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Transformative Innovation Policy: A Case-Study from China

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Abstract

Science, technology and innovation policy has been presented as developing through three "frames": innovation for growth; national systems of innovation; and transformative change (Schot and Steinmueller, 2018). In this paper, we focus on the third frame by exploring the development of transformative innovation policy in China. More specifically, we present a case analysis of the Beautiful China Initiative (BCI). Within this context, we analyse participating actors, activities, and modes of innovation. In conclusion, we discuss three general challenges of transformative innovation policy at a national and international level.

The first challenge is coordination and interaction between governmental agencies and other actors with different responsibilities and jurisdictions. Second, there is a major set of issues related to "development", which must encompass economic development but also societal and environmental development. Third, BCI fits with a broad understanding of the innovation process, including elements which are not directly commercial in orientation. Whether this broader approach can be maintained as BCI develops from its still-early stage into full development will represent a significant challenge. Finally in this paper, we consider the implications of our discussion for future research and practice, and offer three reflections. In particular, we emphasise the importance of scholars' participation across the social sciences rather than leaving this multi-faceted area only to innovation researchers.

Keywords

transformative innovation; innovation policy; China; environmental challenges

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1. Introduction

Policies for science, technology and innovation have often been heavily focused on the relationship between scientific research and economic growth. Recently, however, there has been a move in many nations towards what can be presented as a much broader approach to the social and environmental dimensions of innovation policy. As Diercks *et al*. (2019) have expressed this, newer initiatives in innovation policy share three main characteristics. Firstly, an aspiration for "purposive and directional" innovation. Secondly, an approach which is "challenge-led": specifically seeking to address anthropogenic climate change as a broad societal challenge. And thirdly, the development of a global rather than purely national outlook – not least because societal challenges require "boundary-spanning" collaborations. For Diercks *et al.*, such an approach expresses a turn towards "transformative innovation policy". In this paper, we will focus on this new policy approach – using one example from China as a main case-study.

In a closely-related discussion, Schot and Steinmueller (2018) have described innovation policy as developing through three "frames". The first frame is "innovation for growth". Schot and Steinmueller present this as emerging after World War 2, with a strong focus on the economic benefits of scientific and technological change. Underpinning this frame is the so-called "linear model" of innovation whereby scientific breakthroughs lead directly to the development of new products and processes. The second frame of "national systems of innovation" grew from the realisation that innovation was a more complex process, best characterised by "innovation systems". These systems combine a range of actors and often require, typically national, institutional support if they are to operate effectively.

Linking very much with Diercks *et al.*'s account, the third of Schot and Steinmueller's frames is "transformative change". This frame puts social and environmental challenges at its centre and, as has already been suggested, presents a strong "challenge" orientation. Here, the direction of innovation policy becomes crucial: there are different potential pathways for socio-technical development and choices need to be made about which is the most appropriate.

Whilst the first and the second frames assume that innovation policy is always the driver of a better world – that, in other words, innovation is good for you - transformative change questions this assumption. Innovation can have negative as well as positive social and environmental consequences. The challenge for "transformative change" is to recognise this from the beginning and make innovation policy one element within a larger set of ambitions. As Schot and Steinmueller put it: "Framing 3 encourages a deeper set of questions concerning the fit of current socio-technical systems of provision with societal goals and, ultimately, about the governance of innovation processes" (Schot and Steinmueller, 2018, p. 1565).

The implication of the concept of transformative change - and the closely-associated idea of "transformative innovation policy" - is that social and environmental challenges are complex, globally generated and continuously increasing. These challenges, for example, resource scarcity, food security, clean energy, climate action, and ageing societies, are increasingly influencing innovation policy agenda. This in turn suggests the need for governments to employ broader notions of research impact in their research assessments. At the same time, the systematic development of emerging technologies is transforming societies, altering the ways in which people live, work and communicate. Ubiquitous connectivity will support more flexible working arrangements, though with uncertain consequences for work-life balance (OECD, 2016). New technologies - such as ICTs, Artificial Intelligence (AI), synthetic biology, additive manufacturing, nano- and micro-satellites, and advanced energy storage - may also empower individuals and social collectives (*e.g*. NGOs) to conduct their own research and innovation activities (OECD, 2016). The fundamental challenge for transformative innovation policy is to recognize and work with these changes in a manner which meets social and environmental goals.

It follows also from the concept of transformative change that no country can solve these challenges alone – and that large-scale coordination and cooperation are required even within one nation. In the process of transformation and change, systemic changes need to be carried out, not just the fixing of a single goal or policy objective (Schot and Steinmueller, 2018).

Environmental challenges are likely to be downplayed, or even ignored, by particular industrial sectors. It may also be extremely difficult in practice to take into account and balance the environmental challenges faced when formulating relevant sectoral policies. For example, in the development of new energy vehicles, a focus only on tackling battery problems cannot systematically solve a series of larger challenges faced by the environment and society (Schot and Steinmueller, 2018). Transformative change suggests that there is "no single best pathway" but instead multiple actors building system change in a more open-ended process. In line with this, there is a need for approaches to innovation which emphasise experimentation.

Finally in this short introduction we should emphasise that the "emergence of a new framing does not necessarily replace existing framings" (Schot and Steinmueller, 2018, p. 1555). In other words, the adoption of a "transformative" perspective does not mean that other framings will (or should) be abandoned. Instead, it is possible to imagine different forms of co-existence, depending on goals and context.

With these discussions in mind, in what follows we draw especially upon Schot and Steinmueller's (2018) third framing - transformative change - to discuss the changing nature of innovation policy in the digital era. Applying one analytical framework for transformative innovation policy, this paper will examine a specific case from China (the Beautiful China Initiative: BCI) in terms of three dimensions – actors, activities and modes of innovation (Diercks *et al.*, 2019).

First, we will briefly present a framework for transformative innovation and the challenges of innovation policy. Second, we broadly introduce the context of innovation policy in China. Third, we select and develop the BCI case to unfold the three crucial dimensions and to discuss the challenges of transformative innovation policy in a Chinese context. Finally, we conclude our study with a critical analysis and open the future agenda for research and policy practice.

2. A framework for Transformative Innovation

As has already been suggested, transformative innovation policy offers at least the promise of a more integrated direction for innovation policy, giving priority to societal and environmental challenges. However, and as Schot and Steinmueller note: "such a change cannot be achieved solely by STI policies; other policies need to contribute too… it is a much broader historical process, in which many actors actively participate already" (Schot and Steinmueller, 2018, p. 1565).

Against this background, Diercks and colleagues make two key distinctions. First of all, between an *economic policy agenda* for innovation and a *societal policy approach*. Secondly, between a *narrow* and a *broad* understanding of the innovation process. While a narrow approach views innovation simply as "the commercialisation of technological change" (Rothwell and Zegveld – in Diercks *et al.*), the broader approach "views knowledge production as an interactive learning process, combining different modes of innovation and forms of knowledge" (Diercks *et al.*, 2019, p. 883). Going further, Diercks et al suggest that innovation processes can be understood in terms of three elements: involved *actors*, types of *activities* and different *modes of innovation*. Table 1 shows the three main elements of understanding the innovation process from a broad perspective.

Table 1 A broad approach to understanding the innovation process

Actors	A wide variety of actors with active roles for a diversity of public and civil society bodies
Activities	Demand-side focus (end-use domains) in addition to supply-side
Mode of innovation	Doing, using and interacting in addition to science, technology and innovation

Source: Adjusted from Diercks *et al*. (2019, p. 883)

In what follows, we will apply these discussions of transformative innovation policy to one Chinese case. We will build on the three "framings" developed by Schot and Steinmueller but also Diercks *et al.*'s distinctions between economic/social agenda, narrow/broad approaches, and the three elements of innovation. Our intention will not be to present innovation policy in China as a "perfect case" of any specific framing: all the authors discussed so far consider innovation policy as generally combining framings rather than functioning in one mode only. However, we suggest that innovation policy in China can be usefully compared with Schot and Steinmueller's basic model – at least in terms of its pattern of historical change. We will also argue that this specific Chinese case raises a series of important questions about the nature of transformative change.

In order to develop these points, we now move to the general context of Chinese innovation policy.

3. Innovation Policy in China

In line with the previous discussion of social and environmental transformation, China shares a global concern with the Sustainable Development Goals (SDGs) introduced in 2015 by the United Nations General Assembly with a target date of 2030. As the Chinese President Xi Jinping notably asserted in 2005, "Clear waters and green mountains are as valuable as mountains of gold and silver." In addition, digital transformation and systematic breakthroughs in information and communication technology (ICT), especially the rapid development of AI, big data, the Internet of Things (IoT), Blockchain and other technologies, have brought new impetus to economic and social development – but also challenges in terms of innovation policies.

In what follows, we will briefly consider the development of Chinese policy in this area, drawing upon the three frames presented by Schot and Steinmueller.

3.1. Stage one: innovation policy for economic growth

China's Science & Technology and Innovation (STI) policy officially began in 1985. In that year, the Central Committee of the Communist Party of China (CPC Central Committee) introduced China's first STI policy - *Decision on the Reform of the Science and Technology System* (CPC, 1985; Mu, 2019; People's Daily, 2018) (henceforth "Decision 1985"). Decision 1985 placed particular emphasis on the relationship between technology development and economic growth (CPC, 1985). On the one hand, it pointed to the need to develop technology for economic growth. On the other hand, it highlighted the limitations of economic growth without the development of technology.

At this point, national technology plans and systems were created, aimed at facilitating economic development through science and technology (Mu, 2019). For example, a national science and technology plan and a high-technology R&D plan were set up. By introducing a competitive mechanism and supporting selected projects, the intention was to stimulate the innovativeness of scientists and researchers and to improve the efficiency and effectiveness of scientific research funding (CPC, 1985; Mu, 2019). Moreover, several topics were particularly emphasized, including the relationship between research and development, the gap between design and production, and the separation between R&D and education (CPC, 1985).

3.2. Stage two: national innovation system development

Staying with the three phases presented by Schot and Steinmueller, the second main development stage of STI in China took place in the period between 1996 and 2006, represented by the strategy of building a national innovation system (Mu, 2019; People's Daily, 2018). In 1996, China concluded the ten-year evaluation of Decision 1985 (People's Daily, 2018). At the same time, *The Knowledge-based Economy* report was published by the OECD (OECD, 1996). This important report discussed the relationship between knowledge & information, science & technology development, and economic growth. The knowledge-based economy was at this point contrasted with more traditional economies, in which economic growth relies on labour, capital, materials and energy (OECD, 1996).

From the perspective of the knowledge-based economy, and based on the results of the ten-year evaluation of Decision 1985, there was a huge gap between China and OECD economies in terms of knowledge inputs (*e.g.* R&D, innovation, patents, human resources), knowledge stocks and flows (*e.g.* technology intensities of high, medium and low technology industries), knowledge outputs (industrial R&D intensity), knowledge networks (*e.g.* institutional capabilities to transfer knowledge), and knowledge and learning (*e.g.* private and social rates of return to investment in education and training) (OECD, 1996).

To develop Decision 1985 further, in 1996 the State Council of P.R.C introduced another Decision – *Deepening of the Reform of the Science and Technology System During the "Ninth Five-year Plan" Period* (CGTN, 2020; State Council, 1996) (henceforth "Decision 1996"). Besides the continuous emphasis on S&T as the primary productive force, Decision 1996 introduced the strategy of building integrated and interactive mechanisms of research, development, production, and market (State Council, 1996). Firms were presented as the main body in the technology development system, collaborating with various institutions and universities, to improve the contribution of technology to economic growth. Meanwhile, State-Owned Enterprises (SOEs) in China were facing particular challenges in achieving reform of the existing institutions and structures (Mu, 2019).

Provoked by the difficulties of reform, and realizing the huge gap between China and OECD economies from the perspective of the planned knowledge-based economy, scientists and researchers from the Chinese Academy of Sciences (CAS) developed a report, *To meet the knowledge-based economy and build the national innovation system*, which was submitted to the CPC Central Committee in 1997 recommending the construction of national innovation systems (Jiang, 1998; Jin, 1999; Mu, 2019; Su *et al.*, 2009). President Jiang Zemin commented on the report 'I think we can support them (CAS) to have a pilot programme and let them go early to build our (China's) own innovation system' in 1998 (Jiang, 1998). Following Jiang Zemin's comments, the State Council authorized CAS to develop the Knowledge

Innovation Pilot project in 1998. As a consequence, the development of a national innovation system in China began to take shape.

The CAS Pilot Project of Knowledge Innovation (*CAS-KI*) experienced three periods: kick-off (1998–2000), full development (2001–2005), and optimization (2006–2010). After 2010, CAS reported a series of breakthroughs with regard to science, technology and innovation, both in fundamental research fields and in areas of national and societal practice. For example, in the aviation and communication field around 100 satellites were launched between 2005 and 2010, forming a global earth observation system (Hudson Institute, 2005; Suttmeier *et al.*, 2006). The Dawning 4000 - A Shanghai supercomputer, was developed by the Institute of Computing Technology (ICT) at CAS, and the Godson II central processing unit computer chip with 64-bit performance able to support a Linux or Windows operating system was also developed (Hudson Institute, 2005). *CAS-KI* not only supported the integrated and sustainable development of S&T, but also set a benchmark for SOEs in terms of further market-oriented reform.

China's accession to WHO in 2001 marked a big change in the country's international trading environment. Increasing foreign capital investment and technology introduction in the Chinese market brought both a positive and a negative influence on China's economic and social development. In this context, the *15-year Medium to Long-Term Science and Technology Development Plan (2006-2020)* started development in 2003 and was introduced in 2006 (henceforth "Plan 2006"). Plan 2006 pointed out the future development orientation of China's STI: *indigenous innovation* (zìzhǔ chuàngxīn), *key leapfrogging* (zhòngdiǎn kuàyuè), *supporting development* (zhīchēng fāzhǎn), and *leading the future* (yǐnlǐng wèilái) (State Council, 2006, p. Chapter 2, Section 1). Plan 2006 made it clear that China would focus on indigenous innovation rather than introducing foreign innovation. Subsequent policy documents discussed the details of indigenous innovation, and emphasized that enterprises' innovation capability should play a key role in indigenous innovation. Firms were encouraged to participate in R&D, with supporting tax policies. Hence, in the second development period of China's STI policy, STI policy played a wide role in the development of a national innovation system.

3.3. Stage three: innovation policy for development

Continuing with Schot and Steinmueller's framework, the third development stage of STI in China began in 2007. This extended its scope to innovation and development not only with regard to economy and society, but also the environment. Thus, in *the 11th Five-Year Plan* (2006–2010), the *circular economy* was proposed (CGTN, 2020; Xinhua News, 2006). And in 2007, at the 17th CPC National Congress, President Hu Jintao proposed the concept of "ecological civilization" to emphasize future development goals: "Respect and protect nature, put the construction of ecological civilization into the key place, integrating it into different processes of economic growth, political construction, culture development and society development, and to build a beautiful China" (Hu, 2007). The proposed construction of "ecological civilization" can be linked to the fast growth of the Chinese economy which had led to heavy environmental problems, scarce resources, and ecosystem degeneration, *e.g.*, increasing levels of water and air pollution. At this moment, China explicitly began to rethink the relationship between humanity and nature, economic and social challenges, and environment development.

STI policy at this point also began to reflect upon the new content – and underlying meaning - of "development". Accordingly, in the 18th CPC National Congress in 2012, China implemented *the Innovation-driven Development Strategy* (Hu, 2012). This strategy changed China's development approach across multilateral dimensions. For example, it emphasized that development cannot rely on manual labour or resource exploitation, but should instead be technological-innovation driven. Innovation for development became the goal and not simply publishing papers or applying for patents. The understanding of development should also be broadened, encompassing economic growth, social development, and environmental development (Hu, 2012).

Further important policy documents were introduced to provide detailed guidance on innovation-driven development, such as the *Opinion on Deepening the Reform of Systems and Mechanisms to Accelerate the Implementation of Innovation-driven Development Strategy* (CPC and State Council, 2015) (henceforth "Opinion 2015") , and *Outline of the Innovation-Driven Development Strategy* (CPC and State Council, 2016) (henceforth "Outline 2016"). Opinion 2015 from the perspective of *reform* facilitates the implementation of the *Innovation-driven Development Strategy*, and Outline 2016 from the perspective of *development* facilitates the implementation of the *Innovation-driven Development Strategy* (Mu, 2019).

In this section, we have presented the development of innovation policy in China according to the three-phase model presented by Schot and Steinmueller. Whilst there is a strong correspondence between Schot and Steinmueller's first two phases ("Innovation for growth" and "national systems of innovation") and the first two cases of the development of Chinese innovation policy, differences could be seen between the third phase (namely the "transformative change" in the Schot and Steinmueller framework) and the third case of the development of Chinese innovation policy (namely the "innovation policy for development" in China). Despite this contrast, however, one can identify many common elements: and especially in the move from an economic to a social policy orientation and from a narrower to a broader perspective on innovation. So far, however, we have only examined these changes at the level of national policy-making. In the next section, we will consider the development of "transformative change" in one specific setting.

4. Case Study: The Beautiful China Initiative

4.1. Method

In order to develop this discussion further, we will now present a case study (Yin, 2018) of the Beautiful China Initiative (BCI)[1]. The purpose here is to analyse the expression of transformative innovation policy in practice, and in particular to understand the challenges associated with this. Evaluating the relative success or effectiveness of this initiative is not our goal in the following discussion.

The BCI was selected both because of its intrinsic and its illustrative value. From our perspective, the case has intrinsic value as a prominent innovation-oriented national policy initiative that emphasizes social and environmental challenges. It has historical roots going back to Xi Jinping's principle of "Clear waters and green mountains" initiated in 2005 (People's Daily, 2015), as this was later introduced in 2012 at the 18th CPC National Congress in Beijing (Hu, 2012). The case also has illustrative value since it suggests some of the main characteristics of transformative innovation policy: the initiative has the clear goal of enabling development and innovation from a broad definition; it is based on collaboration between multiple domains; it is also built on the aspiration of national and international collaboration (Diercks *et al.*, 2019; Schot & Steinmueller, 2018).

Our data collection mainly relies on official policy documents: including opinions, plans, guidelines,

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[1] "Beautiful China" is a translation from Mandarin měilì zhōngguó. In this study, we used the broad meaning to refer to its emphasis on both green and sustainable development.

decisions, reports, frameworks, official news introduced by central and local government agencies; and also, the secondary literature. An overview of our data sources is presented in Table 2.

Table 2 Overview of policy data sources

Type of policy data	Title	Proposed time	Setting or location	Document code
Report	Report of the 18th CPC National Congress	2012	The 18th CPC National Congress	R01
	Report of the 19th CPC National Congress	2017	The 19th CPC National Congress	R02
Plan	The 13th Five-year Plan for National Economic and Social Development (Xinhua News, 2016)	2016	The fourth session of the 12th National People's Congress	P01
	The 14th Five-Year Plan for National Economic and Social Development (Xinhua News, 2021)	2021	The fourth session of the 13th National People's Congress	P02
	The proposal of the 14th Five-Year Plan for National Economic and Social Development and the Long-term Goals for 2035 (Xinhua News, 2020)	2020	The fifth plenary session of the 19th CPC Central Committee	P03
Speech	Xi Jinping's speech (Xi, 2018)	2018	The National Conference on Ecological and Environmental Protection	S01
	Xi Jinping's speech (Xi, 2020)	2020	The Scientists' Forum	S02
Policy document	Notice of the General Office of the State Council on Printing and Distributing the "no-waste city" pilot plan (State Council, 2018)	2018	State council	D01
	Decision of the CPC Central Committee on some major issues concerning how to uphold and improve the system of socialism with Chinese characteristics and advance the modernization of China's system and capacity for governance (CGTN, 2019; Xinhua News, 2019)	2019	The fourth plenary session of the 19th CPC Central Committee	D02
	The evaluation index system and implementation plan of BCI (NDRC, 2020)	2020	NDRC	D03
	Implementation opinions on deepening the reform of the science and technology system of ecological environment to stimulate the vitality of science and technology innovation (MEE, 2019)	2019	MEE	D04
	Management Methods of State Environmental Protection Key Laboratory (MEE, 2020)	2020	MEE	D05

4.2. Case description

Beautiful China is a national initiative officially introduced in 2012 at the 18th CPC National Congress in Beijing (Hu, 2012). It aims to meet the social and environmental challenges caused by economic growth and to support innovation-driven development. At the time of writing, the initiative is still active. It is a constituent part of China's commitment to the United Nations' 2030 Agenda for SDGs (Fang *et al*., 2020). It aims to promote green and sustainable development, solve prominent environmental problems, intensify the protection of ecosystems and reform the environmental regulation system (Bosu, 2018). The wider goal of the Beautiful China Initiative (BCI) is to speed up the development of an "ecological civilization" system, together with economic growth, and cultural and societal development.

The governance of air pollution and carbon dioxide emissions has been presented as a main focus of BCI. At the same time, the transformation from traditional industries towards green and energy- saving industries has been greatly emphasized. In particular, in the winter of 2017, steel and cement companies in Beijing, Tianjin and the surrounding 26 cities were forced to close their factories. Steel and cement companies were required to reduce their annual production and upgrade their environmental equipment. These governmental actions aim to control the air pollution created by industrial firms. Furthermore, regarding winter heating, coal-burning systems were replaced by gas-burning equipment in Beijing, Tianjin and the surrounding 26 cities in order to reduce air particulate emissions. Many air monitoring applications such as Airpocalypse, AirVisual and AirMatters have been widely used in China to detect the daily real-time air quality index (Mark, 2021).

After its first introduction in 2012, BCI was then proposed as part of the 13th Five-year plan in 2016 (Hu, 2012). Subsequently, BCI was given goals for 2035 and for 2050 by the report of the 19th CPC National Congress at the 19th CPC National Congress in 2017, and a proposed timetable and road-map at the National Conference on Ecological and Environmental Protection by Xi Jinping in 2018 (Bosu, 2018; Xi, 2018). In 2019, at the Fourth Plenary Session of the 19th CPC Central Committee, the *Decision of the CPC Central Committee on some major issues concerning how to uphold and improve the system of socialism with Chinese characteristics and advance the modernization of China's system and capacity for governance* was authorized which described the further plans and institutional arrangements of BCI (CGTN, 2019; Xinhua News, 2019). In 2020, the National Development and Reform Commission (NDRC) introduced *The Evaluation Index System and Implementation Plan of BCI* which pointed out five first-order indices, 22 second-order indices, and two evaluations in the middle of the 14th Five-year plan period and after the 14th Five-year plan. The timeline of BCI is represented in Figure 1.

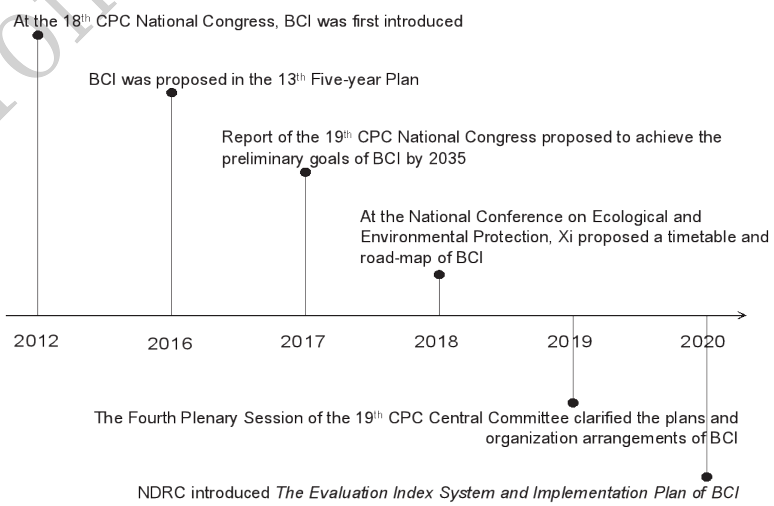

Fig 1. The BCI timeline

From an innovation perspective, BCI focuses on the transformation and upgrading of old industries that emit a high level of pollution, stimulating new "green industry" growth, renewable energy development, and environmental-friendly technologies. As already noted, its roots can be traced back to 2005 and Xi Jinping's principle concerning "mountains of gold and silver", developed when he worked in Zhejiang Province (People's Daily, 2015). China was already the "factory of the world" in 2005, relying mainly on heavily-polluting manufacturing industries. Practical efforts so far have brought limited results. For instance, people's living quality has already been affected by polluted groundwater, surface water and air pollution; and cleaning up smoggy skies, dirty rivers and toxic soil needs greater focus. Moreover, the development between city and countryside is uneven.

To formulate the 14th Five-Year Plan and the long-term Goals for 2035, Xi Jinping, scientists from government institutions, universities, and industries attended the Scientists' Forum in September 2020. The main task of the Scientists' Forum was to collect suggestions and opinions on innovation-driven development with the goal of speeding up technology innovation for the next five years and also long-term economic and social development (Xi, 2020). Xi Jinping emphasized that technology innovation is the key to solving China's new social conflicts between the people's growing need for a better life and the unbalanced and insufficient development, by providing high quality products and services from the supply-side (Xi, 2020). To achieve the green and sustainable development of the economy and society, "it is necessary to focus on global issues such as climate change and human health, and strengthen joint research and development with scientific researchers from various countries" (S02).

In November 2020, the Proposal of the CPC Central Committee on Formulating the 14th Five-Year Plan for National Economic and Social Development and the Long-term Goals for 2035 (the 14th Five-Year Plan Proposal) was published; and in March 2021, the 14th Five-Year Plan was approved at the fourth session of the 13th National People's Congress (Xinhua News, 2021) based on the proposal. The new Five-Year Plan suggested the basic goal of becoming a "beautiful China" by 2035, with innovation and particularly new technology innovation as the core driver; also it suggested a green mode of production, with a goal for carbon emissions to reach their peak between 2020 and 2035 and then steadily decline, as well as a more efficient energy and resource allocation (Xinhua News, 2020).

The rapid development of digital technologies such as the Internet, quantum communication, 5G, IoT, big data and AI provides new drivers to the transformation and upgrade of traditional industries, renewable energy development, new technology application and industry development. For example, Tencent and the World Wide Fund for Nature (WWF) began their strategic partnership in 2018, to jointly work to empower ecological conservation through digital technology (Tencent, 2018; WWF, 2018). The Guangdong-Hong Kong-Macao Bay Area is the first step in the broader effort of BCI to explore a digitally-driven approach to constructing the "beautiful Bay Area" (Tencent, 2018; WWF, 2018).

In the initial collaboration between Tencent and WWF aimed at developing the "beautiful Bay Area", three main projects were proposed. The first project aims to stimulate public interest in ecological protection by encouraging people to participate in an online art and nature exhibition concerning endangered animals and the special nature of the Bay area (Tencent, 2018; WWF, 2018). The public can experience the online exhibition by downloading the application which is supported by Tencent's advanced augmented reality technology (Tencent, 2018; WWF, 2018). The second project aims to provide online training courses for around 370,000 forest rangers working in China's National Parks (Tencent, 2018; WWF, 2018). The third project aims to use big data technology and the Internet to combat the illegal wildlife trade (Tencent, 2018; WWF, 2018). On the one hand, in the digital age, most illegal wildlife trade takes place online. On the other hand, Internet users can play a big role in the fight against the online illegal wildlife trade. Furthermore, WWF can work together with Tencent's dataset to devise future wildlife protection plans.

4.3. Case analysis

In this section, we adopt the three dimension framework – actors, activities, and modes of innovation - proposed by Diercks, Larsen and Steward (2019) to analyse this case. Collected data (shown in Table 2) was inductively coded by the authors.

4.3.1. Actors involved in BCI

The main institutional actors involved in BCI are the cities and regions of China (see Document 3 in Table 2: D03). "Taking into account the development level, resources and environmental endowments of various regions", the achievement goals of each region and city should reflect its own situation, and "not implement one size fits all" (D03). "Regional differences" are permitted by policies to allow particular cities and regions to plan their own goals and actions based on the overall guidelines, policy framework and rules developed by the Chinese central government. For example, both Beijing city and Shanghai city will follow the same guideline proposed by the joint agencies (i.e., Ministry of Ecology and Environment (MEE), National Development and Reform Commission (NDRC)) while these two cities each has the flexibility to make its own detailed plans and goals.

Besides the cities and regions which are fully involved, several governmental agencies are also engaged in policy making, organizing evaluation, green technology and energy development support, institutional support and other related activities. In 2018, MEE was established, superseding the former Ministry of Environmental Protection (MEP). This has provided a new start in terms of meeting social and environmental challenges through an integrated public agency which can take general responsibility and guide civil society, individuals and local public sectors. Before the introduction of the 14th Five-Year Plan, from January 1, 2020 to June 2020, MEE invited opinions on its website – "I offer suggestions for the improvement of the water ecological environment during the 14th Five-Year Plan", "I offer suggestions for the improvement of the marine ecological environment during the 14^{th} Five-Year Plan", and "the beautiful China in my mind" (MEE, 2021). Furthermore, MEE takes a supervision and information disclosure role. For instance, all citizens can check MEE's website and find their city's air quality data under the "real-time city air quality" project – or the equivalent under "real-time region surface water quality". Law enforcement information is also available on the website.

In addition, MEE has introduced policies to advocate different activities concerning environmental protection, *e.g.*, leading the "no-waste city" pilot plan in which ten Chinese cities became involved, and also a further six agencies including the Ministry of Housing and Urban-Rural Development (MOHURD) and the National Bureau of Statistics (NBS) (D01). Preferential tax policies were introduced by MEE to encourage financial institutions to offer funding support to promote the development of the recycling industry in the pilot cities (D01).

Before MEE superseded MEP, NDRC took the main responsibility on BCI to publish related policy documents, and organize other government agencies, *e.g.*, Ministry of Science and Technology (MOST), Ministry of Natural Resources (MNR), Ministry of Housing and Urban-Rural Development (MOHURD), Ministry of Water Resources (MWR), Ministry of Agriculture and Rural Affairs (MOA), National Bureau of Statistics (NBS), CAS, National Forestry and Grassland Administration (NFGA), and the Development and Reform Commissions of all provinces. Even though since 2018, MEE as a new re-organized agency has started to play a central role in BCI, NDRC still takes an important responsibility.

Innovative and technology firms actively participate in BCI, for example, focusing on technology innovation in the environment field. Institutions and universities, on the one hand, take the key role of developing fundamental research and innovation and, on the other hand, collaborate with firms to achieve commercialization. CAS as an institution, not only participates in scientific research but also works to assess the performance of BCI at the city and region level (D03). Table 3 shows the roles and mandate of involved actors in BCI.

Table 3 Roles and mandate of involved actors in BCI

Actors	Roles	Mandate within BCI
Cities and regions	Main actor	Develop their own rules, policies, and plans, and implement actions
MEE	Leading role	Introduce further policies to support policies made by central government and facilitate BCI, including data on air quality, water quality, and earth quality, lead and coordinate other agencies on certain activities
NDRC	Key role	Introduce detailed policies
MOST, MNR, MOHURD, MWR, MOA, NBS, NFGA	Supporting role	Support MEE and NDRC's policies, plans and activities
Innovative and technology firms	Application, main work/ operation of BCI	Active participant in technology innovation within the environment field
Institutions & universities	R&D	Support fundamental research and work with laboratories and firms on commercialization
CAS	Assess	Assess the implementation of BCI
Civil society and individuals	Participant	General participation

4.3.2. Activities of BCI

Within BCI, there is a strong focus on systemic and integrated change. The "emission permit system" requires the promotion of "market-oriented trading of emission rights, energy rights, water rights and carbon emission rights" (P02, P03). Activities including "active participation in and leading international cooperation on ecological and environmental protection such as climate change" are emphasized, suggesting that even though BCI is a national initiative, it is not only focused on China's narrow concerns. China has expressed a willingness to collaborate with other countries on "climate change… infectious disease…global research fund" (P02, P03).

Supply-side reform has been emphasized by the Chinese government to achieve the development of BCI. Fundamental research and technological innovation are presented as becoming more and more important to move the development path from a focus on "quantity" to "quality". The path of "high quality development" is proposed in the 14th Five-year Plan. Supply-side reform based on the development of high technology is mentioned not only in the 13th and 14th Five-year Plans but also in the main BCI policies (P01, P02, D03). The government financially supports "green technology innovation" to upgrade traditional industries and life quality, for example, renovating the urban sewage pipe network and improving people's living environment (P02). "Develop strategic emerging industries" is also included, such as "new energy, new materials, new energy vehicles, green environmental-friendly industry" (P02).

At the same time, demand pull is presented as an important driver of innovation and development. According to the BCI, values created by technology and development should consider people's demand: "Insist on putting people at the centre…adhere to the dominant position of the people, adhere to the direction of common prosperity, always achieve development for the people, development depends on the people, and the fruits of development are shared by the people…stimulate the enthusiasm, and enhance people's livelihood and welfare…continuously realize the people's yearning for a better life." (P02). For example, in the rapid urbanization of China, "promoting the improvement of private and public toilets, domestic waste treatment and sewage treatment" is emphasized to "improve people's living quality" (P02).

4.3.3. Mode of innovation of BCI

The mode of innovation of BCI focuses particularly on experimentation at the city and regional level. It is also practice- and problem- oriented. For example, the "no-waste city" pilot plan (D01) was introduced in 2018 by the State Council, aiming to minimize solid waste generation and maximize recycling in urban areas. All cities can apply to be part of the "no-waste city" pilot programme. A total of 12 government agencies including MEE and NDRC have assessed and selected the applicants. 11 cities and 5 regions were selected as "no-waste city" pilots (the so-called "11+5 no-waste pilot cities"). Participating cities and regions should follow the guideline of "problem orientation and focus on innovation-driven", including "the current outstanding problems of large volume of solid waste, illegal transfer and dumping" (D01).

Furthermore, integrated innovation and coordination of the solution to local practical problems have been emphasized in the development of no-waste cities. For example, promoting key technology breakthroughs and proposing model innovation are included so that other cities should learn and benefit from the pilot cities' practice. In addition, active citizen participation is mentioned in the "11+5 no-waste pilot city" plan (D01).

The mode of innovation of BCI is development oriented, focusing on the State Environmental Protection Key Laboratories and building the platform for transforming scientific and technological achievements and developing the environmental protection industry (D04, D05). The State Environmental Protection Key Laboratories aim to strengthen fundamental research and practice research in the environment area, and to train scientific talents for long-term development.

5. Discussion and Conclusion

Research and practice with regard to transformative innovation policy are still in their infancy. In this paper, we analysed the case of BCI as a way of understanding the potential future development and application of this approach. We will conclude with three main points and then some suggestions for further research and reflection.

First of all, an important part of this case analysis addresses the multiple actors involved and their different, but in principle complementary, roles. More than ten agencies participate in the initiative. Even though MEE is leading most activities, other agencies such as NDRC and MOHURD also play an important role. The collaboration between these agencies at national and regional levels is clearly complicated. This leads us to the first challenge of transformative innovation policy: *coordination and interaction between different governmental agencies with different responsibilities and jurisdictions.*

A wide and long-term perspective on research and innovation policy – as suggested by the notion of "transformative change" – implies that one government department cannot work alone. Moving beyond the particular domain of government increases the challenges even more: transformative innovation policy depends upon a large and divergent network of actors, each with their own perspective and way of working. Seen in this way, research and innovation policy becomes less of a "specialist" field and instead one deeply inter-connected with many levels of governance, institutional action and policy-making.

Secondly, there is clearly a major challenge related to "development", which refers to economic development but also societal and environmental development. The relationship between economic development and societal/environmental development is not necessarily contradictory: it is possible to imagine "win/win" solutions where all aspects of development benefit equally. However, this may not apply in every case and priorities will sometimes need to be made.

We are reminded here of Diercks *et al.*'s basic point: "We conceptualize transformative innovation policy as an emerging policy paradigm seen as layered upon, but not fully replacing, earlier policy paradigms" (Diercks *et al.*, 2019, p.890). Based on the case considered here, we can say that notions of transformative change sit alongside a continuing commitment to economic growth and industrial prosperity. Whilst this relationship can be debated in abstract terms, one purpose of the kind of policy research conducted in this paper is to present activities like BCI as valuable institutional and social experiments. Experimentation in this field seems essential, but also the possibility for cross-institutional and cross-national learning.

Thirdly, one key distinction made by Diercks *et al.* is between a narrow versus a broad understanding of the innovation process. Whilst the narrow approach focuses essentially on the commercialization of technological change, a broader approach takes a much more inclusive perspective on the "new ideas" developed by innovation – which may or may not be commercial in orientation.

Drawing upon this summary of the BCI case, there is much which fits with the broader definition, not least in the inclusion of actors from a diversity of bodies, the treatment of demand-side as well as supply-side factors, and a mode of innovation which extends beyond reliance on science and technology alone. Once again, the BCI is revealed as an internationally-important example of experimentation – and it will therefore be particularly important to assess whether this broader approach can be maintained as BCI develops from its still-early stage into full development. We would add that *a long-term and sustained commitment is crucial in addressing these deep challenges: transformative change is unlikely to happen within a short or even medium-term frame.*

Taking these three final points together, we are left with a strong sense of the appeal and importance of transformative change but also of some of the substantial challenges ahead. The concept has considerable value, but turning it into practice at an international level will involve institutional commitment and work at several different levels. That takes us to the question of where next in terms of future research and practice. Let us offer three last reflections on this.

The first reflection is that, as just noted, it is especially valuable for international research to pay attention to BCI (and similar cases world-wide) and to continue to analyse its significance for transformative change. Here, we are conscious of only making one step forward in this regard. Extending that point somewhat, the second reflection concerns the importance of China with regard to the issues developed here – which we see as a very important (inter)national setting. Certainly, developments over the next decades in that country are likely to have huge social, economic and environmental significance.

The third concluding point is that, just as a broader notion of "transformative" innovation policy requires greater integration between government and policy actors, a similar argument can be made about social scientific research in this field. A case such as BCI calls out for reflection and discussion not only among traditional innovation scholars but also a much large range of specialists across the social sciences. To put it succinctly, transformative innovation policy is too important, too broad and too challenging to be left only to innovation researchers.

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