future will depend critically on developing a comprehensive policy strategy to promote private-sector green R&D and innovation that translates into economy-wide investments across a wide range of sectors and industries.

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