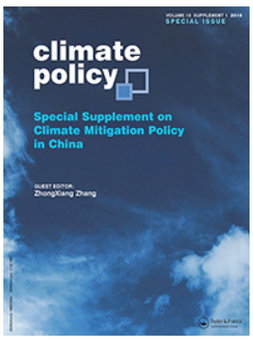

Climate Policy

ISSN: 1469-3062 (Print) 1752-7457 (Online) Journal homepage: http://www.tandfonline.com/loi/tcpo20

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To cite this article: Yongsheng Zhang (2015) Reformulating the low-carbon green growth strategy in China, Climate Policy, 15:sup1, S40-S59, DOI: 10.1080/14693062.2015.1094726

To link to this article: http://dx.doi.org/10.1080/14693062.2015.1094726

Vol. 15, No. S1, S40–S59, http://dx.doi.org/10.1080/14693062.2015.1094726

climate policy

synthesis article

Reformulating the low-carbon green growth strategy in China

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This synthesis article reviews China's efforts and effects concerning low-carbon green growth (LCGG) and explores the policy implications of reformulating the country's LCGG strategy. The article first reviews China's efforts in four major areas – carbon mitigation, market construction, fostering green industries, and managing the negative effects of LCGG – and then reviews China's LCGG effects with respect to the growth effect and the low-carbon effect. The results show that the increasingly stringent low-carbon policy has not diminished the country's economic growth as some had expected. Rather, the policy has fostered green industries and brought impressive quality improvements, including structural change and increased employment. Although the efforts and effects in China are impressive, the global emissions reduction is far from sufficient to achieve the global climate change target. To solve the problem of global climate change and seize the opportunity of green growth, China must reformulate its LCGG strategy, not just enhancing its existing LCGG efforts, but more importantly, rethinking the purpose of development and shifting its development paradigm from one that is highly gross domestic product (GDP)-oriented to one that is well-being-oriented.

Policy relevance

China must reformulate its LCGG strategy on two levels. First, China must enhance its existing efforts. Second, China should learn lessons from the industrial countries and reformulate its development model to one that is well-being-oriented to establish a more forward-looking green growth model in the new context of the Internet era. The time is now ripe for China to make a strategic transition. The 13th Five-Year Plan (FYP, 2016 to 2020) provides an opportunity for a more fundamental change in LCGG strategy. If China could succeed in exploring LCGG, it would make a significant contribution to the whole world.

Keywords: China; development paradigm shift; green growth; low carbon*JEL code*: O44; Q28; Q20; Q32; Q54

1. Introduction

Since the Industrial Revolution, modern economic growth has caused high levels of carbon emissions, pollution, and resource usage. Human activities in this growth model are driving the Earth's system beyond its safe operating space (Rockström et al., 2009). The past few decades, in particular, have seen explosive growth in GHG emissions. According to the third report in the Fifth Assessment series by the Intergovernmental Panel on Climate Change (IPCC, 2014), half of all CO_2 emissions emitted from 1750 to 2010 have been produced in the last 40 years. However, achieving the global temperature goal of a 2°c increase requires that global GHG emissions in 2050 be 40–70% below the

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2010 level and near zero in 2100. Governments must increase their efforts to mitigate the emissions pledged (at Cancun in 2010). Green growth has therefore become the ultimate solution for climate change. Although, to date, no standard definition of 'green growth' has emerged (Huberty, Gao, Mandell, & Zysman, 2011), the term has three dimensions – low levels of carbon emissions, material resource use, and a low environmental footprint (World Bank & DRC, 2012). This article focuses on the low-carbon dimension of green growth (hereafter LCGG).

As the second largest global economy and the biggest annual carbon emitter in the world, China's efforts towards LCGG are crucial to solving the global climate change problem. Initially, China's low-carbon endeavours were primarily driven by international pressure, but China's motivation to mitigate carbon emissions is currently based on the country's own interests (Boyd, 2012; Pan, 2010; Zhang, 2010), because the current growth pathway is no longer feasible and sustainable, and LCGG represents the future (World Bank & DRC, 2012).

The main concern for China is not therefore whether it should take a LCGG pathway, but rather identifying an effective LCGG pathway to achieve both growth and carbon mitigation targets. So far, most studies have focused on emissions and energy-related issues. For instance, Pan (2010) discussed the motivations, challenges, and options for China's low-carbon transformation. Boyd (2012) surveyed key central government documents and articles by China's leading energy academics to investigate the ideas influencing China's new energy and climate policies. Zhang (2010, 2014a) comprehensively catalogued China's efforts towards improving energy conservation, renewable energy use, and the development of clean coal technologies and nuclear power.

However, LCGG is more than an emissions and energy-related issue and requires a focus on a profound and comprehensive transformation of the development pathway. The purpose of this article is to review China's current efforts and their effects and, by rethinking the ultimate purpose of development, to propose a reformulation strategy for the country's LCGG efforts. The remainder of this study is organised as follows. Section 2 derives a conceptual framework for reviewing the LCGG strategy in China. Section 3 reviews China's LCGG efforts with respect to four aspects. Section 4 reviews the growth and carbon mitigation effects of those efforts. Section 5 shows that, in addition to enhancing existing LCGG efforts, a more fundamental development paradigm shift is required. The final section presents conclusions.

2. A framework for reviewing the low-carbon growth strategy

2.1. A conceptual policy framework

A conceptual policy review framework derived from the major green growth theories can facilitate a review of China's LCGG strategy. By definition, LCGG is growth with low carbon emissions. Although existing green growth theories are subject to different theoretical perspectives with varying methodologies, and the benefits from mitigation according to different studies vary from short term to long term and from local to global, the common prerequisite for the triggering of LCGG according to all theories is a *stringent mitigation policy*.

The first research stream, although not strictly green growth theory, is represented by the studies by Nordhaus (1993), Stern (2007), and Garnaut (2008). These authors define the economic benefit of mitigation as the damage avoided by reducing global emissions. Optimal global emissions reduction is the point at which the marginal cost equals the marginal benefit of mitigation (Nordhaus, 1993). Because

the damage to be avoided by current mitigation is primarily a future benefit, time discount rates are central to the debate. This is evident, for instance, in the Stern Review (2007) and the responses to it (e.g. Pindyck, 2013). One relevant type of study is a co-benefit analysis (e.g. Garbaccio & Jorgenson, 2000), which shows that carbon mitigation has substantial local co-benefits. The second major research stream is represented by the publications World Bank (2006), the United Nations Environment Programme (UNEP, 2011), and Hallegatte, Heal, Fay, and Treguer (2012), who apply the natural wealth approach based on Solow's growth model (Solow, 1956). This stream introduces natural resources into the production function, so the growth of a green economy with greater natural resources would be higher than that of a non-green economy (see UNEP, 2011, Annex II, for more details). The third major research stream is the endogenous innovation growth model represented by Acemoglu, Aghion, Bursztyn, and Hemous (2012), who show that government intervention has a short-term cost, but that long-term 'green growth' rates catch up to the 'non-green growth' rates. Another emerging research stream follows Adam Smith's notion of specialisation and the division of labour (Smith, 1776; Young, 1928), as well as its modern incarnation of infra-marginal analysis (see Shi & Zhang, 2012; Yang, 2001; Zhang, 2014b; Zhang & Shi, 2014).This research stream shows that a stringent carbon mitigation policy could possibly become a driver of economic growth because it might drive the economy to a more competitive structure of division of labour with higher productivity.

All green growth theories recognise that a *well-functioning market* is the foundation for LCGG. Specifically, three market levels are directly or indirectly related to LCGG. The first level is the market-based implementation of emission targets. The second is the market-based pricing of factors, for instance, to correct distorted prices for coal, electricity, gas, water, and other resource commodities and to eliminate various subsidies for traditional energy and resource commodities (Zhang, 2014c). The third market level is the fundamental market system.

A stringent mitigation policy and a well-functioning market are not sufficient for LCGG. The third element of LCCG policy is governmental support to foster green industries. Because some green industries are completely new, *government support* at the initial stages is crucial for their development. The various types of support include the building of green infrastructure, favourable taxes, subsidies, and research and development (R&D) support initiatives. For instance, Acemoglu et al. (2012) suggest a carbon tax for dirty innovation and production, and a subsidy for new technology. Additionally, new industrial clusters may require 'big push' development in which the government plays a significant role (Murphy, Shleifer, & Vishny, 1989; Rosenstein-Rodan, 1943).

The last major element is to *manage the negative effects of LCGG*. Although carbon mitigation is beneficial overall, some regions, sectors, and groups suffer in the 'creative destruction' process. Therefore, the government must carefully manage the negative impacts to avoid strong political impediments.

This study thus reviews China's LCGG policy with respect to four major elements: (1) stringent carbon policy as a stimulus; (2) a functioning market; (3) the fostering of green industries, and (4) managing negative effects.

2.2. Approach to low carbon growth

The right approach to implementation will ensure the effectiveness of the LCGG strategy. Government action, including an ambitious mitigation target and various support mechanisms, is a prerequisite for

LCGG. However, a vicious cycle or 'chicken and egg' dilemma exists: green growth requires strong governmental policy action and, for the risk-averse government, bold action requires sufficient evidence of successful green growth. Governments may therefore be reluctant to take firm action in the early stages of LCGG. Consequently, without strong action, evidence of green growth is slow to emerge (Zhang & Shi, 2014).

The key to breaking this vicious cycle is to introduce a *risk-reducing mechanism* that would encourage the risk-averse government to take early policy action. Once the process of LCGG is triggered, the process enters a virtuous cycle and becomes self-fulfilling, and the opportunity for LCGG can be seen (Zhang & Shi, 2014).

The following approaches can be used to reduce the risk of LCGG in China: pilot projects and regional experiments, the reduction of gross domestic product (GDP) weight for performance evaluations to local officials to increase willingness to try the alternative green pathway, the introduction of green insurance, and the implementation of clear and stable policies because political stability can reduce uncertainty and boost green R&D and investment.

3. China's LCGG efforts

China's LCGG strategy is reflected in a series of official documents. In the 18th Chinese Communist Party (CCP) Congress Report, ecological civilisation is prioritised and incorporated into the 'five-in-one' national development strategy together with economic, political, cultural, and social development. In 2014, a guide for ecological civilization construction was issued to operationalise the concept of ecological civilisation (CCP, 2015). Other major documents include the 12th Five-Year Plan (FYP, 2011–2015), the Working Plan for Greenhouse Gas Emissions Control in the 12th Five-Year Plan (State Council, 2011), China's Policies and Actions for Addressing Climate Change (NDRC, 2013), the National Plan in Response to Climate Change during 2013 to 2020 (NDRC, 2014), and the CCP Central Committee Resolution Concerning Some Major Issues in Comprehensively Deepening Reform (CCP, 2013).This section reviews the efforts regarding the four aspects proposed in the previous section rather than documenting the detailed measures.

3.1. Stringent carbon emissions policy in China

China's top leaders share a strong political consensus on a stringent carbon emissions mitigation policy and green development. This has meant that the carbon emissions policy in China is becoming increasingly stringent over time. Moreover, at the international level, although China, as a developing country, is not legally obligated to emissions reduction in the Kyoto Protocol, its carbon emissions policy is strict and obligatory domestically. The stringent emission goal is a necessary condition for LCGG, but what is more essential is how to deliver it.

Before the Copenhagen conference in 2009, China announced its carbon intensity reduction target of 40–45% of 2005 level by 2020. In the 11th FYP (2006–2010), a 20% reduction in energy intensity and other environmental goals were established as obligatory domestic objectives. In the 12th FYP (2011–2015), China set several more obligatory environmental goals, including a 17% decrease in carbon intensity. The State Council also created a specific Working Plan for Greenhouse Gas Emissions Control during the 12th FYP (State Council, 2011). In the Intended Nationally

Determined Contribution (INDC) submitted by China in 2015, the carbon intensity is further enhanced to a 60–65% decrease below 2005 level in 2030.[1]

Another significant step is a move from the intensity target to the cap target. Among the major measures, the notion of an energy cap was adopted in China's 12th FYP, and the nationwide severe air pollution crisis provided strong impetus for China to take unprecedented drastic measures to reduce coal consumption (a key source of both Particulate Matter 2.5 and CO_2). According to the Atmospheric Pollution Prevention Action Plan (State Council, 2013a), coal consumption is strictly controlled in China. The level of coal consumption in areas with severe air pollution (such as the Beijing–Tianjin–Hebei area, the Yangtze River Delta, and the Pearl River Delta) must be reduced in absolute terms. For instance, total coal consumption in Beijing, Tianjin, Hebei, and Shandong must be reduced by 83 million tons by 2017. China is expected to also introduce a carbon cap during the 13th FYP period (2016–2020).

A recent breakthrough was the US–China Joint Announcement on Climate Change, signed in November 2014,[2] in which China stated its intention to achieve peak CO_2 emissions around 2030, strive to peak early, and to increase the share of non-fossil fuels in primary energy consumption to approximately 20% by 2030. This is included in China's INDC.

Compared with international efforts, the efforts made by China are among the greatest in the world. Kartha and Erickson (2011) reviewed several studies comparing developed (AN1) countries' pledges to developing (non-AN1) countries' pledges under the Cancun Agreements, including Climate Analytics et al. (2010), Chen et al. (2011), Höhne et al. (2011), Erickson, Lazarus, and Larsen (2011), and Jotzo (2010). The authors found a consensus in the literature that developing countries' pledges amount to greater mitigation than developed countries' pledges.

China's efforts towards emissions reduction have been underestimated in several studies (Chandler & Wang, 2009; Houser, 2010; Levi, 2009; Qiu, 2009). As Jotzo (2010) clarifies, many standard business-as-usual projections take China's substantial emissions-reducing policies for granted. Höhne, Moltmann, and Hagemann (2010) summarise the underlying approach used in studies that find little ambition in China's pledge. If embodied carbon emissions are considered, it shows that greater effort has been made by developing countries including China (Zhang, 2012a, 2012b). Peters, Minx, Weber, and Edenhofer (2011) show that the US, Europe, and the remaining AN1 countries have all increased their net imports of embodied carbon from developing countries, and these increases have exceeded their Kyoto emissions-cutting targets. Davis and Caldeira (2010) show that net exports accounted for 22.5% of production-based CO_2 emissions in China in 2004. Peters et al. (2011) found that the production of Chinese exports accounted for 18% of growth in global CO_2 emissions. Pan, Phillips, and Chen (2008) estimate that 19% of China's production-based CO_2 emissions were embodied in trade in 2001, and that figure rose to 30% in 2006. Because the production-based emissions measurement underestimates China's efforts and contribution to global mitigation, a more holistic treatment would include reviewing the responsibility for embodied emissions.

3.2. Building the well-functioning market required for LCGG

The strict emissions target must be implemented on a flexible basis to minimise the cost of mitigation. However, at this stage, meeting China's stringent targets relies heavily on inflexible administrative measures. The country found it challenging to reduce its energy intensity by 20% during the 11th

FYP period (2005–2010) (Howes, 2010; Zhang, 2010). Fielding (2010) documented that, in 2010, the Chinese government resorted to ad hoc measures in an attempt to achieve this target. In a policy dubbed the 'iron hand', the government closed many industrial plants and rationed the electricity supply. Consequently, the target of emissions mitigation could not be optimally achieved, making compliance difficult.

To efficiently achieve provinces' targets, simply adjusting the disaggregation of the national mitigation target more on a capacity basis is not sufficient. Because the economically efficient level of actual emissions is unlikely to be exactly equal to its emissions entitlement for any region, flexible implementation is required. Without flexible implementation, some provinces had to take drastic action to meet the rigid targets, such as cutting off power. A flexible implementation includes diverse policy tools, such as an emissions trading scheme (ETS), carbon tax, regulation, and regional joint implementation. Each of these complementary policy tools has its own advantages and disadvantages.

In 2012, China accelerated pilot carbon ETSs in Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong, and Shenzhen. NDRC (2015a) provides a roadmap of nationwide ETS in China. The first stage was the preparation stage (2014–2015), and the second stage is a trial and improvement stage (2016–2020).The scheme will be initiated during the period 2016 to 2017 and will formally be in operation from 2017 to 2020. The third stage (post-2020) will focus on increasing the variety of trading products. Jotzo (2013), Jotzo and Loeschl (2014), and Zhang (2015) provide a detailed picture of China's existing carbon market.

For the enormous informal sectors and small and medium-sized enterprises (SMEs), carbon taxes and regulation are more effective and feasible (DRC, 2011). A large body of literature addresses the use of carbon tax in China. For example, the World Bank has simulated the effects of different levels of carbon tax in three scenarios (World Bank & DRC, 2012, appendix of supportive report 3).

Regarding the reforms for factor pricing, for example, in relation to water, electricity, and oil, there are two focuses. The first is to establish a market-based pricing mechanism, including the introduction of tier prices into water and implementing reforms for natural gas and electricity pricing. The oil price is regularly adjusted according to the international price. The second focus is to internalise the external costs into the factor price, including environmental costs and fossil fuel subsidy reform, etc.

China is also undertaking more fundamental efforts toward consolidating a functioning market economy for LCGG. In 2013, the CCP adopted a milestone package to comprehensively deepen China's reforms. Economic structural reform is the focus of reforms, and the core issue is to address the relationship between the government and the market (see details in CCP, 2013). The implementation of this package will provide a solid institutional framework for LCGG in China.

3.3. Fostering green industries

China hopes to become a world leader in fostering green industries. Broadly speaking, all industries with low direct or indirect carbon emissions are considered low-carbon industries. The 12th FYP focuses on seven emerging strategic industries: environmental protection and energy efficiency, new energy, next-generation information technology, biotechnology, high-end manufacturing, clean-energy vehicles, and high-tech materials, all of which show significant potential for future growth. Essentially, the seven industries all feature green technologies with high value-added potential. Growth in these areas will increase the competitiveness of China's economy. The purpose of this

article is not to elaborate on the detailed government efforts in promoting all green industries in China; instead it focuses on the seven emerging strategic industries and renewable energy in particular.

According to the Development Plan of Strategic Emerging Industries during the 12th FYP, the target is to achieve an average annual growth rate of 20%, with its value-added accounting for approximately 8% of GDP by 2015 and 15% by 2020, and for them to become national pillar industries, or leading industries, by 2020.The major measures taken by the government to achieve the goal include introducing 20 big national projects (e.g. a large broadband project, the Internet of Things, and cloud computing projects), taxation and finance support, R&D and talent support, and removing barriers through structural reforms and market consolidation.

For the renewable energy industry in particular, China's overall plan for energy development is detailed in the Energy Development Plan for the 12th FYP (2011–2015), the Guidance of Service Provision for Connection Distributed Renewable Electricity (State Council, 2013b, 2013c). The efforts include setting ambitious renewable energy targets, expanding domestic demand for renewable energy, introducing the feed-in tariff policy, fostering a distributed renewable policy, streamlining regulations, constructing large renewable energy bases, and building demonstration projects (see details in NEA, 2014; State Grid Company, 2013).

3.4. Managing negative effects

LCGG is beneficial overall, but it is also a laborious process of transformation during which particular sectors, regions, and groups are inevitably affected by stringent carbon emissions policies. First, high-emission industries such as power generation, coal gas, metallurgy, non-metallic mineral products, shipping, coal mining, and oil refining are likely to be directly affected. Although the carbon costs can be transferred to the downstream industries through price, not all prices are completely market-based. Moreover, these industries are usually overcapacity industries with fierce competition. Second, developed regions and underdeveloped regions have different types of problems. Some developed coastal regions based around heavy industries have been locked in traditional high-carbon pathways. For underdeveloped regions, the high-carbon path is no longer feasible, as it was for their developed counterparts. The so-called negative impact of low-carbon policy on poor regions could actually be a blessing because, thanks to their underdevelopment, their healthy environments are conserved, which is advantageous for green growth. Third, energy price increases are progressive rather than regressive, because high-income households use proportionately more energy than poorer households (World Bank & DRC, 2012). However, poor families usually use more coal, and living costs may increase as emissions policy becomes more stringent.

The government should therefore design policy tools to manage any negative impact. Elaborating on all the measures used to mitigate negative effects is difficult because the measures are scattered across various social and industrial laws and regulations, and many of the measures are not labelled as green policy. At this stage, some of the channels used to manage the potential negative impacts of LCGG policies include the establishment of a social security net with full coverage; the reasonable assignment of emissions reduction targets to poorer regions; fiscal transfers to households (financed by revenues from eco-taxes, resource fees, or emissions ration auction); industrial assistance policy; job retraining for displaced workers; the implementation of labour market policies that permit

workers to move jobs and locations at relatively low cost; and tiered pricing for electricity, water, and gas (Li, 2015).

3.5. China's approach to promoting LCGG

Both top-down and bottom-up pilot programmes can reduce the risk of LCGG. Regional experimental pilot programmes have been the most frequently used approaches to risk reduction, allowing China to undertake new reforms. Since 2010, in addition to pilot carbon emissions trading programmes, the central government has also promoted low-carbon pilot projects in selected provinces and cities, and demonstration projects such as low-carbon products and communities. In 2010, the Chinese government selected the first five provinces and eight cities to host low-carbon pilot programmes. In 2012, China nominated an additional 29 provinces and cities for the programme, including Beijing, Shanghai, Hainan Province, and Shijiazhuang. Details can be found in NDRC (2013). Proven programmes can then be scaled on a nationwide basis.

In parallel with the top-down pilot experiments, various novel bottom-up green growth experiments are spontaneously emerging at local levels in China. The political consensus of the central government on green growth provides political guarantee and incentive for local officials to conduct LCGG experiments. One local example is the case of LinZhi, Tibet. By working with outside experts to revive the waning traditional knowledge and skills in rural villages, the local non-physical cultural heritage is used to design and produce various amazing handmade textile products with high value-added, creating a massive number of jobs. A new development pathway based on local culture is taking shape. Another example is in LuAn, Anhui province. The vision of this poor region, with a population of seven million, is to translate the unspoiled natural environment into wealth and leapfrog to a future digital economy through green growth (see the LuAn Declaration on Green Growth in Poor Regions[3]). Both cases exploit the Internet to its full advantage. It is promising that LCGG may achieve a breakthrough in some backward regions in China and then scale up.

4. The effect of LCGG in China

Given the complexities of the Chinese (or indeed any industrial) economy, we cannot analyse all of China's LCGG efforts; instead we will focus on two distinct areas: the effect of policies on growth and the effect on low-carbon emissions

4.1. The growth effect

First, 'green growth' requires 'growth'. Over the past three decades, China has experienced rapid economic growth averaging 10% per year. In recent years, particularly since the 2008 world economic crisis, the Chinese economy has started to slow down. In addition to the short-term impact of the world economy, two major mixed growth effects should be distinguished. One effect is that the Chinese economy, according to the theory of economic growth stage (e.g. Rostow, 1960), is entering a new phase and transitioning from rapid take-off to the mature growth stage (Liu, Chen, & He, 2013). The second effect is the effect of carbon mitigation on growth. Because carbon mitigation policy in

China has become increasingly stringent since the 11th FYP (2006–2011), a typical concern is that carbon mitigation may slow the economy.

Technically, disentangling the effects is difficult, so this study analyses the overall growth and the growth of major green industries. During the period 2005–2015, the Chinese economy grew rapidly at an average annual rate of 10.69%. This is also the period when the country's energy intensity and emission intensity targets became increasingly stringent. The actual economic growth rate is higher than some projections. For instance, Li, Hou, Liu and He (2005) predicted an 8.35% annual growth rate during the same period. Between 2010 and 2015, actual economic growth was higher than many projections. Considering the downturn in the world economy during this period, the growth in the Chinese economy is impressive.

There is no specific evidence that China's carbon mitigation policy has impeded its economic performance. It is widely accepted that the lower level of growth represents a 'new normal' for a new phase of development rather than being a result of China's carbon-related policy (Garnaut, 2014; Huang, Cai, Peng, & Gou, 2013). However, mitigation action has positively contributed to the rapid growth of green industries. This study examines the emerging strategic industries and renewable energy in particular.

The strategic emerging industries are developing rapidly. According to the third China economic census (NBS, 2015), by the end of 2013, employment in the seven industries was 23.6 million and accounted for 8.1% of total employment in all industries. According to CIEDS (2015), the emerging industries are rapidly expanding. In 2011, sales from the emerging industries were RMB 12.4 trillion (approximately US$2.03 trillion), accounting for 14.8% of the total sales in all industries. In 2013, the sales were RMB 16.7 trillion (approximately $2.73 trillion), accounting for 16.3% of the total sales in all industries. According to NDRC (2015b), in 2015 the emerging industries are continuing to grow. In the first quarter, the growth rate for emerging industries was 500% of overall industrial growth while profit increased by 17.7% on a year-to-year basis, which is impressive because the overall industrial profit showed negative growth.

The Internet-based economy is rapidly expanding in China. According to McKinsey Global Institute (2014), the size of China's Internet economy as a share of 2013 GDP was 4.4% higher than that of the US or Germany. The company estimates that the Internet's contribution to China's total GDP is expected to increase up to 2025 from 7% to 22%. The Internet-based economy has significant implications for LCGG. It not only makes the economy more knowledge-based and efficient, but also reshapes a more service-based consumption pattern.

Renewable energy has become a source of economic growth in China. Mathews and Tan (2014) documented China's renewable energy revolution and its global implications. China's investment accounts for 29% of all G20 clean energy investments. In 2013, China installed 14 GW of wind power generation capacity and 12 GW of solar power generating capacity (Magill, 2014). Within just eight years, China has become the world's largest generator of wind power, with the world's largest capacity and the greatest addition of new capacity in 2013. According to China's Wind Energy Development Roadmap (Energy Research Institute and the International Energy Agency, 2013), in 2020, 2030, and 2050 installed capacity will reach 200 GW, 400 GW, and 1000 GW, respectively. Between 2011 and 2050, the total estimated investment in wind energy will reach approximately $2 trillion. According to the projection by DRC and Shell (2013), if more stringent low-carbon policies and industrial upgradation policies are implemented, the share of non-fossil fuel in primary energy consumption

will accelerate to increase to 15.24% in 2020 and 23.88% in 2030 (see Table 1). Therefore, China's enhanced action in its INDC is helpful for the boom of non-fossil fuel industries.

China's strong mitigation action has not only stimulated the green industries – it has also improved economic structure. The Chinese economy is moving away from the traditional model that relies on high investment and heavy industries to a more service-oriented model. From 2006 to 2013, the share of the service industries in GDP increased from 40.9% to 46.1% and is expected to increase to 55% by 2022 (Liu, 2013). In 2013, the service industries' share surpassed the share of secondary industries in GDP for the first time. Because the service sector is typically greener than the manufacturing sector, this indicates that the Chinese economy is moving in a green direction.

Second, employment has increased rapidly, and the service sector's share of employment increased faster than its share in GDP. Despite a slow-down in the economy and increasingly stringent carbon mitigation policy, China created 13.2 million new jobs in 2014, a rate that is 32% higher than the target[4] (Li, 2015). This implies that economic growth is becoming more inclusive in China.

4.2. The low-carbon effect

China's efforts have placed the country on track to reach its mitigation target. The emissions intensity of the Chinese economy has declined steadily since 2005, and China should be able to meet its target of reducing emissions intensity by 40–45% for the period 2005–2020. During the period 2005–2013, China's average annual GDP grew by 10%, while its carbon intensity steadily declined by 29% (Stern & Jotzo, 2010).

Teng and Jotzo (2014) provide an illustrative scenario in which China's carbon emissions peak during the 2020s, return to a level below the 2020 level by 2030, and return to current level by 2040. This is an assumption consistent with the US–China Joint Announcement on Climate Change in 2014 and China's INDC in 2015, which states an intended emissions peak in China around the year

Table 1. Mix of primary energy consumption in China

		2010		2020		2030	
		Million TCE	Share (%)	Million TCE	Share (%)	Million TCE	Share (%)
Fossil energy	Oil	617	91.36	744	84.76	885	76.12
	Natural gas	143		418		762	
	Coal	2210		3255		2940	
Non-fossil energy	Nuclear	25	8.64	152	15.24	335	23.88
	Hydro	213		358		504	
	Solar	13		61		157	
	Wind	16		113		233	
	Biomass	14		110		210	
	Total	3251	100	5211	100	6026	100

Source: Calculated based on the Optimized Scenario in DRC and Shell Global (2013, figure 2).

2030.

The illustrative assumption of GDP growth rate in Teng and Jotzo (2014) approximates the existing projections. For instance, the authors assume a 7.4% economic growth rate during the period 2014–2020, but, according to the projection conducted by China's Development Research Centre of the State Council using the computable general equilibrium (CGE) model, the growth rate during 2013–2022 is expected to be 7.1% (Liu, 2013).

The projection for the peak years of China's major demands on emission-intensive outputs shows that the likelihood that the emissions will peak earlier than 2030 is substantial. Using the CGE model and/or conducting international comparisons, the DRC research team (Liu, 2013) projected the peak year of major outputs or demand (see Table 2). The projections of the research team use industrialisation experience in the industrial economies as a benchmark, but for them there was no low-carbon policy, current new technologies, or the Internet-based new economy. This implies that the peak years of major industrial products in China could be even earlier.

Considering the increasingly intense low-carbon policy and economic transformation in China, the emissions peak year is likely to arrive earlier than 2030. For instance, Garnaut (2014) investigated emissions reductions in electricity, transport, and industrial processes in China and found remarkable achievements. These encouraging developments caused some authors to predict an even earlier peak year around 2025 in the context of Chinese economic transformation (e.g. Jiang, 2014). Garnaut (2014) echoed the optimistic projections for China in reaching a peak in the absolute level of emissions by 2020. However, substantial uncertainty surrounds the prediction of an early emissions peak for

Table 2. The peak years of major output and demand in China

Sector	Peak year
1. Housing completion	2019
2. Infrastructure	1998. Share of infrastructure investment in fixed assets investment. The potential for the share to increase is small until 2022.
3. Auto demand	2022
4. Manufacturing industries	
4.1. Labour-intensive: textile, sewing, leather, papermaking, stationary, food, forestry industries	Already reached their peaks of industrial proportion around 1998 and continue to fall.
4.2. Heavy industries: metallurgical, electric, coal, building materials, petroleum and chemicals	Around 2015, and then falling.
4.3. Capital and technology-intensive: metal product, machinery manufacturing, transportation equipment manufacturing, electrical machinery, electronic and communication equipment manufacturing	Keep rising and will stablise around 2020.

Note: The data on housing are from chapter 3 in Liu (2013), data on infrastructure are from chapter 4, data on auto demand are from chapter 5, and data on manufacturing are from chapter 12.
Source: Compiled based on Liu (2013).

China.

Unfortunately, although it is promising that China will meet its mitigation commitment, the aggregated pledges of all countries are far from sufficient to meet the requirements for the global climate change target of 2 °C. According to the third report in the IPCC's Fifth Assessment series (IPCC, 2014), if global warming is to be kept at less than 2 °C (relative to the period 1861–1880) with a probability of over 66%, there is 'space' for only 1000 $GtCO_2$ to be emitted from now and into the future. Thus, in only 20 to 25 years, if the current rate of emissions continues, the ability of the Earth to absorb the gases (within the limits of maintaining warming below 2 °C) will be exhausted. Without substantial additional action to reduce global emissions, the rapid growth in emissions and GHG concentrations is projected to raise the global mean surface temperature by 3.7–4.8 °C above pre-industrial level by 2100. The mitigating actions pledged by countries under the Copenhagen Accord and Cancun Agreements are considered insufficient to avoid dangerous climate change (UNEP, 2012; World Bank, 2012).

5. How to reformulate China's LCGG strategy

To reformulate its LCGG strategy, China must fully recognize the opportunities of LCGG (World Bank & DRC, 2012), change its mindset from burden-sharing to opportunity-sharing in climate negotiations (Zhang & Shi, 2014), and understand green growth in the context of the digital era. The reformulation should be conducted on two levels: to further enhance the country's major existing efforts with new thinking, and to advance to a more fundamental development paradigm shift.

5.1. Enhancing existing major efforts

The first action is to impose a more ambitious carbon mitigation target at home to seize the opportunity. The latest theories of LCGG and green practice in China reviewed in this article show that strict carbon mitigation policy could also be an opportunity, rather than just a burden for economic growth, which provides a new rationale for enhancing carbon mitigation ambition in China. Strict carbon policy can improve the quality of growth and stimulate a green economy. This is even more the case in the digital age.

The second action is to enhance structural reforms so that the more supportive institutions required for LCGG can be established. Green growth is profoundly different from the typical growth of the industrial era. The existing institutions, including taxation, finance, regulation, performance evaluation of officials, governance, and legislation, were all established for supporting traditional industrialisation and cannot efficiently serve the needs of green growth (Zhang, 2013).

Third, at the international level, China should facilitate the strategic transition of climate negotiations from burden-sharing to opportunity-sharing and play a more active role in establishing an equitable and effective international agreement on climate change. No individual countries can succeed in reducing emissions without coordinated global action. The introduction of a self-fulfilling LCGG mechanism should be put at the heart of the new agreement, which is more important than focusing on negotiations around a specific number related to burden-sharing (Averchenkova, Stern, & Zenghelis, 2014; Zhang, & Shi, 2014). An effective international agreement would not only provide pressure and incentive for mitigation at home, but more importantly it would bring certainty and confidence, encouraging green R&D and investments.

5.2. Towards a more fundamental paradigm shift

Fundamentally, climate change is the consequence of the traditional industrialisation pathway established since the Industrial Revolution. Climate change cannot be completely solved by marginally improving the existing growth pathway. As Albert Einstein famously said, 'we cannot solve problems by using the same kind of thinking we used when we created them'. Reformulating the LCGG strategy in the right direction requires rethinking the purpose of development.

The ultimate objective of economic growth is a high level of well-being, but high GDP from the traditional industrialisation pathway could also imply a low level of well-being. As Sen (2011) notes, 'there is little case for confusing (1) the important role of economic growth as means for achieving good things, and (2) growth of inanimate objects of convenience being taken to be an end in itself'.

According to Stiglitz, Sen, and Fitoussi (2009), the time is ripe for the measurement system to shift emphasis from measuring economic production to measuring people's well-being. Note that changing the emphasis does not mean dismissing GDP and production measures. Emphasising well-being is important because there appears to be an increasing gap between the information contained in aggregate GDP data and what counts for the well-being of the people.

In essence, what Stiglitz, Sen, and Fitoussi (2009) argued is not about measurement itself, but changing the content of development since 'what we measure affects what we do, and if our measurements are flawed, decisions may be distorted'. To some extent, a development paradigm shift would be to change the content of development to minimise the gap between GDP and well-being. Apparently, green growth could be such a pathway with a high level of well-being and new content of GDP.

Economic growth is a process with which to meet all human needs by deepening the division of labour and specialisation; human needs are never limited to only physiological needs, as traditional industrialisation emphasises. Stiglitz et al. (2009) elaborated that the material living standards currently emphasised by GDP are only one of the eight dimensions for well-being. Wealth extends beyond material wealth. Maslow (1943) proposed five types of need: physiological, safety, belongingness and love, esteem, and self-actualization. Although the hierarchy of needs is only partially supported by evidence, the classification of needs is convincing (Wahba & Bridwell, 1976). Max-Neef (1992) organised human needs into two categories: existential and axiological. These categories are further classified into the needs of subsistence, protection, affection, understanding, participation, creation, leisure, identity, and freedom.

The implications of the needs taxonomy for LCGG are crucial. First, any fundamental human need not satisfied implies a kind of human poverty (Max-Neef, 1992) and, accordingly, development concentrating on the physiological need in traditional industrialisation cannot deliver a high level of happiness.[5] According to a review of happiness studies in Ng (2003), evidence shows that those who are more materialistically inclined are less content. After a certain minimum level, higher material consumption does not increase levels of happiness in individuals, because other needs are not satisfied (Max-Neef, 1992).Second, needs beyond physiological need can also be important sources of economic growth. All needs can give rise to various new products and services and can be the source of economic growth. Third, growth not relying on material resources is environmentally friendly and is sustainable. Therefore, beyond a threshold, moving away from the typical material wealth-based growth model towards the alternative pathway of meeting all-round needs can ensure (1) high productivity or

high economic growth, (2) high satisfaction or well-being, and (3) environmentally friendly growth. This is what green growth is about.

This notion is widely embraced in various forms. For instance, Hepburn, Beinhocker, Farmer, and Teytelboym (2014) and Hepburn and Bowen (2013) argue prosperity within planetary boundaries. The IPCC's Fifth Assessment report (Fleurbaey et al., 2014, chapter 4) cites rich research literature on sustainable consumption developed over the past decade (Black, 2010; Jackson, 2009; Le Blanc, 2010; Schrader & Thogersen, 2011;Tukker, Cohen, Hubacek, & Mont, 2010). The authors focus on the unsustainable nature of current lifestyles, development trajectories, and economic systems and the ways in which these lifestyles could be steered in a more sustainable direction. Several definitions of sustainable consumption have been proposed within policy, business, and academia (Pogutz & Micale, 2011).

This notion dates back to Adam Smith (1759), who noted that the productivity of the market economy is driven by the misguided belief that material wealth brings happiness. 'It is this deception which rouses and keeps in continual motion the industry of mankind . . . which have entirely changed the whole face of the globe'. A large component of material consumption demand in modern society is actually 'commercially created' through advertising and marketing and does not represent genuine human need, yet the concept that modern focus on consumption is the direct result of decades of conscious social engineering remains almost entirely unacknowledged (Atkisson, 2012).

Similar to other developing countries, China considers industrial economies to be role models and emulates their high resource usage, high emissions, and high environmental footprint model. China duplicates the consumerism and materialism of the industrial countries. Nonetheless, according to Easterlin, Morgan, Switek, & Wang (2012), there is no evidence for an increase in life satisfaction similar to the fourfold improvement in level of per capita consumption that has occurred in China. It is time for China to fundamentally reformulate its unsustainable development paradigm toward a sustainable consumption pattern and well-being-oriented development. This is the substance of LCGG.

6. Concluding remarks

This article reviews China's efforts and effects concerning low-carbon green growth (LCGG) and explores the policy implications of reformulating the country's LCGG strategy. It reviews China's LCGG efforts with respect to four major aspects – carbon mitigation, market construction, the fostering of green industries, and managing negative effects. This article shows that China has adopted prevalent international practices in promoting LCGG, and the country's mitigation efforts are also among the greatest in the world. China's stringent low-carbon policies have not affected its economic growth as some predicted. In contrast, China's increasingly stringent environment policies have fostered green industries. Although the positive changes cannot be simply attributed to LCGG strategy, the quality of China's economy is improving, with rapid increases in the service sectors and a rapid increase in new jobs.

However, the insufficiency of global emissions mitigation to meet the requirement of the 2 °C target and the changing context require China to reformulate its LCGG to solve global climate change and seize the opportunity for green growth. China should reformulate its LCGG strategy on two levels: (1) to enhance its existing efforts, and (2) more fundamentally China must reformulate its

development model towards a more well-being-oriented and dematerialised model. The reformulation could become a new source for economic growth, decrease carbon emissions, and improve well-being. The time is now ripe for China to make a strategic transition. The 13th FYP (2016–2020) provides an opportunity for a more fundamental change in LCGG strategy. In the INDC China submitted to the United Nations Framework Convention on Climate Change, more ambitious low-carbon targets are proposed, which provides new momentum for fostering its LCGG. If China could succeed in exploring LCGG, it would make a significant contribution to the whole world.

Acknowledgements

The author is grateful to the valuable comments and suggestions from the three anonymous referees, as well as Zhongxiang Zhang, Jianwu He, and seminar participants at the Development Research Centre of the State Council, P.R. China. Any errors or omissions are solely those of the author.

Disclosure statement

No potential conflict of interest was reported by the author.

Notes

1. See http://www.china.org.cn/environment/2015-06/30/content_35950951.htm
2. See https://www.whitehouse.gov/the-press-office/2014/11/11/us-china-joint-announcement-climate-change
3. See http://www.chinadaily.com.cn/m/drc/2014-10/20/content_18768787_2.htm
4. Due to difficulties in gathering statistics on jobs, a double-counting problem exists.
5. The notions of well-being, happiness, and life satisfaction are used interchangeably, yet they have different subtle meanings. The intention here is not to go into detail but rather to make a broad point.

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