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Corporate Strategy and Ecological Modernization: Industrial Water Management in North China

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Abstract

In the ecological modernization of China, how firms respond to environmental constraints ought to be investigated to inform environmental reform in China. In industrial water management in particular, socio-economic development in China is boosting industrial water demand, yet water scarcity, severe in the drier north, has exacerbated the conflict between this natural resource and industrial need. While the Chinese government initiated various engineering projects, the largest being the South to North Water Transfer Project, to increase water supply in areas of demand, better management (e.g. changing consumption, reuse and recycling etc.) is argued to be of more urgency and sustainability in China. Positive changes in people's values, attitudes and behaviours towards water could lead to efficient use of this limited resource.

Therefore, this thesis takes a behavioural approach to investigate water management strategies in North China industrial organizations through the lens of ecological modernization. Empirical research is based on firms located in two regions, Beijing and Hebei. It investigates how industrial firms, one of the major market actors in ecological modernization, respond to both physical and regulatory environmental constraints. The methods used are primarily qualitative: semi-structured in-depth interviews and direct observation, supported by secondary data collection. The physical and institutional water availability in the study areas is firstly assessed. Then firm strategies in water management that patterned organizational behaviour are identified. Through analyzing strategies in different firms, the impact of firms' own characteristics within their borders and the impact of locality attributes are disentangled.

The thesis demonstrates ecological modernization a useful tool for understanding water management in China. It finds that North China's industries are faced with both physical and regulatory water stress, though current prices fail to regulate industrial consumption. Environmental and institutional circumstances are driving environmental upgrading in this region. Firm-level adaptations featuring both upgrading and downgrading strategies include innovation, relocation, outsourcing, factory closure and rule breaking, depending on firm capabilities and orientations. I further argue that both firm characteristics (ownership, size/scale, financial status, market position, and sectoral character etc.) and locality factors (infrastructure and institution) play significant roles in shaping firm behaviour in water management, while interacting with each other. By building a tentative analytical framework to analyze the impact of firms' own characteristics and locality on firms' water strategy, this study contributes to both management and geographical theories within the framework of Chinese ecological modernization. And through the empirical analysis, water management suggestions for decision makers in both state and enterprise level are given.

Declaration

This is to certify that

i) the thesis comprises only my original work towards the degree of PhD,

ii) due acknowledgement has been made in the text to all other material used,

iii) the thesis is less than 100,000 words in length, exclusive of tables, maps, bibliographies and appendices.

Chenchen Shi

April 2020

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List of Acronyms

AQSIQ	Administration of Quality Supervision, Inspection and Quarantine
CCP	Chinese Communist Party
CEM	Corporate Environmental Management
COD	Chemical Oxygen Demand
COE	Collectively Owned Enterprise
CSR	Corporate Social Responsibility
EHS	Environment Health and Safety
EKC	Environmental Kuznets Curve
ENGO	Environmental NGO
EPB	Environmental Protection Bureau
EU	European Union
FAO	Food and Agriculture Organization
FIE	Foreign-Invested Enterprise
GDP	Gross Domestic Product
ISO	International Standardization Organization
MEP	Ministry of Environmental Protection
MIIT	Ministry of Industry and Information Technology
MOC	Ministry of Construction
MWR	Ministry of Water Resources
NDRC	National Development and Reform Commission
NGO	Non-Governmental Organization
OECD	Organisation for Economic Co-operation and Development
PPP	Public-Private Partnership
SNWT	South to North Water Transfer
SNWTO	South to North Water Transfer Office
SNWTP	South to North Water Transfer Project
SOE	State-Owned Enterprise
TVE	Township and Village Enterprise
WA	Water Authority

Chapter 1 Introduction

The conflict between economic development and environmental protection is faced by many industrializing and developmental regimes. Ecological modernization, the enhanced mode of environmental governance originating from the Europe in the 1980s, holds that the capitalist economy could solve this problem through technological advances that mitigate the trade-off between economy and environment, with the participation of civil society actors in addition to state and market actors in a democratic setting. According to ecological modernization theory, the conflict between industrial development and environmental protection could be resolved through environmental innovation without fundamental change to production and consumption. China is now undergoing an environmental reform process consistent with the principle of ecological modernization (Mol, 2006; Mol & Carter, 2006; Park, Sarkis, & Wu, 2010). Green development in China, exemplified in "Two Mountain Theory[1]", the most recent political discourse under Chinese President Xi Jinping, calls for coordinated development of environment and economy. Therefore, I adopt the ecological modernization theory in this thesis and apply it on a firm scale, for corporate behaviour must be consistent with China's green development (Fu & Geng, 2019). In the state-led ecological modernization of China, firm responses to both physical and regulatory environmental constraints need to be examined to ensure that policy approaches achieve the desired behaviour (Williamson & Lynch-Wood, 2012). It is also important to understand the context in which firm operate and perceive their environment to refine policy making (Baylis, Connell, & Flynn, 1998a, 1998b). Therefore, this research investigates how firms respond to ecological modernization in China. And while ecological modernization theories focus more on the social and institutional sphere, this research, using industrial water management as a case study, also examines firms' responses to physical environmental change to better understand firm behaviour.

Worldwide, industry accounts for about 20 per cent of total water use. The balance is used by agriculture (70 per cent) and the domestic sector (10 per cent) (Kohli, Frenken, & Spottorno, 2010). However, in recent years, the percentage of global water use for agriculture has been decreasing and industrial water use has been increasing, especially in developing countries like China (Piao et al., 2010; Z. Zhang et al., 2020). Industrial water use and its future demand is a priority for China (Y. Jiang, 2009). How businesses are managing water needs therefore to be investigated. China has been known as the world factory for the past decades, but along with the rapid development of manufacturing came environmental degradation (Jianguo Liu & Diamond, 2008). For manufacturing firms in northern China, the problem is severe given the physical water shortages and high levels of water pollution in this region (D.-L. Hong, Chien, & Liao, 2019).

[1] Green mountains and clear waters are indeed mountains of gold and silver.

Therefore, in the face of resource constraints and environmental pollution, North China industries are under huge pressure to upgrade their environmental practices. In this thesis, I examine industrial water management in North China, using the case of the Beijing-Hebei region. I aim to analyze firm-level water management strategies in the face of resource and regulation constraints. Further, I explore how firm characteristics and locality factors exert impact on corporate water management.

This chapter serves as the introduction of this thesis. It starts by setting the research background on industrial upgrading under ecological modernization in China and using industrial water management as an explicit case study. Three research questions are constructed to achieve the research aim. Then the case study of this research is introduced, noting the significance of this research in context. Finally, the structure of the whole thesis is presented with an overview of each chapter.

1.1 Background

Water scarcity in China

With economic development and population booming worldwide, both industrial and municipal water demand have been increasing (George, Malano, & Davidson, 2007). According to FAO, these two types of water withdrawals account for 18 and 12 per cent, respectively, of the global total (FAO, 2011). Not only does industry consume large amount of water resources, it also comprises a huge source of pollution. However, global scarcity of water resources is increasingly drawing attention from both academia and governments in many countries as the situation continues to worsen. China is among those countries that are under high water stress (Jiao Wang, Zhong, & Iceland, 2017). In addition to resource constraints, inappropriate management has resulted in irrational utilization of resources and generated massive pollution (R. Xu et al., 2019). Water use efficiency in Chinese industry, in terms of output per unit of water, is less than one-tenth of the average in developed countries (Anonymous, 2014).

Therefore, this thesis sets out to investigate the water use behaviour of industrial organizations in China. The research was conducted in the context of the mega water transfer, South to North Water Transfer Project, which is expected to change the water availability within four major river basins, six provinces and three megacities (Barnett, Rogers, Webber, Finlayson, & Wang, 2015). In addition to the physical water supply change, regulatory water availability has also changed in China during the process of ecological modernization with the tightening of environmental policies over the past decade. Manufacturing enterprises are faced with increasing pressure on water resource conservation and pollution control, which will be elaborated in the next subsection. Understanding how industrial firms respond to both physical and regulatory water availability change is my major investigation in this thesis.

Water is used in industrial firms for a variety of purposes: "cooling and transporting intermediate inputs, producing steam, producing electricity, sanitation and for inclusion in the firm's output (e.g., beer production)" (Renzetti, 1993, p. 181). Some recent studies generalize industrial water use into two categories, manufacturing water and power generating water (Hanasaki et al., 2013). In industrial organizations in China, production water could be classified, according to use, into cooling, slurry, boiler, process and product water. Official classifications of water in industrial entities in China divide it into three types: production water (water used in the production process), including cooling water, slurry water, boiler water, process water and product water; ancillary production water (used to clean facilities and equipment); and auxiliary production water, used in the daily life of staff. In this study water used for different purposes will be distinguished.

Also, industrial water possesses dual attributes. On the one hand, as one kind of natural resource, water is an environmental factor. Being an environmental capital, its consumption and trade could determine economic growth, which in reverse contributes to the depletion of this resource. On the other hand, as a means of production, water is an economic good (P. Rogers, De Silva, & Bhatia, 2002), or economic resource (Winpenny, 2005). Therefore, in the theoretical development, this dual attribute will be considered. In addition, given its economic attribute, water is one of the factor-inputs in industrial production. However, unlike other factor-inputs (e.g. land or electricity), the cost of water is low. According to my empirical evidence, the cost of water only takes a minimum proportion (<1/1000) of the total input costs for a manufacturing enterprise. Though numerous scientists, government officials, and water operators advocate that China develop water markets and use pricing mechanism to promote conservation, this thesis might have to challenge this common belief that higher prices lead to less demand: such an economic instrument may not work for water conservation in Chinese industries. Therefore, in this thesis, the water pricing issue in China will be particularly analyzed from the perspective of industrial users.

Ecological modernization in China

Following the approach developed by Mol (2006), I examine ecological modernization in China through political modernization, economic actors and market dynamics, civil society and international integration perspectives, paying specific attention to state and enterprise actors in the empirical case. Over the past 70 years, the rapid development of Chinese economy has come at the expense of its ecological environment, and the amount of environmental discourse has been increasing in Chinese Communist Party (CCP) political discourse (C. Shi, Shi, & Guo, 2019). Now with ecological modernization, Chinese industry is faced with increasing social and political pressure to pursue environmental upgrading. The North China cluster with its geographical and institutional proximity to the central government has been under the spotlight of China's environmental campaigns.

Now Chinese firms are restructuring both to boost production efficiency and to minimise environmental impact. On the state level, resource conservation and pollution control policies have been issued to strengthen environmental governance and improve corporations' environmental behaviour. In water governance, in 2012, State Council established the Strictest Water Resources Management System, commonly known as the Three Red Lines, to cut water consumption, increase water use efficiency and control water pollution (Moore, Shaofeng, & Nickum, 2017). In 2015, State Council issued the Water Pollution Control Action Plan to further improve water environment quality (Sternfeld, 2017). The Thirteenth Five-Year Plan for Energy-Saving and Environmental Protection, released in 2016, also set caps for water consumption and proposed new initiatives to reduce water pollution (A.-G. Hu, 2016). The revised Water Law in 2016 increased the penalties for water pollution. The revised Water Pollution Prevention and Control Law (2017), put into effect in 2018, proclaimed the River Chief and Lake Chief Systems, holding major government officials accountable for water pollution (Q. Lu, 2019).

Not only are there stringent regulations, but the government's resolve to enforce these regulations is also increasing. Local Environmental Protection Bureaus (EPB) now devote large amounts of labour to environmental monitoring (环境监察) (Ministry of Environmental Protection, 2012), since environmental pollution has long been condemned nationwide. Local industries, especially pollution-heavy industries, are under regular and random inspections from local environmental authorities. In addition to routine inspection by local government, in 2016, the central government launched the first central environmental inspection (中央环保督查) (Dong, 2018), starting from Hebei province, by sending out inspection teams to monitor local environmental practices, putting local governments and enterprises on notice. Empirical research also shows that central environmental inspection, as an innovative strategy, is advancing ecological modernization in China (R. Li, Zhou, Bi, Liu, & Li, 2020). When local governments fail to accomplish environmental protection objectives and tasks or are responsible for major or especially serious environmental emergencies, discussions are arranged by the central government with the leaders of those local governments. These are commonly known as environmental protection discussions (环保约谈). Since 2014, 23 provinces were involved in such discussions; Hebei ranked first in the number of these (Xing, 2018). In other respects, monitoring techniques have also evolved; pollution-heavy firms, which are often named on national or provincial key monitoring lists, are required by Environmental Protection Bureaus to install online monitoring systems (在线监测), leaving such enterprises little room to escape sanctions if they break the rules (W. Gao, 2016). Institutional innovations, like the third-party monitoring also help to improve environmental data quality, advancing environmental governance in China (Niu, Wang, Gao, & Wang, 2020). Empirical study also shows that corporate policy compliance is conducive to China's green development (Fu & Geng, 2019), which is also what I will be mainly investigating in this thesis.

Along with political modernization, institutional change and policy innovation in China's ecological modernization, particularly in environmental regulations have been witnessed (C. Shi, Guo, & Shi, 2019) – the main topic of this thesis. But other mechanisms that are driving corporate environmental management (CEM) will also be explored. At the enterprise level, environmental behaviour is driven by two major factors, namely policy compliance (Gunningham, Thornton, & Kagan, 2005) and technological innovation (Xin Zhao & Sun, 2016). At the regional scale, restructuring results in the adjustment of regional industrial structure, exemplified by a move up the value-added chain and a reduction in the number of resource and pollution intensive firms. Within industrial facilities, firms either initiate innovation to comply with policy or defy regulations. Firm-level environmental adaptation strategies encompasses both resource conservation and pollution control measures – measures that are initiated either in compliance with environmental policy or because of innovations that are driven by more complex reasons, or both. In this thesis, I examine how firm characteristics and physical as well as institutional locality factors are encouraging or discouraging firms' environmental behaviour.

In terms of civil society, though environmental governance in China now is decentralizing and increasingly engaging market and civil society actors (H. Shi & Zhang, 2006), the fundamental fact of state power remains (Martens, 2006). As a matter of fact, nonstate actors' environmental action commonly reflects the influence of the state (G. Deng, 2010; Guttman et al., 2018; Schwartz, 2004). Grassroot environmental NGOs in China, for example, still operate under the scrutiny of the state, the 'hidden rules' of which require that they "refrain from democratic claims-making and addressing social needs that might fuel grievances against the state" (G. Deng, 2010; Ho, 2001; Spires, 2011, p. 1). The dynamic of state and NGOs is, to a large degree, unilateral, with NGOs encouraged to carry out state environmental practice and to abandon attempts to influence or sharpen government policies (K. Zhang & Wen, 2008). Civil society still plays a marginal and indirect role in China's environmental politics (Lei Zhang, He, Mol, & Zhu, 2013).

As for international integration, according to Mol, it will shape firm environmental management in two main respects. First, it can add to firm capability in environmental management through direct financial aid or environmental technology transfer. Second, it might influence the environmental position a firm takes by imposing international standards and through international interactions. In this thesis the impact of international integration on firm behaviour will also be examined.

1.2 Aim and research questions

In the process of ecological modernization, how industrial firms, one of the major market actors, respond to environmental regulation as well as physical constraints will be explored through the lens of ecological modernization theory with the case of industrial water management. The

general issue that underlies this thesis is the applicability of ecological modernization in water governance in China. To reach that end, I firstly establish the physical and regulatory water availability in Beijing-Hebei, especially after the South to North Water Transfer Project (SNWTP). Secondly, I investigate what adaptation measures organizations have adopted to confront the change and manage their water. Then the internal and external factors that influence firm water management will be explored. This thesis asks:

Is ecological modernization a useful tool for understanding water management in China?
This study sets out a framework for analyzing firm strategies in water management under ecological modernization, jointly shaped by firm characteristics and locality. The analysis is a case study in the North China industrial cluster. How industrial firms respond to physical and regulatory water availability change in this region is investigated. The thesis is guided by the following secondary research questions:

1. (Background question) What is physical and regulatory water availability in northern China?
By answering this question, this thesis manages to figure out water availability for North China industrial firms. Has the South to North Water Transfer Project changed the water resources supply in the receiving area? And in terms of quality, quantity and pricing, to what extent has this transfer altered the water availability specifically for industrial production? Are manufacturing facilities subject to other regulatory constraints on water use and waste emission in the process of ecological modernization? How is pricing playing a part in regulating firms' water use?

2. (Firm strategies) What do industrial firms do to manage water?
The water consumption and waste treatment in firms are constrained both by the physical supply of water and environmental regulations. Firms might alter their water use behaviour voluntarily to cut input cost or in compliance with public policies. Regarding water scarcity in North China, how much attention have firms attached to their water management? How is water managed in industrial firms? In answering this question, I aim to identify water management strategies that pattern firm behaviour under the guidance of organizational behaviour theories.

3. (Impact factors) How do firm characteristics and locality factors exert influence on water management strategies?
By investigating different types of firms, this thesis manages to distinguish strategies taken in those firms. How do firms' own nature and attributes, in terms of, scale, ownership, share listing, business culture, CSR (Corporate Social Responsibility) and the like exert impacts on firm strategy by influencing the incentives and capabilities of their adaptation behaviour. In addition, I try to figure out how locality influences decision-making on water management while interacting with firm characteristics. Locality factors, including government regulation, local politics, physical infrastructure, resources availability are considered.

There are several concepts in my research question that I would like to clarify. Behaviour: for water use behaviour investigated in this thesis, I mainly look into how water is used in a manufacturing facility and how wastewater is treated. Strategy: the adoption of courses of action and the allocation of resources necessary to achieve the organization's goals. And in my case what measures an organization has taken to change its water use and wastewater treatment. Water management in this study is the activity of planning, developing, distributing and optimally using water resources under defined water polices and regulation. Since I am examining industrial water, wastewater treatment is also considered a part of industrial water management.

1.3 Case study and significance

To ground this research in context, I selected the Beijing Municipality and Hebei Province in North China (Figure 1.1), the development of which is constrained by physical water shortage, pollution and stringent environmental regulations. As an important contingency in this research, SNWTP, initiated by the central government, was set out to deal with the spatially unbalanced availability of water resources in China and to remove the water resource constraint to economic development in the north (World Bank, 2002). Beijing and Hebei are now both receiving water from the Middle Route of the SNWTP to sustain their urbanization and industrialization. However, by emphasizing the resource shortage, the project neglects deficiencies of management in the current system, which are regarded by many scholars as the most efficient and sustainable measure to deal with water stress in China (Barnett et al., 2015; S. Rogers, Jiang, Shi, & Zhang, 2018). By imposing this project, the government has rendered it as an example of technopolitics and concealed the anthropogenic sources of water crisis in China (Crow-Miller, 2015). Will the transfer alleviate the water stress in the north? Could it possibly compromise the incentives for better water management? This thesis tries to inform such questions by considering enterprise-level water management. And as the SNWTP in China is assumed to boost urban expansion in the north at the expense of resource loss in the south, I examine the eventual influence on production and industrial water uses in the destination region. Hopefully, this thesis can provide water management suggestions for decision makers in both governments and firms and shed light on the effects of SNWTP in water receiving areas.

Figure 1.1 Location of the case study area in China

The literature about water management in China mainly focuses on state initiatives, characterizing government management on a regional scale (Pahl-Wostl, 2019; D. Shen & Speed, 2009; R. Y. Wang et al., 2017), while the behaviour of enterprises, the ones being regulated, are often overlooked. In this thesis, I take a behavioural approach and investigate water management from the perspective of the firm. Further, I disentangle the interplay of different actors in environmental management through the dynamic of regulation enforcement and policy compliance. In other words, if I am to assess ecological modernization in China, then I need to understand the manners in which firms are responding to modernization of the state's ecological governance.

Environmental management comprises many environmental elements, such as air, water, land, energy, climate change. Different areas are subject to different forces. Air quality, for example, especially urban air quality management in China, is the most high-profile environmental management area (J. Liang & Langbein, 2015), with enormous research effort, since air quality deterioration is highly visible and literally suffocating; it therefore draws public attention and participation. In this thesis, I examine China's environmental governance in water, which is constraining socio-economic development in China yet often overlooked. In addition, much previous research on Chinese water governance largely focus on agricultural water use (R. Y. Wang, Liu, & Dang, 2018), while there is less work on industrial water use. Industrial water governance with its unique feature of pollution control, a challenge that agricultural water management is not usually faced with, is given due attention in this thesis.

In addition to environmental element heterogeneity, there is a distinction between resource conservation and pollution control, which is scarcely mentioned in the environmental management literature. Previous empirical studies either focused on management of a particular environmental element (Gilley, 2012; C. Wong & Karplus, 2017) or investigated either conservation (Olmstead & Stavins, 2009; Xiaofan Zhao & Ortolano, 2010) or pollution (Lingxuan Liu, Zhang, & Bi, 2012; Lo & Leung, 2000; Lo & Tang, 2006) separately. There is no comparative study of resource conservation and pollution control. This thesis also aims to fill that gap.

In theory development, this study applies ecological modernization theories in the Chinese context and examines in particular firms' responses, to compare policy with compliance. In analyzing firms' responses, this thesis contributes to a holistic view to the complexity of firm strategy in environmental management, taking firm characteristics and locality factors into account; in firms' water use adaptation, constraints arise from infrastructure and institutions inside and outside firms. The result is a picture of firm behaviour in water management, which is co-shaped by firm's own natures and attributes as well as the institutions of territories, where knowledge, technologies and infrastructure co-evolved in firms and territories.

Thus, this thesis also contributes to the application of evolutionary concepts in enterprise-level environmental management in a non-Anglo-American context. It is found that water management in Chinese industrial firms is highly path dependent. Regular industrial users pay scant attention to water, as water supply and consumption are routine matters. Adaptations to regulatory risk are also dependent on previous technological and institutional conditions. In the end, environmental performance is often improved as a by-product of production technological innovation. On the other hand, relocation breaks the lock-in of technology and creates a new path, which leads to innovation in water use. Therefore, relocation of manufacturing factories in the study region, though coerced by the state much of the time, provides an opportunity for path creation.

1.4 Thesis structure

Subsequent sections of the thesis are structured as follows:

Chapter 2 lays out the theoretical background of this research. It begins with an introduction to ecological modernization theories, organizational theories and evolutionary economic geography concept of path dependence, that provide the theoretical basis of this study. Pulling all theories together, an analytical framework is developed for this thesis. The reviews of empirical studies of firm behaviour under resource constraints, of corporate environmental management and industrial water management in the case study region are presented in the empirical chapters.

Chapter 3 introduces the research method. It explains the research design and specific methods applied in this thesis. The methodological design used to investigate industrial management

through a comparative case study in two provincial level cities in China is firstly introduced. Both qualitative and quantitative approaches were adopted; the justification and detailed description of these methods are also explained in this chapter. A brief introduction of the study area is given, as well as the criteria of firm sample selection. Data needed for this research and data collection methods as well as data source are also presented.

Chapter 4, 5, 6, 7 present the empirical results of the case study. Chapter 4 sets the ground of this thesis by describing the background of the study region, its physical and regulatory water availability and regional industrial structure, in response to research question 1. Chapter 5 presents the findings about water management strategies that pattern firm behaviour, in response to research question 2. Chapter 6 is an analysis of how firm's characteristics impact on water management, in response to research question 3. Chapter 7 is an analysis of how locality factors influence firm strategies while co-shaping firm characteristics, also in response to research question 3.

Chapter 8 concludes with an assemblage of firm strategy, characteristics and locality. I argue that both firm characteristics and locality play significant roles in shaping firm behaviour in water management, while interacting with each other. In this chapter, I also reflect on the research question, explain the contribution that the case study makes to studies of ecological modernization in China and corporate environmental management from the enterprise-state perspective, and give suggestions for further research.

Chapter 2 Literature Review

2.1 Introduction

As introduced in the first chapter, this thesis aims to characterize firms' adaptation to environmental constraints, which is different from individual or government adaptation. To understand this phenomenon, it is necessary to delve into approaches to firms' decision making which have been discussed in geographical, sociological, economics and management literatures. Based on those literatures, this study adopts a view of the firm that is resource-based and traces the implications of that for an empirical design to enrich geographical understandings of corporate behaviour and the literature on adaptation to environmental stresses. This research builds on recent insights in ecological modernization theory, organizational behaviour, and economic geographic theories of industrial upgrading, innovation, relocation, policy compliance, path dependence, governance, infrastructure, institution and so on so forth. In characterizing firms' response to environmental governance in China, the thesis focuses on firm behaviour in water management and documents some of the ways different kinds of firms attempt to deal with the intensified physical and regulatory risk of water. Water governance literatures mainly focus on state initiatives, characterizing government management, while in this thesis I investigate water management from firms' perspective, the view from those being regulated, and disentangle the interplay of a variety of actors involved in this dynamic. This chapter reviews the literature on ecological modernization, organizational behaviour, along with the evolutionary economic geography concept of path dependence, and corporate environmental management to lay a theoretical foundation for my inquiry into firms' behaviour and their interaction with other actors and territories.

On the micro scale of a firm, as a behavioural study, this thesis employs organizational behaviour theories to understand firm adaptation in water management. Guided by organizational behaviour theories, I investigate the decision-making process in a firm and explain how adaptation is shaped by attention in organization, while exploring both the internal and external factors that influence firm behaviour. While organizational behaviour theory guides the analysis of firm behaviour and its impacts, I also adopt the evolutionary concept of path dependence to explore the effect of firm routines on behaviour to understand the co-evolution of technology and institution. Path dependence is not only used at the firm level, but also at the local and regional scales to depict the interaction between firms and locality and help explain how locality factors directly influence firm behaviour or indirectly affect it by shaping firm characteristics. An analytical framework is then built to examine firm behaviour as co-shaped by firm characteristics and locality factors. Potential theoretical contributions of this thesis to both organizational behaviour theory and evolutionary economic geography will also be discussed in this chapter.

This chapter sets out the theoretical background of this research. Subsequent sections are structured as follows. The chapter begins with an introduction to the ecological modernization theories, organizational theories and corporate environmental management theories that provide the theoretical basis. The analytical framework developed for this thesis is then described. Empirical studies featuring firm behaviour under resource constraints and industrial water management in the case study region will be introduced in empirical chapters of the thesis. This chapter concludes that it is important to examine ecological modernization from the perspective of economic actors; in my case it is important to investigate water management from an enterprise perspective, exploring both internal and external factors that influence firm behaviour in water management.

2.2 Ecological modernization

The ideas of ecological modernization

The concept/theory of ecological modernization emerged in the 1980s in early industrialized regimes (e.g. Germany, Netherland, the United Kingdom etc.) that were seeking ways of industrial restructure to delink economic growth from environmental damage (Simonis, 1989) and approach modernization issues from an ecology-inspired perspective; with early theorists including Martin Janicke and Joseph Huber (Huber, 1982, 1991; Jänicke, Mönch, Ranneberg, & Simonis, 1989). In the environment-induced transformations of institutions and social practices in industrialized societies, ecological modernization tries to "understand, interpret and conceptualize the nature, extent and dynamic of such transformation" (Mol, 2002, p. 93). It was adopted in policymaking at national and supernational levels (e.g. EU, OECD) (Gouldson & Murphy, 1996; Mol, 1999) and articulated first by environmental sociologists in characterizing human-nature interaction (Mol, 1997; Spaargaren, 2000b; Spaargaren & Mol, 1992), describing changes in environmental policy and politics (Hajer, 1995) and then widely by environmental studies researchers (Buttel, 2000). According to ecological modernization scholars, environmental modernization theory not only has analytical value but also normative virtues in informing or contesting sustainable environmental reforms (Phung, 2002; Mol and Sonnenfeld, 2000:7).

Environmental modernization theorists argue that environmental problems can be solved through effective institutionalization of social, political and economic systems. Mol (1995:58) summarized the institutional characteristics essential for the ecological restructuring processes being "a democratic and open political system; a legitimate and interventionist state with an advanced and differentiated socio-environmental infrastructure; widespread environmental consciousness and well organized environmental NGOs; intermediate or business organizations; a state regulated market economy; negotiated policy; sufficient and reliable environmental data;

and advanced technological development making". Unlike deep ecology (Devall & Sessions, 1985) or critical political ecology (Warner, 2010), which call for radical changes to human-nature relations and ways of life, ecological modernization recognizes the necessity of production and economic growth. It stresses preventive environmental policy and calls for structural changes to production and consumption patterns towards green contemporary capitalism (Andersen & Massa, 2000) and for an evolution from end-of-pipe approaches of environmental governance to pollution control and preventative strategies. It tends to argue that the advancement of science and technology will help mitigate the environmental deterioration brought by economic growth and that the environment and economic development do not have to be in an oppositional relationship (Mol, 1999).

Though originating from a production perspective, ecological modernization is also applied to the consumption sphere, characterizing consumer behaviour (Carolan, 2004; Spaargaren, 2000a; Spaargaren & Mol, 2008; Spaargaren & Van Vliet, 2000). Spaargaren and Van Vliet found in 2000 that ecological modernization of domestic consumption is happening in some European countries. Spaargaren (2000a) illustrated the need to modernize domestic routines and lifestyles with greater consumer integration. Carolan (2004) argued that there was a heavy 'productivist' orientation in ecological modernization with not enough problematization of (over)consumption. With ecological modernization as a political program, Spaargaren and Mol (2008) also discussed sustainable consumption policies for green consumption practices. In this thesis how consumer behaviour would in return impact on enterprise behaviour will also be examined through the lens of ecological modernization and corporate social responsibility.

In addition to the under-conceptualization of consumption, there are also other debates over ecological modernization theory, for example on the indicators of a country's ecological modernization. The experience of modernization can be regarded as the peculiarity of single country experience and does not necessarily have to be followed by other countries (Smith, 2001), suggesting that locality matters in applying the theory. Other critiques pointed out that ecological modernization has been used to explain "almost any environmental policy innovation or environmental improvement" (Buttel, 2000, p. 59), while to respond from a social theory perspective, more conceptual development is needed (Carolan, 2004).

Being a reform-oriented approach to environmental policy making, the concept of ecological modernization is often compared to sustainable development (Berger, Flynn, Hines, & Johns, 2001). The prescriptions advocated by the former were even considered as a practical way of the latter (Boons, 1997). Some even characterize sustainable development as a concept of ecological modernization (Huber, 2000), while others argue that they should not be conflated (Langhelle, 2000). Some local empirical studies characterize ecological modernization as a weak form of

sustainable development (Hills & Welford, 2002). As there are theories of weak and strong sustainability, there are also weak and strong approaches to ecological modernization. Early ecological modernization scholars sought a technocratic and corporatist approach to environmental externalities, which is conceptualized as weak ecological modernization (Christoff, 1996). By contrast, strong ecological modernization addresses the ecological, institutional/systematic, communicative, deliberative democratic, and international dimensions of environmental institutions. In short, weak ecological modernization rests on technology change and modest governance reforms, while strong ecological modernization encompasses bolder institutional and economic structure changes, embracing open and democratic decision-making.

Other similar theories include the Environmental Kuznets Curve (EKC), which holds that economic modernization will reconciliate the conflict between economic and environmental interests (Grossman & Krueger, 1991). EKC is about the relationship between environmental degradation and growth at different levels of economic development. At low levels of income, people pay attention to growth and worry little about the environment, so growth produces degradation; at higher incomes, people pay more attention to environment compared to growth, therefore degradation declines with increasing incomes, making the relationship between growth and degradation takes the shape of an upside down U. However, fundamentally, the EKC is a generalized empirical relationship rather than a solid theory. The driving force of EKC is thought to be the changing relationship between demand for higher income versus demand for better environment; whether this is achieved through technology or environmental controls, however, is not specified in the EKC literature. Even so, at higher levels of income, the downturn in degradation with growth is consistent with the interpretation of ecological modernization theory that emphasizes technological advance and institutional innovation.

Ecological modernization has been characterized as a social theory as well as a theory of politics and the state (Buttel, 2000), making the state and its policy making the major research objectives. As a mode of environmental governance and a process of environmental reform, ecological modernization also focuses on market adaptation, technological advance, civil society and public participation (Leroy & Van Tatenhove, 2000). For market and economic actors, ecological modernization theory calls for the internalization of environmental costs at both micro (business and corporation) and macro levels to ‘green the economy’. However, less empirical research on ecological modernization has been done at the firm scale. As an analysis of firms within the framework of ecological modernization, (Baylis et al., 1998a, 1998b) examined the impact of ecological modernization policies on firms in conjunction with firms’ own and sectoral characteristics and found that industrial sector, company size and type of environmental regulations impacted on firm response to environmental policy. Therefore, it is crucial to examine how ecological modernization policy aligns with firms’ goals and strategies in more detail and in

a different context. If policy is to 'work', it must push firms to do what is consistent with the goals of the policy. Hence, this study sets out to approach ecological modernization in China from the view of firm responses to understand the relationship between ecological modernization and business practices and reveal a way forward towards ecological modernization.

Ecological modernization application in China

Though built on empirical experience from the north-west European countries, ecological modernization theories have also been applied outside Europe – for example, in Central and Eastern Europe (Rinkevicius, 2000), North America, Australia and in developing and industrializing countries (Frijns et al., 2000; Sonnenfeld, 2000; Zhang, 2002; Liu 2005); as well as in the context of globalization (Mol, 2002, 2003; Weidner, 2002). These applications in non-west European contexts indicate that the analytical power of ecological modernization may be limited in different socio-political, economic and cultural settings and that it is important to view ecological modernization as an evolving concept and to use it as a flexible framework (Zhang et al, 2007) to: "analyze processes of environmental change and transformation; identify new actors and institutional processes of environmental reform; go beyond conflict models to explore opportunities for collaborative conservation & environmental solutions; articulate the engagement and participation of varied actors ('stakeholders') at multiple levels of scale; and strengthen environmental sustainability efforts in all sectors (Sonnenfeld, 2009)."

It was not until recent decades that environmental sociological and politics researchers in China started to use ecological modernization theory and focus on its implications for China. Mol (2006) examined the appropriateness of ecological modernization framework in China and pointed out that China differs from its European counterparts in three major ways, namely: the institutionalization of environmental interests; the respective roles of state, market and civil society; and environmental reform with Chinese characteristics[2]. Hills and Welford (2002) indicated that ecological modernization is a development path for Hong Kong and the rest of Asia to follow. De Jong *et al* (2018) developed a typology for ecological modernization pathways for Chinese cities and found that different industrial and regional profiles lead cities to different development paths, suggesting the study of regional heterogeneity. Though scholars claim that China already exhibits key elements of ecological modernization (Tracy, Shvarts, Simonov, & Babenko, 2017), more contextualized research is needed to reflect on ecological modernization theory and its application in China.

[2] The institutional arrangements in the environmental governance in China that have no equivalent in European countries. For example, environmentally oriented government-organized NGOs, the environmental responsibility contract system, the strong role of informal networks, rules and institutions, along with other institutions are unique to China.

In a study of the empirical application of ecological modernization theory in China, Yee *et al* (2013) found that the changing roles of state, market, civil society in recent environmental reform in China were compatible with Mol's conjectures. Zhang *et al* (2007) denoted a 'China-style' of ecological modernization as the reflexive/second-time modernization that differs from the north-west European version of ecological modernization in its greater emphasis on economic and technological approaches rather than institutional and governance change. Under China's framework of ecological modernization, many state-led initiatives such as circular economy, cleaner production, or industry ecology are adopted (Yongjin Li, Chen, & Chang, 2008; Yuan, Bi, & Moriguichi, 2006); with empirical research has investigated some of the explicit programs that have been labelled as ecological modernization, such as eco-city (Caprotti, Springer, & Harmer, 2015; Q. Zhu, Geng, Sarkis, & Lai, 2015), renewable energy (Dent, 2015), green GDP (V. Li & Lang, 2010), green government procurement , green building program (Yu Zhou, 2015), and various ecological construction projects (Yeh, 2009). These researches show that China's state-centred approaches to ecological modernization still need non-state actor integration and stronger public participation; the need for political modernization is not exempted in China's ecological modernization process yet (Yu Zhou, 2015). Researchers also find that in the ecological modernization of the Chinese economy, domestic economic actors hardly articulate environmental interests except for large Chinese firms in international markets and environmental industry and research & development (R&D) institutions (Mol & Carter, 2006). There has been little attention to the manner in which different types of firms articulate environmental interests.

Studies of ecological modernization from firms' perspectives explore how organizations can and will be able to balance economic growth and environmental stewardship (Park et al., 2010). There are empirical studies of green supply chain management (Q. Zhu, Geng, & Lai, 2010; Q. Zhu, Geng, Sarkis, & Lai, 2011; Q. Zhu, Sarkis, & Lai, 2012), green logistics management (Lai, Wong, & Cheng, 2012), environmental innovation (Yina Li & Ye, 2011) and corporate environmental disclosure (H. Wang & Bernell, 2013). They hold that all these green environmental initiatives in China fit into the ecological modernization framework, and that there is a growing pressure for Chinese enterprises as well as the state to pursue for ecological modernization. Yet ecological modernization in China has been largely interpreted as the radical shift from a resource- and pollution-heavy secondary sector towards the tertiary sector rather than upgrading of existing manufacturing industry to achieve higher economic value at lower environmental cost (De Jong et al., 2018). Nevertheless, manufacturing firms do have to balance their economic performance against environmental externalities, particularly with regard to environmental regulation (Williamson & Lynch-Wood, 2012) – and it is this process that this thesis examines among manufacturing facilities in the Beijing and Hebei industrial cluster.

One of the trending political narratives under Chinese President Xi's leadership is the 'Two Mountain Theory'. This theory focuses on both resource- and environment-carrying capability and socio-economic development; it aims to build an 'ecological civilization'. However, some local governments still consider that these two tasks contradict each other. In response to central policy, some localities even ceased industrial development to meet the green target (pers. comm); others continue to pursue growth at the expense of the environment (T. Hong, Yu, & Mao, 2019). If governments at all levels were to assimilate the ideas of ecological modernization theory, it might help better realize the goal of 'Two Mountain Theory'. The central government and scholars (M. Yu, 2020) have realized that ecological modernization is a promising way towards 'Two Mountains', but local governments continue to see growth and environmental protection as contradictory, justifying empirical analysis of locality in this study. Research on the interactions between locality and central policy through the lens of ecological modernization here seems particularly important.

It is worth mentioning that ecological modernization and ecological civilization[3] are two distinct concepts, though sometimes scholars and policymakers tend to mix them up. Though both are used in environmental policymaking, ecological civilization[4] is a Chinese concept. It was first introduced into CCP ideology in 2007 at the CCP's 17th Congress, endorsed by President Xi in 2013 in environmental law and policy making and written into the constitution in 2018. Hansen *et al*. (2018, p. 195) regard ecological civilization as "a sociotechnical imaginary in which cultural and moral virtues constitute key components that are inseparable from the more well-known technological, judicial, and political goals"; the imaginary is wielded by the CCP to solve environmental problems with science and technology. The concept of ecological civilization does bear some similarities with ecological modernization theory, in for example, targeting improved legislation and monitoring institutions, technological innovation and public participation (Geall & Ely, 2018). Still researchers need to distinguish this Chinese government ideology from the broader ecological modernization theory. Or ecological modernization can be viewed as a pathway towards ecological civilization.

One general feature of ecological modernization research in China is that many scholars are content with theory-testing through empirical application without much theoretical development. One recent theoretical development in research on Chinese ecological modernization defines ecological modernization as a techno-economic approach that combines technocratic ideals with

[3] There are also similar concepts such as green growth, green development, green modernization originating from the Chinese context and seen in various environmental discourse.

[4] The theory behind the national strategy of 'ecological civilization' and its counterparts, such as green development and circular economy, is the human-ecology theory developed in China at almost the same time as ecological modernization in early 1980s, the Social-Economic-Natural Complex Ecosystem (Ma and Wang, 1984; Wang 1989).

a growth-oriented sustainability paradigm (Westman & Castán Broto, 2019). In this research, through the empirical application of ecological modernization theory in China's water governance, I aim to further develop ecological modernization theory. The next section summarizes the gaps that this review has diagnosed in ecological modernization theory and so my potential theoretical contributions to the theory through this thesis.

Current gaps in ecological modernization theory

As ecological modernization theory is still a growing literature with competing and complementing interpretations (Mol, 2006), there remain several gaps in the ecological modernization literature, which this thesis aims to fill.

First, ecological modernization theory is too general, in the sense that it does not differentiate among various environmental elements, does not distinguish between pollution control and resources conservation, and does not recognize differences between localities. (To be fair, other schools of environmental governance also pay insufficient attention to these details.) Studies do show that industrial structure difference (Midttun & Kamfjord, 1999) and country-specific particularities (Smith, 2001) must be considered in defining best practice environmental governance under the ecological modernization theory. In this thesis, one of the contributions to ecological modernization theory is to specify the above-mentioned specificities, with attention paid to the distinction between resource conservation and pollution control, locality and industry.

Secondly, in ecological modernization theory, there is overwhelming focus on political institutions, while market dynamics and corporate responses are under-studied. Huber (2008) pointed out that there are three key components of environmental innovation: stringent regulation, pioneer companies, and pacesetting lead markets; market and corporate dynamics need to be explored in detail.

Thirdly, many studies are focused on the conceptualization of ecological modernization or on its discourses. Examples include the discourse on institutionalization advanced by Hajer (1995) about the uptake of eco-modernist thinking and discourse in policy making; and discourses in environmental governance (Berger et al., 2001; Di Gregorio, Gallemore, Brockhaus, Fatorelli, & Muharrom, 2017; Pascoe, Brincat, & Croucher, 2019; Spaargaren, 2000b). After all, ecological modernization is regarded as an attendant discourse of sustainable development by some scholars (Bulkeley, 2001). By contrast, this thesis focuses on the detail – of environmental policies being implemented and state-corporate interactions in ecological modernization. In a word, this thesis, while applying the ecological modernization theory to understand China's water governance, aims to critically respond to the assumptions in existing theory, and make potential contributions to this school of literature through empirical assessment.

To conclude, current studies of ecological modernization pay scant attention to firm behaviour and differences between places. In order to understand these, this study investigate firm behaviour across space under the ecological modernization framework, where ecological modernization serves as the analytical tool. In the next section, theories of firm behaviour will be reviewed to facilitate the major investigation of this thesis.

2.3 Organizational behaviour

The main purpose of this research is to understand 'why' and 'how' organizations change their behaviour in the face of resource and regulatory constraints. Therefore, the empirical investigation will be based on organizational theories and explore firm behaviour particularly from the perspective of strategic management and decision making. Organizational behaviour is the systematic study and application of how individuals and groups think and act within organizations and how these activities affect the effectiveness of the organization (Buchanan, 2019).

It can be studied from many viewpoints, for example, strategic management, behavioural science, organizational science etc. and uses a variety of theories. Prominent theories are resource dependence theory, organizational ecology, neo-institutional theory and so on so forth (Miner, 2003). In this thesis, I adopt the resource-based view (RBV), which has been widely used in corporate environmental management (Aragón-Correa & Sharma, 2003; González, Sarkis, & Adenso-Díaz, 2008; Lee & Rhee, 2007; Menguc, Auh, & Ozanne, 2010; Russo & Fouts, 1997) to examine firm response to environmental constraints from the perspective of firm resources and capabilities.

Resource-based view

The resource-based view of the firm (Barney, 1991; Barney, Ketchen, & Wright, 2011; Karamouz, Mojahedi, & Ahmadi, 2010; Wernerfelt, 1984) assesses firms in terms of their resources rather than their products. Resources here are not confined only to labour, land, or capital, but to a broader set of strength or weakness that a firm possesses. Resource-based view of firm is applicable in the domain of corporate environmental strategy through the emergence of unique organizational capabilities interacting with firm competitiveness. This theory emphasizes the assets that firms possess, and in this case the competitive advantage they gain through the process of confronting water constraints. Profitability and social acceptability are the major two benefits that a firm is likely to gain from water conservation behaviour through better economic and environmental performance. Evidence shows that these two performances are positively correlated and could both contribute to the competitive advantage of a firm (Russo & Fouts, 1997). RBV-based empirical research on firm strategy also finds that engaging with pollution prevention creates valuable assets that do not undermine economic performance, which is consistent with ecological modernization theory (Schroeder, Bates, & Junttila, 2002).

In adopting the RBV in this research, I aim to establish the link between organizational processes and the success or failure of a firm and describe how resources are developed (Barney, Wright, & Ketchen, 2001). In doing this, I hope to enable a better understanding of corporate environmental management within ecological modernization. Moreover, in this research I also aim to develop the resource-based perspective empirically to better measure intangible resources; problems of measuring intangible resources have been a constant obstacle to the resource-based research (Barney et al., 2001; Godfrey & Hill, 1995). In this study I combine qualitative information, which is good fit for measuring intangible resources, with quantitative methods to analyze tangible indicators.

Resource dependent theory

While the resource-based view is focused on the internal aspects of a firm – on what a firm is capable of doing when it is given the opportunity to react – resource dependent theory (RDT) (Pfeffer & Salancik, 2003), which is another influential theory of organizational behaviour and strategic management, recognizes the influence of external factors. This theory values the importance of social context, organizations' pursuit of autonomy and interests as well as power. It stresses the relationship between a firm and other outside actors. For example, water service organizations' relationship with stakeholders in corporate water management, are characterized as buyer-supplier relations (Barringer & Harrison, 2000; Oliver, 1990), which would be investigated under RDT to explore the influence of external factors on water utility behaviour.

RDT also combines well with other theoretical perspectives to explore organizational interdependencies. Research has been done integrating RDT with other management theories including stakeholder theory, real options theory, population ecology, institutional theory, contingency theory and other micro-perspectives (Hillman, Withers, & Collins, 2009). In the analytical framework of this study, RDT is integrated with RBV, which is also hardly new. Previous research proves this integration productive, as the synthesized theory sheds light on both gaining control of crucial resources to advance the competitive advantage and developing interdependencies on those very resources (Barney, 1986, 1991).

Attention-based view

Casting doubt on the limitations of human rationality in firms' decision-making, William Ocasio introduced a perspective on firm behaviour, forming an attention-based view (ABV), the central argument of which is that "firm behaviour is the result of how firms channel and distribute the attention of their decision-makers" (Ocasio, 1997, p. 187). ABV explains how organizational adaptation is shaped by attention in organizations. Over the years, different frameworks have been developed from ABV, often together with other management theories to understand firm behaviour (Grimpe & Kaiser, 2010; Kim, Kim, & Foss, 2016; Sapienza, De Clercq, & Sandberg,

2005; Stea, Linder, & Foss, 2015; Tuggle, Sirmon, Reutzel, & Bierman, 2010). Empirical studies of corporate environmental strategies also show that managerial interpretations of environmental issues have an impact on environmental strategies (Sharma, 2000). In this thesis, ABV will be drawn on to examine how much attention has been given to water management by firm managers and what outcome has been attained.

Like RDT, ABV can work together with RBV in organizational behaviour research, as it is often used in the analysis of decision-making (Pugliese, Minichilli, & Zattoni, 2014). Research has also explored the interaction between performance and attention within a firm under the guidance of the two theories (Ferreira, 2015). Since this exploration is still scarce, this thesis will develop the empirical as well as the theoretical study of this performance-attention relation.

These three organizational theories, namely, RBV, RDT and ABV, are not mutually exclusive (Gulati & Sytch, 2007; Hillman et al., 2009). Therefore, in this research I integrate them to understand firm's environmental adaptation. RBV and RDT are used to guide the assessment of firm performance, considering both internal and external factors, while ABV is employed to investigate the decision-making process in the firm.

Path dependence

In analyzing regional differences in firm behaviour, I adopted evolutionary economic geography's concept of 'path dependence'. One specific application of those theories of firm behaviour in geography is the idea of path dependence, which assumes that behaviour and success depend on routines. These routines might be because of the RBV of firm or its dependence or its attention. Therefore, path dependence is a specific sub-set of those organizational behaviour views and a particular application of those views within geography. Evolutionary economic geography theory "assumes behaviour and success of firms to be dependent primarily on the routines a firm (or its founder) has built up in the past" (Boschma & Frenken, 2006, p. 291). In addition, the resource-based, dependent and attention-based organizational behaviour is also path dependent (Lockett & Thompson, 2001; Miller, 2003; Sydow, Schreyögg, & Koch, 2009); therefore path dependence will be first explored at the firm scale and then aggregated to the regional level. This study will examine the path dependence and path creation features of a firm's environmental management and dig into the institutional dynamic within the path-dependency – as noted by Strambach (2010), the under-explored area of its application in economic geography.

Past empirical analysis of path dependent firm behaviour were mainly focused on innovation (Ruttan, 1997; Thrane, Blaabjerg, & Møller, 2010), knowledge accumulation (Kogut & Zander, 1992) and competence (Danneels, 2002), especially from the technological perspective (Arthur, 1989; Patel & Pavitt, 1997; Schilling, 1998). I draw on these literatures as my field data indicate technological choice, organizational knowledge and competence play a part in the path

dependence of firm's environmental management. However, in terms of corporate environmental behaviour, path dependence literature is scarce. Stern (2007) found that social customs and expectations lead to 'path dependency' that limits responses to climate change adaptation policies that were designed to raise efficiency. Faber and Frenken (2009) reviewed evolutionary economic modelling in environmental policy making and explored the possibilities of internalizing policy-making in environmental innovation. English literature on the applications of path dependence in Chinese industries is also scarce. Yeung (2009) identified institutional path dependence of non-market economies in the Chinese banking industry. Ma and Hassink (2014) tested the path dependence model in the tourist industry of a south China city. This thesis contributes to the empirical application of path-dependence in firm's environmental management in China.

Studies of Chinese manufacturing based on evolutionary economic geography have pointed out two major factors that are often neglected in traditional analysis of evolutionary economic geography, namely firm heterogeneity and regional institutional context. In the canonical path dependence model, one assumption is regional homogeneity of firms within a cluster (Martin, 2010); firm heterogeneity is overlooked. By contrast, in this thesis, firm heterogeneity is recognized by analyzing behaviour in different types of firms. Another issue overlooked by evolutionary economic geography literature is the role of institutional context in industrial diversification (S. Zhu & He, 2018) – that industrial diversification can be different across regions, and regional institutions might affect the intensity and nature of industrial diversification (Boschma & Capone, 2016). In this thesis, China's diversified economic and institutional landscape implies that the role of institutional territories in industrial evolution must be examined. Therefore, this thesis will contribute to evolutionary economic geography literature by acknowledging firm heterogeneity and institutional context.

Furthermore, path dependence is widely used in understanding changes in regional economies, industrial districts or clusters and other localized forms of industrial specialization (Hassink, 2007; Martin & Sunley, 2006; Maskell & Malmberg, 2007). However, there are few studies analyzing the path dependence in individual firms and how firm behaviour is influenced by historical experience. In particular, research on path dependence in Chinese industrial development focuses on regional development, though paying less attention to local social, political and institutional contexts in shaping industrial path. In this thesis, I aim to apply an analysis of path dependence at a firm as well as regional level, to investigate the evolutionary dynamic at both scales. The locality factors that co-shape the evolution of firm behaviour will be explicitly investigated.

This thesis' empirical work includes firms that have relocated and firms that have not relocated. Relocations provide a good context within which to study how creative destruction (Schumpeter, 1947), induce by relocation, causes new infrastructure and technology to replace old ones – paths

are broken. For business as usual firms, new paths may be created through technological innovation deriving from technological relatedness. Both types of path creation will be explored in the case study.

Another gap in current studies in evolutionary economic geography lies in the general neglect of environmental issues. Evolutionary economic geography concepts are utilized in various disciplines, such as geography, urban studies, regional science, management and on diverse issues with most being done on innovation, regional economies and industrial restructuring (S. Zhu, Jin, & He, 2019). However, attention to environmental studies is scarce (Boschma & Martin, 2010) and it has been argued that evolutionary economic geography would be empowered by incorporating environmental concerns (Patchell & Hayter, 2013). The evolutionary nature of environmental issues and path dependence in adaptation measures need to be investigated from the evolutionary economic geography perspective. As one of the externalities of industrial organization that might potentially constrain its development, environmental management in industrial firms deserves more attention from economic geographers. As a behavioural understanding of corporate geography, in this study, industrial water management is examined from the evolutionary economic geography perspective.

To conclude, in this section (2.3), general theories of organizational behaviour are reviewed. The three major theories and their applications are not mutually exclusive, they will be integrated in this research. RBV and RDT are used to guide the assessment of firm performance, considering both internal and external factors, while ABV is employed to investigate the decision-making process in the firm. Through this means, this study aims to provide details about: what is important about the assessment of firms' environmental reforms, their decision-making process and external environmental factors. The organizational theorise are utilized to facilitate the analysis of CEM. The next section provides a review of CEM and its influences, to offer additional level of details to complete the empirical meaning of the RBV, RDT and ABV in the specific space of CEM.

2.4 Corporate environmental management

In order to apply organizational behaviour theories in CEM, I need to investigate how the previously reviewed theories play out in the empirical case of CEM to find out what the influences upon firms are. Among them, firm characteristics and localities stand out. The literatures on CEM and its drivers are as follows

Industrial enterprises play an important role in environmental governance. Corporate environmental management is widely studied to investigate strategies, driving mechanisms and performances to better manage corporate environmental behaviour. Studies on CEM strategies involve green supply chain management, adoption of standardized environmental management systems (Darnall & Edwards Jr, 2006; Jayathirtha, 2001; Zeng, Tam, Tam, & Deng, 2005),

environmental information disclosure (Kuo, Yeh, & Yu, 2012; Meng, Zeng, Shi, Qi, & Zhang, 2014; Zeng, Xu, Dong, & Tam, 2010; Zeng, Xu, Yin, & Tam, 2012) or specific measures such as pollution control (H. Wang & Jin, 2007; Warren et al., 1999). These environmental management strategies yield different outcomes. Although the standard classification of corporate environmental strategies involves resistive, reactive/responsive, and proactive environmental behaviour (Warren et al., 1999), recent work has characterized corporate environmental coping strategies along four dimensions, namely, formalism, accommodation, referencing and self-determination[5] .

In terms of driving forces, previous studies tend to categorize drivers of CEM into external and internal factors (X. Liu et al., 2010), to study the external government regulations (Ding, Qu, & Shahzad, 2019), market or internal firm characteristics' impact. In this study, I also look at drivers of CEM from firm's characteristics (Chapter 6) and locality aspects (Chapter 7). Previous studies of the modernization of state environmental policy in the context of individual firms reveals that various firm characteristics, for example, company size (Baylis et al., 1998a) and sector (Baylis et al., 1998b), exert an impact on their response to environmental regulations. As Williamson and Lynch-Wood put it, firms' capabilities and orientations impact the environmental position they take, and consequently their approaches to compliance. Empirical research in China also shows how firms in China integrate ecological concerns into their operation and embedded institutional contexts (Yee et al., 2013). Different kind of regulations also influence the firms in different ways (Williamson & Lynch-Wood, 2012).

Among the studies distinguishing firm characteristics (Table 2.1), ownership is identified as a major factor influencing CEM (J. Yu, Lo, & Li, 2017). Evidence shows that ownership influences environmental adaptation costs (Darnall & Edwards Jr, 2006). In China in particular, ownership also influences the chances of getting government subsidies for environmental adaptation (Jin, Shang, & Xu, 2018). Moreover, ownership is also linked to disclosure of corporate social responsibility and environmental information, therefore exerting an influence on CEM (Kuo et al., 2012; Zeng et al., 2010). In addition to ownership, studies also find that firm size/scale (Bourlakis et al., 2014; Q. Zhu, Sarkis, Lai, & Geng, 2008), sector (Gunningham et al., 2005), environmental sensitivity (Kuo et al., 2012), and financial status (Zeng et al., 2012) all have an impact on CEM, which this study will explore. Also a firm's position in a global value chain influences self-regulation (Christmann & Taylor, 2001). Especially when firms seek to enter a

[5] According to Liu *et al*. (2016), formalism refers to a traditional 'go-by-the-book' coping strategy that strictly follows formal rules within a command-and control regulatory context; accommodation refers to a coping strategy that gives priority to meeting political or bureaucratic demands; referencing refers to a coping strategy that imitates peers' compliance practices or follows guidelines recommended by professional associations; and self-determination refers to a coping strategy that emphasizes intellectual flexibility, managerial discretion, and autonomy.

global market, they need to abide by international environmental regulations, which may evoke proactive environmental management (Zeng et al., 2005), which is consistent with ecological modernization theory's ideas about international integration (Mol, 2006).

Table 2.1 Firm characteristics that affect CEM

Characteristics	Reference
Ownership	Liu *et al*. (2019) ; Jin *et al.* (2018); Zhu *et al.* (2018); Yu, Lo and Li (2017); Kuo *et al.* (2012); Xu *et al*. (2012); Zeng *et al*. (2012); da Silva Monteiro and Aibar-Guzman (2010) ; Zeng *et al.* (2010); Chan (2010) ; Wang and Jin (2007); Darnal and Edwards (2006); Wang and Jin (2002)
Size/Scale	Zhu and He (2017) ; Cai *et al*. (2016) ; Bourlakis *et al*. (2014); Lu and Abeysekera (2014) ; Andrikopoulos and Kriklani (2013); da Silva Monteiro and Aibar-Guzman (2010); Darnall *et al*. (2010) ; Zeng *et al.* (2010); Liu and Anbumozhi (2009); Zhang *et al.* (2008); Zhu *et al*. (2008); Baylis *et al*. (1998a); Gunningham *et al.* (2005); Gao *et al*. (2005) ; Hillary (2004)
Others	
Listed on stock market	Xu *et al*. (2012); Zeng *et al.* (2012); Gao *et al*. (2005)
International integration	Zhu and Sarkis (2006); Zeng *et al*. (2005); Christmann and Taylor (2001)
Customer integration	Zhang *et al.* (2008)
Supply chain integration	Zhang *et al.* (2008); Zeng *et al*. (2005)
Sectoral characteristics	Lu and Abeysekera (2014); Zeng *et al.* (2012); Zeng *et al.* (2010); Wang (2008) ; Gao *et al*. (2005); Gunningham *et al.* (2005); Baylis *et al*. (1998b); Henriques and Sadorsky (1996)
Profitability	Lu and Abeysekera (2014); Andrikopoulos and Kriklani (2013); da Silva Monteiro and Aibar-Guzman (2010)
Environmental sensitivity	Kuo *et al.* (2012); Liu and Anbumozhi (2009)
Reputation sensitivity	Zeng *et al.* (2012); Gunningham *et al.* (2005); Zeng *et al*. (2005); Downing and Kimball (1983)
Industrial peers	Zeng *et al.* (2012); Barringer and Harrison (2000)
Manager perception	Liu *et al*. (2019); Shahab *et al*. (2018); Rowe and Guthrie (2010); Daily and Huang (2001) ; Egri and Herman (2000); Warren, Ortolano and Rozelle (1999)
Corporate environmental ethics	Chang (2011)

As for the locality factors, based on previous literature (Table 2.2), I divide all the locality factors into two categories, institutions and infrastructure. From an institutional perspective, policy and its enforcement (Dasgupta, Laplante, Mamingi, & Wang, 2001; Francesch-Huidobro, Lo, & Tang, 2012; Shahab, Ntim, Chengang, Ullah, & Fosu, 2018), local politics in terms of whether there is room for rule breaking (Dasgupta, Wheeler, & Huq, 1997) or government-enterprise collusion (Guo & Shi, 2017), institutional deficits (Hsieh & Song, 2015), or social pressure (Lo, Fryxell, & Tang, 2010) are found to be the external institutional factors encouraging or discouraging CEM. From the infrastructure perspective, physical water supply (F. Yu, Chen, Sun, Zeng, & Wang, 2011) and water infrastructure (Cheng, Hu, & Zhao, 2009; Yi, Jiao, Chen, & Chen, 2011) also stand to become external factors influencing firm behaviour. However, there is scarce research that explored locality impact on corporate environmental management from both perspectives

with infrastructural factors often overlooked in management researches. In this thesis, the analysis of locality factors' impact on firms' water strategies will be elaborated from both two perspectives, infrastructure and institution, and explicit factors in each category will be identified from the case study.

Table 2.2 Locality factors that affect CEM

Reference	Locality factors
Dasgupta *et al*. (1997)	Strictness of enforcement; monitoring deficiency, scarce inspectors, lenient courts, corruption of inspectors; regulators' discretion
Cushing, Wise and Hawes-Davis (1999)	State oversight and prestige
Warren, Ortolano and Rozelle (1999) Zhao and Sun (2016) Hu, Wang and Yang (2018) Shahab *et al*. (2018)	Environmental policy/regulation
Dasgupta *et al*. (2001)	Monitoring and enforcement activities, e.g. inspection and pollution charges
Gunningham, Kagan and Thornton (2004)	Social pressure
Child and Tsai (2005)	Institutional constraint, including pressures from NGOs
Berkhout, Hertin and Gann (2006)	Policy and market condition; resources external to the organization
Cheng, Hu and Zhao (2009) Yi *et al*. (2011) Liu (2019)	Physical infrastructure
Chan (2010)	Regulatory stakeholder influence
Lo, Fryxel and Tang (2010) Liu *et al*. (2010) Liu *et al.* (2016)	Stakeholder pressure (local government, industry, social pressure)
Menguc, Auh and Ozanne (2010)	Intensity of government regulations and customers' sensitivity to environmental issues
Rowe and Guthrie (2010)	Institutional contexts, 'coercive government institutional involvement'
Van Rooij and Lo (2010)	Convergence of governmental, social, and economic institutional forces
Yu *et al*. (2011)	Resource availability
Francesch-Huidobro, Lo and Tang (2012)	Pro-environmental orientation of environmental officials, institutional capacity of environmental agencies, external political support for environmental units
Zhu, He and Liu (2014)	Environmental regulations, regional hub effect and political environment
Lo *et al*. (2016)	Institutional contexts, support from non-state actors, quality and value of enforcement officials
Guo and Shi (2017)	Government-enterprise collusion
Zhou and Wang (2017)	Institutional impact
Liu and Mukheibir (2018)	Infrastructure, water metering in the case of water management
Liu *et al.* (2018)	A perception of clear political commitment to environmental protection across multiple government levels and units; a perception of policy ambiguity, in the form of confusing regulatory standards and enforcement; intensive inspections
Liu *et al*. (2019)	Severity of environmental problems

2.5 Analytical framework

Under ecological modernization, to examine firms' adaptation to environmental constraints, a resource-based analytical framework of firm is built to examine path dependent adaptation behaviour. While previous research on organizational behaviour and evolutionary economic geography pays less attention to firm-level environmental management, the theoretical framework constructed in this section aims to fill in those gaps in current organizational behaviour and evolutionary economic geography literatures.

This thesis explains firm-level adaptations to changes in water availability: a firm's ability to adapt to the change is one of its internal resources that increase its comparative advantage. The decision on whether to adapt to the change depends upon whether a manager's attention is attached to it, according to the attention-based view. Moreover, according to the resource dependent theory, firms' relationship with external organizations also influences their adaptation behaviour. Here, outsider organizations mainly include other stakeholders in a firm's water use, for example water supply companies, wastewater treatment plants, environmental service or consultant companies that deal with use of reclaimed water or wastewater treatment, and government agencies, like the Environmental Protection Bureau or the Water Authority. I investigate both internal and external drivers of firms' environmental management, as well as the interaction between these two drivers.

Guided by the three theories of organizational behaviour, this thesis will mainly investigate decision making about water use, including both resource conservation and waste treatment. I also evaluate the performance of the adaptation behaviour, which may in turn influence further decision-making with increased knowledge. Within industrial organizations, various factors influencing decision-making processes, both internal and external, and the final decision, as well as alternative decisions, will be investigated. The internal factors include attention paid to resource constraints. The external factors include changes in water availability (here induced by the water transfer) from the supply side and market influences from the demand side. Public policy plays a crucial role in firms' decision making, interacting with both the resource supply and market factors. The relationship with other organizations and whether firms act to strengthen this relationship will be addressed since this is another direction of firm's adaptation behaviour.

The key concept here is pro-environmental behaviour. Faced with an environmental constraint, the issue is whether firms make decisions to adopt pro-environment behaviours to conserve water resources, in terms of a reduction in consumption or better treatment of the waste. Those behaviours could be achieved through changes in products (D. Hu, Wang, & Yang, 2018), production scale or technological innovation. A second issue is whether the decision is made

voluntarily or imposed by public policy or market forces. Both issues will be probed to gain a comprehensive understanding of firm behaviour.

Once a decision is made to adapt to water resources, the performance of firms' adaptation behaviour will be evaluated from both economic and environmental perspectives. One key concept is economic performance, which is measured by firms' profitability, and which in turn affects decision-making. The other key concept is environmental performance, which may also exert an impact on firm's decision-making through its strengthening of corporate social responsibility. The change in social responsibility may also affect firm's profitability, through changed public image and customer appeal.

This thesis sets out to study firms' behaviour to understand their response to ecological modernization. In analyzing firm behaviour, with organizational behaviour theory and evolutionary economic geography theory as guides, the analytical framework (Figure 2.1) uses the resource-based view to explain firm-level adaptations to changes in water availability: a firm's ability to adapt to the change is one of its internal resources that increase its comparative advantage.

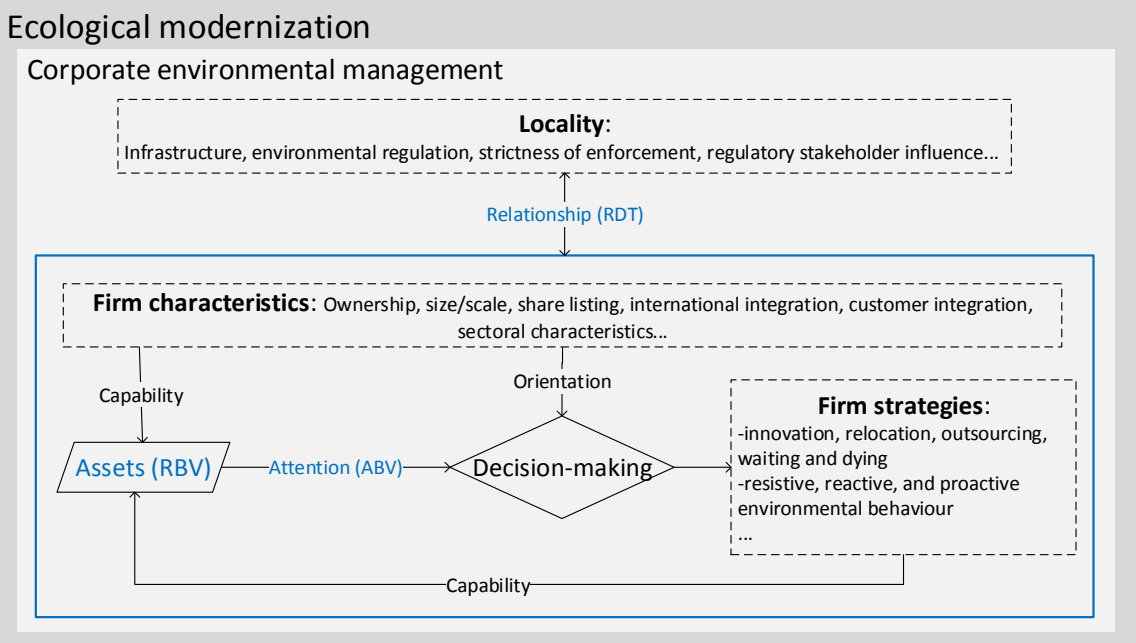


Figure 2.1 Analytical framework of firm adaptation in environmental management

While management theory is mainly used to analyze firms' strategies in water management, evolutionary economic geography concepts are applied to explore firm heterogeneity and regional disparity. In explaining firm restructuring in the Chinese apparel industry, Zhu et al. (2014) proposed a framework that synthesized environmental regulation, regional hub effects, political environment and firm characteristics. Following this lead, I construct an analytical framework, emphasising firm characteristics and locality factors in the account of firm behaviour. The shades

and boxes in Figure 2.1 set the boundaries (of places and firms). In the blue box, within an individual firm, I probe the micro-routines of the organization, while one dashed box represents the strategies that take place within an organization. Outside the firm, on a macro scale, I investigate how the institutions of territories play a part in formulating firm characteristics and influencing firm behaviour; and how sectors and networks are evolving in the locality, including the co-evolution of firms, technologies and territorial institutions. This analytical framework acknowledges the complexity of the manner in which firm characteristics and locality shape firm strategies.

The research aims to contribute to the two main constructs in corporate environmental management with locality as a specific form of external factor and firm characteristics as a specific form of internal driver of firm behaviour. This analytical framework explores how these two main constructs impact on firm strategies with the mechanisms (relationships) in Figure 2.1 through organizational behaviour theories. In short, firm characteristics and locality factors co-shape firm strategy while interacting with each other. Specific factors under the main constructs are to be discovered in empirical analysis of this thesis. The empirical research aims at identifying influencing locality and characteristics factors and evaluate their impacts with this analytical framework. The specific factors may include but are not confined to the factors listed in Figure 2.1. Whether they play the same role also depends on the empirical analysis.

2.6 Conclusion

This chapter laid out the theoretical basis of this study and identified gaps in current empirical studies in ecological modernization from the firm perspective and in this case industrial water management at an enterprise-level. The analytical frameworks guiding this research were also described to facilitate the inquiry into firm behaviour considering both internal and external driving factors.

Concepts similar to ecological modernization has been embraced by Chinese policy makers and demonstrated in various political discourses and environmental policies, with the process of environmental reform in China examined by scholars through the lens of ecological modernization theory. While previous empirical research on ecological modernization in China mainly focuses on state actors or large-scale industrial restructuring from manufacturing to services, this thesis investigates how existing manufacturing firms cope with ecological modernization processes in China.

As a behavioural study, this research follows three prominent organizational behaviour theories. Firstly, the RBV focuses on a firm's resources rather than its products. The key resource is a firm's capacity to retain its competitive advantage – in this case, its ability to confront environmental constraints, to adapt to resource availability change. This capacity is viewed as one

of the major assets that firms try to strengthen, possibly leading to better economic and environmental performance. While the resource-based view is focused more on the internal aspect of a firm on what a firm can do when given the opportunity to react, RDT, the second organizational theory, recognizes the influence of external factors. It stresses the relationship between firms and other outside actors – in this case, the firm's relationship with, for example, water service organizations. According to this theory, firms act to reduce the uncertainty of dependence on outside organizations. The third organizational theory, ABV, explains how organizational adaptation is shaped by attention in organizations. In this thesis, RBV and RDT are used to guide the assessment of firm performance, considering both internal and external factors, while ABV is employed to investigate the decision-making process in the firm.

Evolutionary economic geography's concept of 'path dependence' is adopted to analyze regional differences in firm behaviour. This thesis contributes to evolutionary economic geography literature by acknowledging firm heterogeneity and the impact of institutional context. In addition, this thesis also contributes to evolutionary economic geography, in terms of scale, by bringing attention back from regional differences to firm dynamics and connect firm to locality. Finally, it contributes an environmental investigation, which is often overlooked in the evolutionary economic geography literature.

The empirical studies relevant to this research include the literature on firm behaviour under resource constraints and firm adaptation and industrial water management in the case study region and the SNWT, which is an influential background factor; these studies will be elaborated in empirical chapters. A brief preview of some major conclusions is given here to help better understand this thesis. Most previous research of resource conservation is concentrated in energy conservation, while water conservation has long been neglected. This research does show that behavioural approaches prove useful in energy conservation. Studies of firm adaptation are mainly focused on adaptation to climate change, with water availability being one of the changes induced by climate change. Engaging in R&D program to develop technologies to reduce water use while minimizing the impacts of plant operations on water quality proves an effective way in dealing with water availability constraint, though those programs are often initiated by government and imposed via public policy. Previous research on firm behaviour also shows that different types of firms have different behaviours and performance. Therefore, I differentiate different types of firms in my research. Studies on corporate environmental management identified internal and external factors that affect firm's environmental performance, upon which the general analytical framework of this thesis is built.

Current research on industrial water management in the Beijing-Hebei region recognizes physical shortages, use of reclaimed water (non-traditional water resource), and identifies industrial sector

change (economic structure change) as the major solution to water stress. Little research takes a qualitative approach to characterize regulatory risk. In addition, vast amount of researches are done at regional or sectoral levels with less at the firm level, which reveals one of the problems in water management literature, not only in China, but more generally: attention is paid to government behaviour, while the behaviour of enterprises, those being regulated, are often overlooked. Therefore, through this thesis, I aim to fill the gaps in water management literature by reflecting on the same issues, but by studying different actors and exploring the interaction among different actors in this process. SNWTP literature on its operation and implications is still scarce with current researches focusing largely on management of the project, the hydrological process and eco-environmental impact. None is engaged in its broader socio-environment or water management connotations.

The subsequent chapters will ground the framework and advance the research on firm-level environmental adaptation with empirical analysis of industrial water management in China. The next chapter presents the research design of this study, with descriptions of overall methodology, context of the study area, sample selection criteria, and data collection methods.

Chapter 3 Research Design

3.1 Introduction

As presented in Chapter 1, this thesis aims to understand firm strategies in water management under the influence of firm characteristics and locality factors through the lens of ecological modernization. The review of existing literature in Chapter 2 concluded that various firm characteristics and locality factors affect the dynamic of firms' environmental management. Therefore, an analytical framework considering the complexity of this dynamic was established to explore water management behaviour in firms. The thesis draws on organizational behaviour and evolutionary economic geography theory to understand firm behaviour in water management and documents some of the ways different kinds of firms are attempting to deal with the intensified physical and regulatory risk of water. I also explore how firm characteristics and localities are exerting influence on firm strategy in water management. The empirical findings are interpreted using concepts from several disciplines, including management, economic geography and political economy.

This chapter explains the research design and specific methods applied in this thesis. Section 3.2 describes the overall methodology in this thesis to investigate industrial management through a comparative case study in Beijing and Hebei, North China. Qualitative approaches were mainly adopted; the need for these and detailed description of the methods are also explained in Section 3.2. Section 3.3 gives a brief introduction of the study area and covers the criteria through which the sample of firms was selected. Detailed description of regional water availability and industrial water consumption in the study area will be presented in Chapter 4. The fourth section in this chapter identifies the data needed for this thesis, data collection methods and data sources.

3.2 Overall methodology

This study aims to interpret firm behaviour in the face of resource constraints. Qualitative analysis, which serves as the primary approach in this research, is suitable to develop an appreciation of the underlying motivations of organizational behaviour. In addition, this research is multi-level (Kemper, Stringfield, & Teddlie, 2003). At regional and sectoral levels, industrial water consumption and industrial production, as well as their relationship, were measured via quantitative calculations to provide an overview of the influence of water availability on regional economic output. At a firm level, water management behaviour and its consequence for individual firms were examined with qualitative methods – interviews and observations – to gain insight into firm strategies on water management and their impact on production. Also, at the firm level, quantitative measures are taken to measure the performance effects of firm behaviour.

As a behavioural study, qualitative methods are mainly adopted to give fine-grained insight into the water management in individual firm and the social, economic and political context in which the decisions are made. The empirical study is based on my field work during June 2017 to July 2018 in the Beijing-Hebei region of China. It includes in-depth interviews with local enterprises, accompanied by a shop floor visits to the operational sites. In addition to firm interviews, government officials and researchers were also interviewed to shed light on company data and regional water governance. The data gathered in the interviews were complemented with background information about the specific firms and the industry in general. Detailed data collected through qualitative methods are elaborated in Section 3.4. This research was reviewed and approved by the Human Ethics Advisory Group of the University of Melbourne. Due to confidentiality agreements with the interviewees, their identity and affiliations remain with me. Qualitative methods are mainly applied at sectoral, regional and national levels to present the spatial and sectoral difference in firm's environmental performance and their effects on water use.

The study period of this thesis is set from 2012 to 2017. During this period, the Middle Route of the SNWT began to operate, and the study region started to use water transferred from the south. A detailed account of the subsequent change in resource availability will be elaborated in Chapter 4, along with a review of water governance in the study period. As China's environmental governance is in transition and ecological modernization is under way (Mol & Carter, 2006), new regulations and enforcement initiatives in the study period will be introduced to lay the institutional background. In addition, during the same period, coordinated development of the Beijing-Tianjin-Hebei region has been strengthened, along with social and economic development; the possible implications of this development for ecological modernization will also be investigated in this thesis.

3.3 Study area and sample selection

In order to investigate industrial water management, a case study was carried out in Beijing and Hebei in North China, one of China's fastest growing industrial clusters in the period since the marketization, decentralization and globalization of Chinese economy (S. He, Bayrak, & Lin, 2017; W. Liu & Lu, 2002). With its coastal locational advantage, preferential policies and proximity to the central government, North China has a vigorous economy, high level of openness as well as innovation and dense population (Yang, Liu, Li, & Li, 2018). In 2016, North China was dominated by the service industry (57.5 per cent of GDP), followed by secondary industry (37.3 per cent of GDP), with primary industry taking only 5.2 per cent of GDP. Mining and manufacturing, featuring steel, electricity, automobile, cement, chemical and petroleum processing, are prominent. Such heavy industries contribute to both GDP and resource consumption as well as environmental pollution to this region. Beijing and Hebei are now both under the spotlight of China's environmental campaigns. Among all the provincial-level

governments that are engaged in environmental protection discussions[6], Hebei ranks first (Xing, 2018). This region also has stricter environmental regulations than its counterparts in China; however, between Beijing and Hebei, policies as well as their enforcement differ depending on physical and institutional proximity to the central government. The reason why Beijing and Hebei are selected as the case study area is water shortage in both of the two provincial level administrative regions, therefore, firm behaviour is expected to be important in these two localities. In addition, there is difference in the characteristics of these two places, with one highly developed, central government dominated and the other more rural, less developed with spill-over firms. Therefore, firm behaviour and government influence are expected to be different in these two places. Such contrasts made the two cases meaningful. The contrast will be elaborated in Chapter 4.

One of the major environmental problems in study region is the shortage of water resources. This shortage has been alleviated by the gigantic South to North Water Transfer Project, though whether this can sustain urbanization and industrialization is still uncertain. In addition to water shortage, the study region is also one of the regions with the most serious air pollution problems in the world, where local industries are often condemned for their pollutant discharge. Right now, water resources conservation and air pollution control are among the major issues in environmental governance in this region (D. Zhang, Fan, & Park, 2019; Zou & Zhao, 2018). Local industries are under high social and political pressure to boost production efficiency and minimise environmental impact. Central and provincial-level governments have strengthened resource conservation and pollution control policies; enforcement of government regulations has also been tightened, with local Environmental Protection Bureaus having devoted large amounts of labour to supervision (Z. Tian, Tian, Chen, & Shao, 2020).

What is also special about industries in the study region is that now, that with the national policy of 'Coordinated Development of the Beijing-Tianjin-Hebei Region[7]', there is relocation of general manufacturing industry[8] from Beijing to Hebei and Tianjin. Such spatial restructuring makes Tianjin and Hebei increasingly resource and pollution intensive. According to the Beijing Municipal Commission of Economy and Information Technology, from 2013 to 2016 the government relocated or closed 1341 polluting firms, while promoting green industries such as electronics, automobiles and healthcare services (You Li, 2017). By the end of 2016, 7.76 per

[6] An environmental protection accountability system, under which polluting local governments or enterprises are interrogated by the central government.
[7] The Politburo of the Central Committee of the Communist Party of China approved the Program Outline for Coordinated Development of the Beijing-Tianjin-Hebei Region on 30 April 2015.
[8] According to "Industrial classification for national economic activities" (GB/T 4754-2017) of the People's Republic of China, industries in category C including 31 sectors are general manufacturing industries. The 31 general manufacturing industries are listed in Appendix A.
Source: http://www.stats.gov.cn/statsinfo/auto2073/201710/t20171017_1543130.html

cent of Beijing's enterprises (55250 enterprises) were engaged in mining and manufacturing, employing around one million people and contributing 19.26 per cent of local GDP[9]. Industries in Hebei now are led by steel and iron, chemicals and cement manufacturing (C. Wong & Karplus, 2017). At year-end 2016, 198,384 enterprises were in secondary industry, accounting for 25.26 per cent of all enterprises in Hebei, employing around 1.78 million workers and contributing 47.57 per cent of local GDP[10]. Now industrial restructuring in the North China cluster remains under the guideline of 'Program Outline for Coordinated Development of the Beijing-Tianjin-Hebei Region (2015)', 'A Guide to Industrial Transfer in Beijing-Tianjin-Hebei Region (2016)', 'Catalogue of Prohibitions and Restrictions on New Industries in Beijing (2015)', and 'Catalogue of Polluting Industries, Production Process and Equipment Adjustment and Elimination in Beijing (2014)'. How such involuntary relocation of firms exerts an impact on corporate environmental management will be investigated in this thesis. It is noteworthy that, given the geographical and institutional heterogeneity of China, the study region does not represent the whole country. However, it provides important clues for understanding corporate environmental management and environmental governance in China.

The research was designed as multiple case studies (Eisenhardt, 1989), focusing on industrial firms within water sensitive sectors in Beijing and Hebei. 'Water sensitive industry' is the research target, defined here as industry whose elasticity of output with respect to water input is high (Figure 3.1). Those sectors include firms that consume large amount of water (Hassan, 2003) e.g. manufacturing, power production (S. Pfister, Saner, & Koehler, 2011), construction, water supply (Bo Zhang, Chen, Zeng, Qiao, & Chen, 2016) etc. However, since previous studies of the impact of water availability have focused on these water intensive industries, this thesis also includes firms whose output is likely to be influenced by water resource constraints. Moreover, in this thesis, specific attention was paid to the water sector, including water supply and wastewater treatment industries.

[9] Data source: China Statistical Yearbook 2017.
[10] Data source: China Statistical Yearbook 2017.

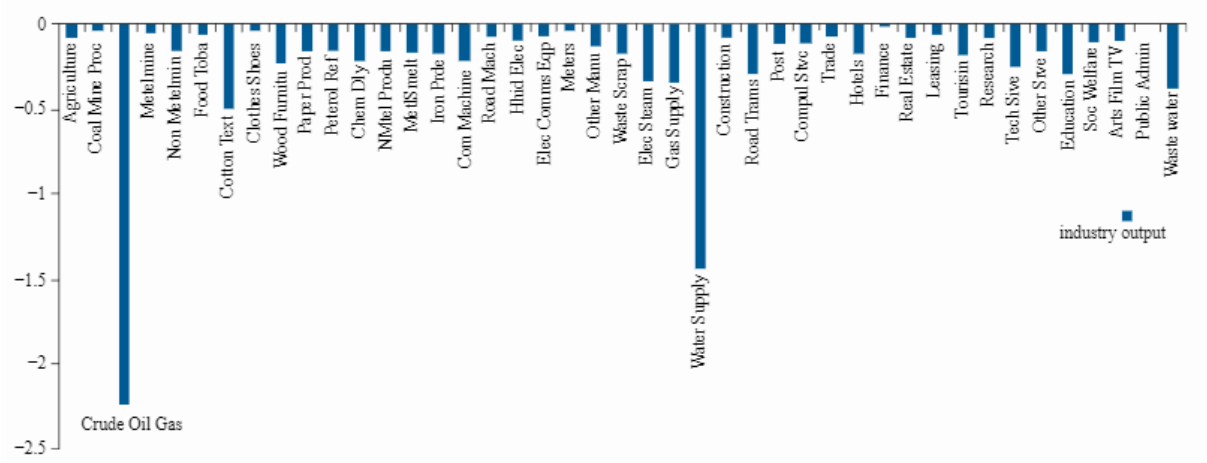


Figure 3.1 Industry output following 10 per cent increase in water price

Source: Xia, J., Deng, Q., & Sun, Y. (2010). Integrated water and CGE model of the impacts of water policy on the Beijing's economy and output. Chinese Journal of Population Resources and Environment, 8(2), 61-67.

Sector classification in this research followed the "Industrial classification for national economic activities" (GB/T 4754-2017) of the People's Republic of China[11]. Firms from the following 18 sectors in Beijing and Hebei were investigated, including one special industry (which faced a higher water price than other sectors): Auto Part Manufacturing, Car Manufacturing, Cement Manufacturing, Chemical Fibres Manufacturing, Chemical Manufacturing, Chemical Product, Electricity Supply, Equipment Manufacturing, Food Manufacturing, Garment Manufacturing, Metal Manufacturing, Paper Manufacturing, Petroleum Manufacturing, Petroleum Refining, Pharmaceutical, Special industry[12], Water Supply, Wine Manufacturing.

Firms were selected through snowball sampling. Sampling stopped after 30 manufacturing firms from the above-mentioned 18 sectors had been interviewed. At this point no new insights were arising from the investigation, which had thus reached theoretical saturation (Glaser & Strauss, 1967) to explain the question under study. With a limited qualitative sample, this research tries to cover different types of firms to explain the impact of firms' characteristics, including ownership, scale/size, financial status, market position, sectoral characters. The sample of firms is not meant to be representative of all the firms in this region. Nevertheless, these firms help highlight environmental challenges faced by most firms in this region and their corresponding adaptation strategies. Table 3.1 below lists basic information about the firms interviewed in this study, including location, scale and sector.

[11] Source: http://www.stats.gov.cn/statsinfo/auto2073/201710/t20171017_1543130.html
[12] Special industry refers to industries with special water pricing in the study region, including, car washing, bottled water, golf courses and ski resorts.

Table 3.1 List of sample firms in this study

Firm	Location	Scale	Sector
1	Beijing	Medium	Auto Part Manufacturing
2	Beijing	Large	Car Manufacturing
3	Beijing	Small	Food Manufacturing
4	Beijing	Large	Car Manufacturing
5	Beijing	Small	Equipment Manufacturing
6	Beijing	Large	Equipment Manufacturing
7	Beijing	Large	Petroleum Refining
8	Beijing	Small	Garment Manufacturing
9	Beijing	Medium	Pharmaceutical
10	Beijing	Small	Special industry
11	Beijing	Medium	Pharmaceutical
12	Beijing	Small	Wine Manufacturing
13	Beijing	Medium	Petroleum Manufacturing
14	Beijing	Large	Petroleum Manufacturing
15	Hebei	Large	Car Manufacturing
16	Beijing	Large	Electricity Supply
17	Hebei	Small	Paper Manufacturing
18	Hebei	Small	Paper Manufacturing
19	Hebei	Small	Chemical Product
20	Hebei	Large	Equipment Manufacturing
21	Hebei	Medium	Water Supply
22	Hebei	Medium	Electricity Supply
23	Hebei	Large	Metal Manufacturing
24	Hebei	Large	Chemical Manufacturing
25	Hebei	Medium	Chemical Manufacturing
26	Hebei	Large	Chemical Fibres Manufacturing
27	Hebei	Large	Chemical Fibres Manufacturing
28	Hebei	Medium	Chemical Product
29	Hebei	Medium	Cement Manufacturing
30	Hebei	Medium	Paper Manufacturing

Note: The scale of firm is classified according to the 'Criteria for Classifying Small and Medium-sized Enterprises' issued by the Ministry of Industry and Information Technology, the National Bureau of Statistics, the National Development and Reform Commission and the Ministry of Finance in China. For details refer to Appendix B.

3.4 Data sources

Data along with collection methods and sources are listed in Table 3.2 to address the research questions.

Table 3.2 Data and sources

Research question	**Anticipated results**	**Data needed**	**Method/source**
What is physical and regulatory water availability in northern China?	- Industrial water availability (quality, quantity and price), change in study region after receiving North-South water - Regulations on water consumption and waste discharge	Regional level: Water supply data (quantity and quality) Water pricing Public policy on water usage and discharge Firm level: Water use Awareness to water availability change	- Interviews: with government officials, firm personnel and other informants - Secondary data
What do industrial firms do to manage water?	- Water management strategy (what are the most frequently adopted strategies and what are the outcomes?) - Build up a framework for analyzing water management in business organizations	Decision-making in firms: How do firms interpret water constraint? Proposed measures to cope with the change Decisions on adaptation strategy Factors influencing the process: Resource dependence Relationship with other stakeholders Resources put into strengthening the relationship	- Interviews: with firm personnel and other informants - Onsite observation - Secondary company data
How do firm characteristics and locality factors exert influence on water management strategies?	- Firm's own nature and attributes that influence its water management - Locality factors that influence firm behaviour Implications from this research - Water management suggestions for decision makers in both government and firm level - Conclusions about firm response to ecological modernization in North China industrial cluster	Comparisons between difference types of firms: Scale, ownership, share listing, business culture, CSR, technology, infrastructure, … Government regulation, infrastructure, local politics, resource availability, institutional and cultural context, …	- Interviews: with firm personnel and other informants - Onsite observation - Secondary company and regional data

Three major types of data are needed to understand the issue in question, namely firm behaviour, firm characteristics and locality. These data are mainly collected through semi-structured interview and observation. As there are formal and informal aspects of organizations, I tried to engage in in-depth interviews and observations in firms to gain insights into the attitudes, values, interactions and group norms that affect organizational functioning and effectiveness. Secondary data were also collected, including literature, statistical data, company and government documents (processed later with discourse and content analysis), as well as news coverage (processed through content analysis).

Interviews

Semi-structured in-depth interviews served as the primary source of data and information in the field work. Because of confidential agreement with the participants, their personal identities as well as their affiliations remain with me. A total of 53 people was interviewed, including 39 firm personnel from 30 manufacturing firms and 7 water service firms, 10 government officials from 9 government agencies and 4 scholars from 1 research institute and 3 universities. Some of the informants were interviewed more than once. Interviews were conducted in Mandarin [the author is a native Mandarin speaker] and audio recorded with keynotes during the interview. The average duration of each interview was 1 hour. The audio recordings were transcribed and translated into English for data analysis. The quotes in the thesis are translated into English by the author. The form of the interviews and the themes pursued throughout varied among different types of participants:

Firm personnel (N=39)

Interviews with personnel from manufacturing firms were designed to explore in fine detail firms' awareness of changes in water availability, decision-making in taking counter measures and performance of adaptation behaviour. Interviewees were mostly senior or middle managers knowledgeable of environmental strategies and practices of the firm, including CEOs, EHS (Environment Health and Safety) managers, facility managers, logistics/public utilities managers, engineering/operation managers etc. In addition to manager interviews, I tried to engage with staff in a single entity from different levels (for example, technicians and workers) to gain a full understanding about how decisions are made and carried out. With different types of interviewees, the themes pursued are different. With managers, focuses were placed on the decision-making process. With technicians, concrete adaptation measures, their technical efficiency and performance were emphasized. With workers, the actual carriers of adaptive measures, focuses were on the implementation of firm policies.

In addition to 30 manufacturing firms, 7 firms in the water supply, sewage treatment and environmental service sectors were also interviewed to provide outsider perspectives on manufacturing firms' water use behaviour.

Government officials (N=10)

Government officials were selected through snowball sampling from specific government agencies identified in advance as being centrally engaged in work on water management as well as industrial production in Beijing and Hebei. Interviews were conducted to gain insight into water supply, pricing and quality control, as well as policies on industrial water use, regulations and the enforcement of water conservation and waste treatment. Officials from local governments and the following government agencies were interviewed: Municipal Environmental Protection Bureau, Water Authority, Government Committee of Economic Development Zone, Urban and Rural Planning Bureau, Investment Promotion Bureau, Office of the South-to-North Water Diversion Project Construction Committee.

Detailed interview questions with firm personnel and government officials are shown in Appendix C. Profiles of major interviewees are listed in Appendix D.

Other informants (N=4)

Four expert interviews were done with scholars based in Beijing doing research on water resources, regional development and environmental policy. Those expert interviews were important for data triangulation with company data and regional resource endowment and regulations.

Observation

During firm interviews, I asked my interviewees whether they could provide me with a shop floor visit to the operation site. Such observations would enable me to systematically observe and record people's behaviour, actions and interactions to obtain a detailed description of the social setting. I walked through the plant with a firm member, who introduced me to the social setting and the usual activities that take place. I asked the member to describe certain things related to the study that were observed on the walk.

Other secondary data

Literature on water availability and industrial water use and conservation in the study region were reviewed for supplementary data and information. Statistical data, including industrial water withdrawal and consumption data, industrial input and output data, were collected to facilitate the analysis of changes in industrial water conservation, as well as their effects. Government documents (e.g. China government gazettes, bulletins, announcements and proclamations etc.) on

water and industrial policy were also collected and analyzed to shed light on local industrial water use, together with the locality factors that influence firms' water management. Related news coverages on regional water governance and industrial water conservation also serve as data sources. Appendix E lists laws and regulations related to this study from secondary data source.

3.5 Conclusion

This chapter explained the research design of this thesis. Firstly, the overall methodology was presented as a case study based on qualitative approaches that explored in fine detail firms' behaviour in water management on the one hand, and quantified firms' performance and the spatial articulation of firm strategies on the other hand. Then the case study area was introduced covering basic physical and institutional locality characteristics in Beijing and Hebei. (More detailed locality factors will be described in Chapter 4 and the impact of locality on firm behaviour will be analyzed in Chapter 7.) The sample of firms was selected from various industrial sectors covering different types of firms to further the investigation about the way in which firms' characteristics impact on firm strategies. Finally, data needed to answer the research questions were specified with data collection methods and data sources.

The empirical evidence mainly derived from my field work during 2017-2018 in Beijing and Hebei. Data were mainly collected through in-depth interviews with local enterprises, accompanied by a shop floor visit to the operation site when asked and granted. In addition to firm interviews, government officials and environmental experts were also interviewed to shed light on firm behaviour and regional governance. In sum, 30 manufacturing firms from 18 sectors were interviewed. A total number of 53 people, mainly from the sample of manufacturing firms, was interviewed. The data gathered in the interviews were complemented with background information about the specific firm and the sector it belongs to. In addition to interviews and on-site observations, document analysis was also employed with literature, statistical data, government document, newspaper coverage to provide further information on industrial water use and policy, as well as other firm and locality factors.

Though being a case study of firms in Beijing and Hebei, the overall analytical framework applies to firm responses to environmental constraints in China in general as introduced in Chapter 2. The results of this case study can be informative about the behaviour of firms outside Beijing and Hebei, though in different contexts there may be new firm strategies or new influential characteristics and locality factors. Therefore, the analytical framework should be used as a flexible tool to explore the heterogeneities. With this case study, I do not intend to draw decisive conclusions about China, but to confirm that firm response to ecological modernization depends on firm characteristics and locality and to explore the specifics with this case. Since firms were sampled until theoretical saturation, trying to capture as many behaviours and influencing factors

in this case region as possible, it is anticipated that firms in other places exhibit similar forms of behaviour. Certainly, though a large scale study with more firms could help generalize the findings.

Chapter 4 Changing Water Availability and Firms

4.1 Introduction

This chapter describes in detail the localities of the case study, setting the stage for the study of industrial water management in North China. I begin with an overview of the study area, namely Beijing Municipality and Hebei Province, and a review of empirical studies relevant to this research. Then the regional physical and regulatory availability of water in North China are reviewed. The South-to-North Water Transfer Project, the largest water diversion project in the world, is also discussed as the study area is one of the SNWTP's water-receiving areas; regional water availability has been greatly altered by this project. Then the chapter introduces the North China industrial cluster, a large water consumer and pollution emitter. Through this chapter, I aim to answer the first research question of this thesis, to determine the physical and regulatory water availability in Northern China, especially after the South to North Water Transfer, as these are considered crucial features of regional localities that influence firms' water management behaviour.

General background of the study areas

The North China industrial cluster, also known as the Beijing-Tianjin-Hebei region, like its counterparts, the Yangtze River Delta and Pearl River Delta, has experienced rapid development since the economic transition in China (S. He et al., 2017; W. Liu & Lu, 2002). Now, North China is one of the coastal regions that are home to most of China's manufacturing industries (C. He, Pan, & Chen, 2016). However, unlike those other coastal economic zones, the proximity of this region to the central government both geographically and institutionally has brought certain advantages to local manufacturing enterprises, with preferential financial policies and prioritized access to input factors, such as labour, land and water (Ye, 2011). On the other hand, with the worsening of environmental degradation and natural resource scarcity (Shaojian Wang, Ma, & Zhao, 2014) – in this area particularly and in China generally – together with the increase of public environmental awareness (Kay, Zhao, & Sui, 2015) in the past decade, industries in the study region are now under political and social pressure towards environmental upgrading. Within this cluster, regional disparities also exist, for example, between the capital Beijing and its pollution dump site, Hebei. As state-centred strategy has been developed in this region in which Hebei and Tianjin serve to facilitate the development of Beijing (Zou & Zhao, 2018). In this thesis, I use Beijing and Hebei as the primary study areas; intra-region inequality in terms of industrial development and resource use can be investigated through the comparison of these two provincial-level divisions.

Beijing, the capital, is the most political, economic and intellectually advantaged city in the country. It is located at the northern part of the North China Plain, backed by Yanshan Mountains,

adjacent to Tianjin and Hebei Province. Beijing has a monsoon-influenced humid continental climate (X. He et al., 2015) . By year-end 2017, the municipality occupied an area of 16,410 square kilometres and possessed a population of 21.707 million. The regional GDP was 2,800.04 billion yuan (UDS 400 billion)[13]. Beijing's industrial structure is dominated by secondary and tertiary industries. From 1994, the output of tertiary industry began to exceed that of secondary industry. By 2015, the output of the service sector was four times that of the secondary sector; agriculture only accounted for 0.6% of regional output[14].

In terms of water use efficiency by sector, though secondary now uses less water than the agricultural sector[15], industrial water use efficiency in Beijing surpasses that of agriculture (X. Liu, J. D. G. Hewings, X. Chen, & S. Wang, 2016; Z. Wang, Huang, Yang, & Yu, 2013). Water shortage is now one of the major concerns for future development of Beijing (Y. Wei, Wang, Wang, Yao, & Li, 2018). The SNWTP is argued to be about prioritizing the water supply for Beijing, as will be elaborated in the following sections.

Hebei, where most of China's steel and iron, cement and chemical manufacturing industries are located (C. Wong & Karplus, 2017), has a population of 75.2 million and covers a total area of 188,800 square kilometres, with a total regional GDP of 359.64 billion yuan (USD 51.38 billion) by year end 2017. There are 11 prefecture-level cities in Hebei, three of which are investigated in this thesis. In 2013, the integration of the Beijing-Tianjin-Hebei region became a national strategy, incorporating Hebei into this North China metropolitan region. In 2017, the Chinese Communist Party Central Committee and the State Council issued a notice establishing Xiong'an New Area (Xinhua., 2017), which incorporates three counties and surrounding regions in Baoding, Hebei. The planned new area with national significance is compared to the well-developed Shenzhen Special Economic Zone and Shanghai Pudong New District (Zou & Zhao, 2018), apparently endowed by the CCP with 'thousand year of great national importance' (L. Zhang, 2018). As a coastal province, Hebei also harbours three large ports, with over 1 billion tons of annual capacity[16], which also promote regional economic development.

Resource conservation and firm adaptation

The relevant empirical literature concerns firm behaviour under resource constraints and firm adaptation. In this thesis I consider only physical resources, e.g. water, energy or material, to shed light on water management. Firms initiated resource conservation activities for sustainable

[13] Data source: China Statistical Yearbook 2018.
[14] Data source: China Statistical Yearbook 2016.
[15] From 2010 to 2018, the agricultural sector was consuming more water than the industrial sector. Date source: Beijing Water Resource Bulletin 2018.
[16] Data source: Hebei Economic Yearbook 2018.

performance (Bourlakis, Maglaras, Aktas, Gallear, & Fotopoulos, 2014) or under policy influence (DeCanio, 1998).

Studies in firm behaviour under resource constraints are largely concentrated on energy conservation behaviour rather than water. In 1993, DeCanio discovered that energy-efficient investment was a profitable and innovation opportunity for firms, but difficult for firms to realize. In 1998, he further suggested there was a demand for comprehensive theories to understand investments behaviour of firms. From studies of unsuccessful energy-saving policy, other researchers identified the factors that influence investment behaviour of firms, their perception of various types of energy policy, and their adaptation to environmental policy change (De Groot, Verhoef, & Nijkamp, 2001). Recent work shows that energy-saving in firm is still mostly driven by public policy (Xiaofan Zhao, Li, Wu, & Qi, 2014). And that is the exact case in China: pro-environmental behaviour in firms is largely policy driven. Since governments have started to emphasize energy conservation, a lot of research has been done on the techniques and effects of energy conservation, while water protection has been overlooked. Water conservation deserves more attention in face of crisis and requests for sustainable plans (Jianguo Liu & Yang, 2012), perhaps using evidence drawn from studies of energy. Studies have shown that behavioural and social study proves useful in energy conservation (Allcott & Mullainathan, 2010; Costanzo, Archer, Aronson, & Pettigrew, 1986); this is the approach that I am adopting in this thesis for conservation of water.

In terms of water conservation, researchers have been focusing on water-saving and adaptation in agriculture (Piao et al., 2010; Yongping Wei, Langford, Willett, Barlow, & Lyle, 2011), which consumes 70% of total water resources worldwide (Kohli et al., 2010). As one aspect of water availability, many studies have been done on water pricing not only in agricultural sector (Foltz, 2003; Webber, Barnett, Finlayson, & Wang, 2008). Pricing is widely used by the government, supposedly to promote equity, efficiency and sustainability in the water sector (P. Rogers et al., 2002). Opinions vary on the rationale and effectiveness of pricing mechanisms in water resource management (Olmstead & Stavins, 2009; Webber et al., 2008). Therefore in this thesis, changes in water pricing and their impact on firm behaviour, as well as market adaptation (Rosegrant, Cai, Ringlerl, & Cline, 2005), which in turn would influence firm behaviour, will be particularly investigated. This thesis thus furthers the debate over water pricing in secondary industry and at the same time fills in the gaps in the scarce literature about industrial water conservation.

Research on firm adaptation is mainly focused on adaptation to climate change, with water availability being one of the effects induced by climate change (Neil Adger, Arnell, & Tompkins, 2005). In this thesis, I intend to investigate firm behaviour triggered by physical water availability and regulation change. Studies show water availability has an impact on production in industrial

firms, especially water intensive firms (Nicot & Scanlon, 2012). Previous studies focus on using economic (Aviso, Tan, Culaba, & Cruz Jr, 2011; Berrittella, Hoekstra, Rehdanz, Roson, & Tol, 2007; Bo Zhang et al., 2016) or engineering (Koch & Vögele, 2009; Takama, Kuriyama, Shiroko, & Umeda, 1980) models to simulate the impact and give allocation or adaptation strategies. At the product level in industrial firms, life cycle assessment methods are also often adopted to calculate products' potential contribution to water scarcity (Ridoutt & Pfister, 2010), and environmental impact of water consumption in firms (Stephan Pfister, Koehler, & Hellweg, 2009; S. Pfister et al., 2011). Engaging in R&D programs to develop technologies in firms to reduce water use while minimizing the impacts of plant operations on water quality proves an effective way of dealing with water availability constraints (Feeley et al., 2008), though those programs are often initiated by government and imposed via public policy.

Previous research on firm behaviour shows that different types of firms have different performance standards. Ownership – whether a firm is a public or private company – impacts efficiency (Estache & Rossi, 2002) and productivity (Abbott & Cohen, 2009). Research has been done on decision-making over water supply sources: on what factors contribute to a firm's choice of water source (Renzetti, 1993). However, there is scarce research on how a firm's choice of water source – whether it is self-supplied or supplied by a public utility – could affect the firm's water use behaviour, as different sources are subject to different contingencies. Also, firm size matters to its sustainable performance (Bourlakis et al., 2014; Russo & Fouts, 1997). Since the above-mentioned characteristics of firms affect the incentive and capability of their adaptation behaviour, I propose examining different types of firms.

Industrial water uses and availability change

Studies on industrial water use in the study region have long recognized the resource shortage that accompanies the rapidly growing economy. In 1998, researchers identified serious waste of industrial water, due to irrational use in various sectors, by calculating water use efficiency and water reuse rates (H.-R. Wang & Wang, 1998). Since then related studies have given suggestions on wastewater reuse (H. Jia, Guo, Xin, & Wang, 2005; L. Liu, Zeng, Dong, & Chen, 2013; L. Liu, Zeng, Xin, & Chen, 2011; Z. Tong, 2001; Xiaoyan Wang, Fan, & Cheng, 2011), and Beijing has indeed been integrating reclaimed wastewater as a vital water source since 2003 (D. Chang & Ma, 2012). One recent participatory research about the perception of different stakeholders, including industrial sectors, on water reuse in Beijing shows that water resource managers, industrial sectors and researchers firmly support the use of reclaimed water (W. Chen, Bai, Zhang, Lyu, & Jiao, 2015).

Other measures include developing water production and supply sectors while promoting industries that use less water (Banchongphanith & Kaneko, 2009). Economic structure

transformation is becoming one of the most discussed measures to counter insufficient water supply, together with augmentation of virtual water imports (Han, Guo, Chen, Ji, & Li, 2014; Q. Shi, Chen, Shi, Wang, & Deng, 2014; Z. Wang et al., 2013). Quantitative studies also show that only when all the measures, including water-saving, wastewater reuse and inter-basin transfer are implemented jointly, could the growing industrial demand be satisfied (J. Tian & Dai, 2010). Other scholars suggest that water resource management should now focus on water conservation, efficient inter-basin water transfers, and use of non-traditional water resources (Jianhua Wang, Shang, Wang, Zhao, & Yin, 2015). Yet there is still no empirical evidence supporting those claims. As a matter of fact, those in favour of virtual water imports and consumption structure readjustment (X. Liu et al., 2019; D. Zhou, Zhang, & Shi, 2015) cast doubt on the cost effectiveness of inter-basin water transfers: if scarcity can be alleviated by importing virtual water-rich commodities, why bother transferring water north, especially if the transferred water might go back south in the form of virtual water? However, scholars also point out that such virtual water strategies may not be suitable for every region given economic and ecological heterogeneity (Cui et al., 2018) and that adjustment of industrial structure could exert negative effects on water conservation (X. L. Liu, J. D. G. Hewings, X. K. Chen, & S. Y. Wang, 2016). It seems the only agreement we can reach here is that there is no best practice for water conservation without considering local context.

Methods used in studies of industrial water use or conservation in the study region are largely quantitative, with analysis of input-output tables, calculation of indicators (water footprint, virtual water and so on so forth), econometric models or other professional tools like the water Sankey diagram (G. P. Hu, Ou, Zhang, & Karplus, 2013). In addition, the above-mentioned studies are mostly at the regional or sectoral levels, with only a few at the firm level, therefore tending to give ambiguous or ambitious conclusions or policy suggestions, from adjustment of industrial structure to population control, that require enforcement through political force. Therefore, in this thesis, I take the behavioural approach and start from the firm level.

4.2 Water in North China

In this section, the endowment of water resources of the study area is first introduced, followed by an introduction to the two specific research areas, Beijing and Hebei. The SNWT and its influence on water supply and consumption in the study areas will be explored. In addition to physical water conditions in North China, water governance in this region from the perspective of regulations and enforcement of water conservation and pollution control are also explored to shed light on regulatory water risk of North China water users.

Physical water risk

At present, water resource represents one of the core ecological problems in Beijing and Hebei. The current regional water resources carrying capacity exceeds the warning line of the United Nations (M. Liu, Wei, Wang, & Wang, 2017; Y. Tong, 2011), and the adverse risks caused by industrial and agricultural production are more prominent than ever (Chu, Deng, Jin, Wang, & Li, 2017; Luo, Shen, Qi, Zhang, & Xiao, 2018).

The majority of Beijing and Hebei is located in the Haihe River Basin. In the past 50 years, this area has exploited a large amount of groundwater and intercepted surface water to meet the demand from agricultural and urban development, and to cope with climate change, resulting in a continuous decline in groundwater level and a reduction in surface water availability (Mingna Wang, Zhang, & Yan, 2013). In addition, inappropriate management also resulted in severe pollution (Y. Liu, Liu, Zhao, & Zhang, 2016), further decreasing regional water availability. Due to changes in natural climatic conditions and regional water consumption, the amount of water resources in the region has been reduced from 28-29 billion cubic meters in the late 1950s to 14-15 billion cubic meters in the early 21st century (Jinping Liu, 2014). The per capita water resources in the region are less than 300 cubic meters, one seventh of the national average (Zhai, Wang, Zheng, & Huan, 2011). At the same time, due to over-exploitation of groundwater, the groundwater level was declining by 1.1 meters annually during the 1980s and 1990s[17]. Baiyangdian, the largest freshwater lake in Northern China, has experienced a degrading trend and a drying crisis (Moiwo, Yang, Li, Han, & Yang, 2010). The capacity of the water system to support the regional ecology has greatly reduced (Q. Chen, 2011), resulting in the phenomena of land desertification, urban heat island effect, and rain island effect[18]. Meanwhile, with the unceasing expansion of urban areas and the lack of ecological and municipal infrastructure, the mega-city areas are facing severe problems (Bai et al., 2017). Though these problems are claimed by the central government to have been alleviated by the South to North Water Transfer Project, whether this can sustain future urbanization and industrialization in this region is still uncertain.

Beijing includes five major river systems, namely: Juma River, Yongding River, Beiyun River, Chaobai River and Ju River (Figure 4.1). They mainly originate from mountains northwest of Beijing, flow through the plains to the southeast, and finally join the Bohai Sea (the Ju River is different). While there are no natural lakes in Beijing, 85 reservoirs are in Beijing; among the largest are Miyun Reservoir, Guanting Reservoir, Huairou Reservoir and Haizi Reservoir. The average annual recharge of groundwater in Beijing is about 2.921 billion cubic meters, and the

[17] Source: Beijing Water Resources Bulletin 2016. Hebei Water Resources Bulletin 2015, 2016.
[18] Rain island effect is an increase in urban precipitation caused by the urban heat island effect (Cao, Ge, Xue, & Song, 2009).

average annual exploitable amount is about 2.4 to 2.5 billion cubic meters[19]. The annual average total amount of disposable natural water resources is 5.521 billion cubic meters[20].

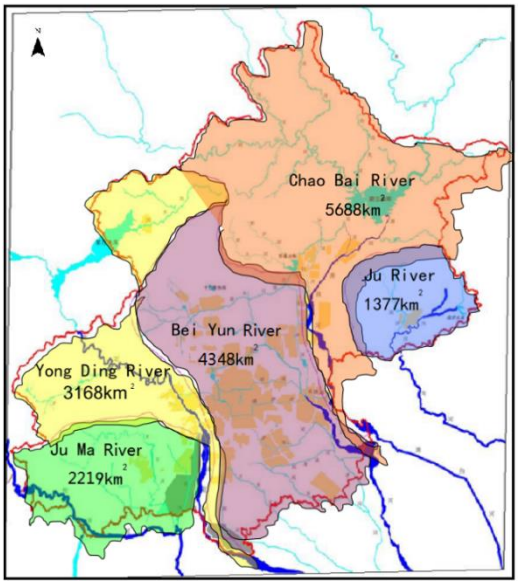


Figure 4.1 Main rivers of Beijing water system

Source: Adapted from Gourbesville, Philippe & Batica, Jelena. (2014). Flood risk assessment strategies. 10.13140/RG.2.1.2083.6323.

According to the 'First Beijing Census for Water' in 2013, the total annual water use in Beijing amounts to 3.525 billion cubic meters. Of this, 0.852 billion cubic meters is for domestic water use, 0.892 billion cubic meters for agricultural use, 0.497 billion cubic meters for industrial use, 0.033 billion cubic meters for construction industries, 0.643 billion cubic meters for tertiary industry and 0.608 billion cubic meters for ecological and environmental usage. In recent years (Figure 4.2), domestic consumption has consistently taken the largest share of the city's water, while in production, agricultural consumption outweighs industrial water use, though the output of agricultural sector in this region only accounts for around 3% of industrial output.

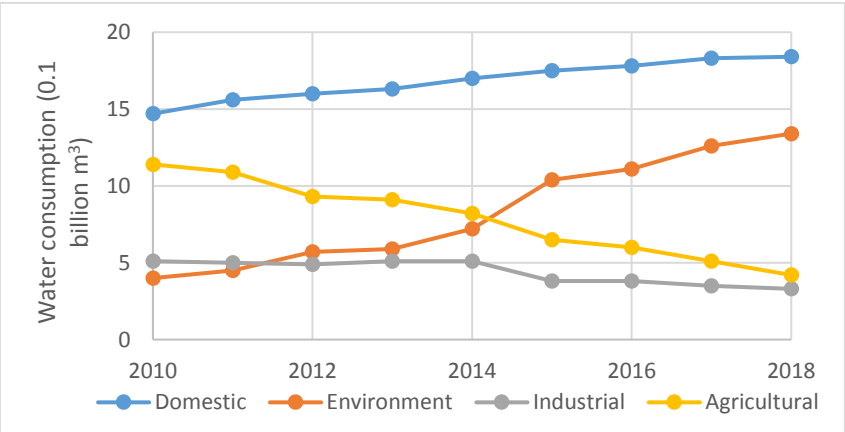


Figure 4.2 Water consumption in Beijing, 2010-2018

Data source: Beijing Water Resources Bulletin 2010-2018

[19] Data source: Beijing Water Resources Bulletin 2010-2018.
[20] Data source: Beijing Water Resources Bulletin 2010-2018.

Ever since Beijing began to receive water from the SNWTP, it is claimed by the government that water stress has been alleviated (M. Wei & Li, 2014). In the second diversion year, which covers the period from November 1st, 2015 to October 31st, 2016, 3.83 billion cubic meters of water was transferred through the Middle Route, with Beijing alone receiving 1.1 billion cubic meters of water (Shuo Wang, 2016). Though the general water amount has been increased, the accessibility of water to individual firms is yet to be discovered. And whether the transfer increases or diminishes an organization's incentive to conserve water needs to be investigated to give a comprehensive evaluation of this project.

In Hebei, there are more natural rivers. There are more than 300 rivers with a length between 18 to 1000 kilometres[21]. Most of the rivers in the province originate or flow through the Yanshan, Jibei, and Taihang Mountains. From the south to the north, the main rivers include the Zhangweinan Canal, Ziya River, Daqing River, Yongding River, Chaobai River, Jiyun Canal, and Luan River (Figure 4.3).

Figure 4.3 Map of Hai River basin

Source: Adapted from Wikimedia Commons, Phig88 CC BY-SA 3.0

The average annual precipitation of Hebei is 531.7mm. Its average annual water resources amount to 20.469 billion cubic meters, which is 0.72% of the national average. The amount of surface water resources is 12.017 billion cubic meters, the groundwater resources are 12.257 billion cubic meters[22]. According to the statistics of population and cultivated land published by Hebei Province in 2000, the per capita water resources of the province are 306.69 cubic meters, which

[21] Source: Department of Water Resources of Hebei Province.
[22] Data source: Hebei Water Resources Bulletin 2010-2018.

is one seventh of the national average. In terms of water consumption (Figure 4.4), located in one of China's grain production bases, agriculture consumes 70-75% of water in Hebei. However, from 2010 to 2018, agricultural water consumption has been decreasing, as is industrial water. Domestic and environmental water consumption increased during the same period. Total water consumption in Hebei decreased from 19.37 billion cubic meters in 2010 to 18.24 billion cubic meters in 2018.

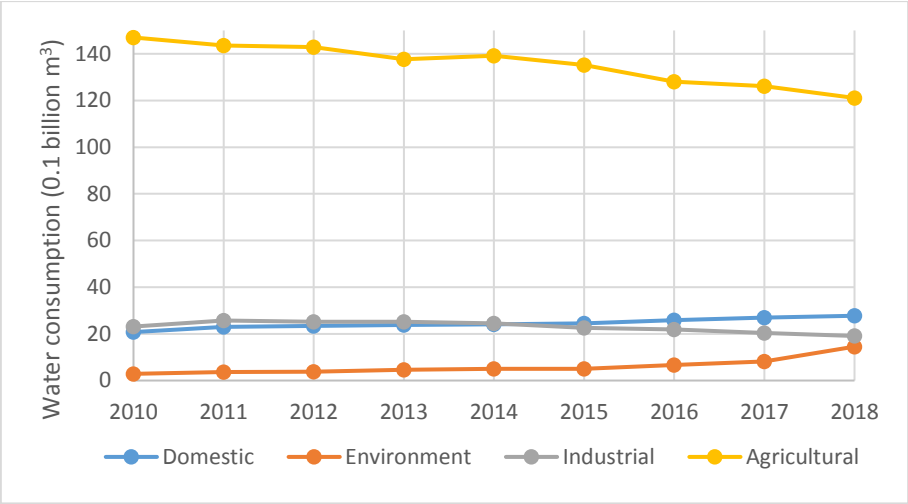


Figure 4.4 Water consumption in Hebei, 2010-2018

Data source: Hebei Water Resources Bulletin 2010-2018

In addition to the resource-based water shortage, the long history of pollution in Beijing and Hebei, further reduced reginal water availability (Y. Gao, Wang, Han, Wang, & Wang, 2010; Huang, He, Shi, Zhao, & Yang, 2009; Ji & Ma, 2006). Figure 4.5 illustrates the wastewater treatment rate in Beijing since 1978. It shows that the wastewater treatment rate in Beijing was below 30% before 2000. The capacity began to increase rapidly after 2000, reaching 80% in 2009 and 94% in 2019. The massive discharge of domestic and production wastewater and the lack of sewage treatment capacity in the 1980s and 1990s led to a sharp decline in the quality of Beijing's water environment. In the 1990s, water quality in the Guanting Reservoir reduced to Type Five inferior[23]; this reservoir was forced out of the Beijing drinking water system in 1997. In the 7 square kilometres of lakes in Beijing, 4.47 square kilometres have water quality of Type Four and below, and the total phosphorus and nitrogen content of many investigated rivers and lakes in the urban area indicate that they are in a serious eutrophication state (Du, Wu, Yang, Wu, & Liu, 2005). In 2005, water quality in only 45% of the measured river length was up to standard, and the proportion of poor water quality in Type Five is still very high. The eutrophication of rivers and lakes in urban centres is common, and downstream rivers are heavily polluted (Du et al., 2005). Beyond that,

[23] According to 'Environmental quality standards for surface water (GB 3838-2002)', surface water areas are divided into five types based on usage and protection objectives, where water quality is degrading from Type One to Type Five.

with discharge of various pollutants from a large number of human activities, groundwater is also polluted (the pollution of groundwater water is not easy to control), further decreasing water availability in Beijing (H. Liu, Li, Zhang, Zhang, & Lin, 2006).

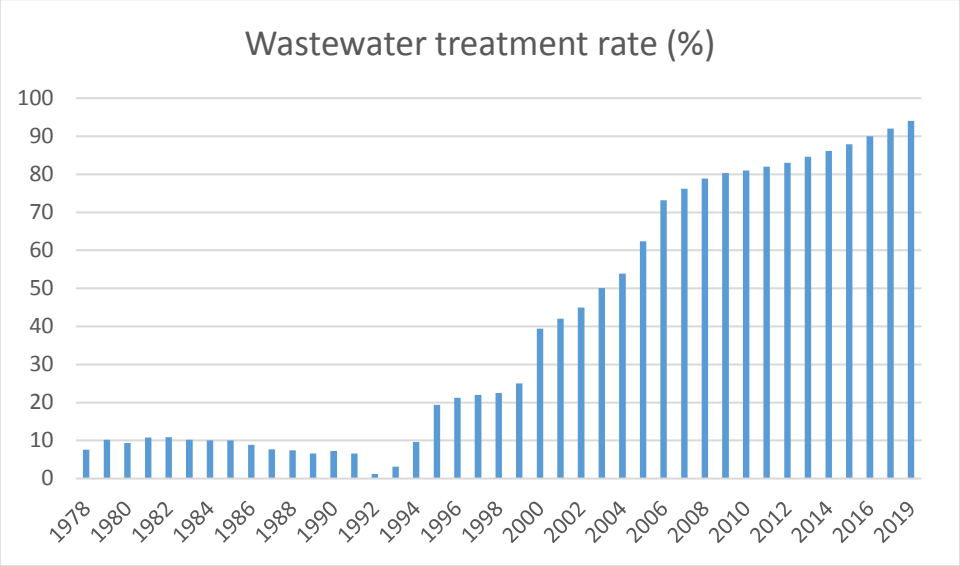


Figure 4.5 Wastewater treatment rate in Beijing, 1978-2019

Date source: Beijing Water Authority, Beijing Municipal Commission of Urban Management, Beijing Municipal Ecology and Environment Bureau

Water pollution in Hebei is also due to massive industrial discharges and inadequate waste treatment capability. During the 2000s, economic growth in Hebei was realized through high investment, high consumption of resources and high emission of pollution (Ji & Ma, 2006). The discharge of wastewater per ten thousand yuan of output value in Hebei is 32.9 percent higher than the national average[24]. In 2004, the output value of paper, chemical, food and pharmaceutical industries accounted for 15.5% of the total industrial output value of Hebei province, while the emissions of COD[25] in these sectors accounted for 65.7% of the total emissions of Hebei province[26]. This extensive mode of economic growth has resulted in the high discharge of the main pollutants in the water environment of Hebei province, with the discharge of COD and ammonia far exceeding the environmental capacity (Ji & Ma, 2006).

Regulatory water risk

Water governance in China is in principle regulated by various laws, regulations, targets, standards, quotas/norms. Recently (in 2012), State Council established the Strictest Water Resources Management System, commonly known as the Three Red Lines, to cut water

[24] Data source: First National Census on Pollution Sources 2010.
[25] Chemical oxygen demand (COD) is an indicative measure of the amount of oxygen that can be consumed by reactions in a measured solution. COD is used in quantifying the amount of oxidisable pollutants found in wastewater.
[26] Data source: Hebei Statistical Yearbook 2005, Hebei Environmental Protection Bureau.

consumption, increase water use efficiency and control water pollution. In 2015, State Council issued the Water Pollution Control Action Plan to further improve water environment quality. The Thirteenth Five-Year Plan for Energy-Saving and Environmental Protection, released in 2016, also set caps for water consumption and proposed new initiatives to reduce water pollution. The revised Water Law in 2016 increased penalties for water pollution. The revised Water Pollution Prevention and Control Law (2017), put into action in 2018, proclaimed the River Chief and Lake Chief Systems, holding major government officials accountable for water pollution. According to one of my interviewees, a researcher who has in-depth engagement in environmental law making in China, "legislation in China is easy; with a little push from the People's Congress, making the law is not a problem" (pers. comm. with researcher in environmental policy, 21 June 2018). However, implementation of policies could be another story.

Not only are there stringent regulations, the government's resolve and capacity to enforce these regulations are also increasing. Local Environmental Protection Bureaus have devoted large amounts of labour to environmental monitoring, since environmental pollution has long been condemned nationwide. Local industries, especially pollution-heavy industries, are under regular and random inspections from local environmental authorities. In addition to routine inspection by local governments, in 2016, the central government launched the first central environmental inspection (Dong, 2018), starting from Hebei province, by sending out inspection teams to monitor local environmental practices, putting local governments and enterprises on notice. When local governments fail to accomplish environmental protection objectives and tasks or are responsible for major or especially serious environmental emergencies, discussions are arranged by the central government with the leaders of those local agencies. These are commonly known as environmental protection discussions. Since 2014, 23 provinces were involved in such discussions; Hebei ranked first in the number of these (Xing, 2018). Monitoring techniques have also evolved; pollution-heavy firms, which are often named on lists of national or provincial key monitoring enterprises, are required by Environmental Protection Bureaus to install online monitoring systems, leaving such enterprises little room to escape sanctions if they break the rules (W. Gao, 2016).

Compared with its counterparts in China, the study area, home and neighbour of the central government, is under the spotlight of environmental campaigns in China. Therefore, regulations here are tighter with stricter enforcement than their counterparts (G. Zhang, Zhang, Zhang, & Li, 2019). Industrial users interviewed for this thesis reported increased pressure to comply with water pollution control regulations. This regulatory risk for industrial water users will be further elaborated in Chapter 7 as one of the locality factors that influence corporate water management. The details of laws and regulations pertaining to corporate water management in Beijing and Hebei are shown in Appendix E, which lists 33 relevant laws and regulations.

A major issue that can be identified in current water policy agenda in China is the distinction between water resource conservation and water pollution control. Water conservation-related policies are often not mandatory, no matter the Evaluating Guide for Water Saving Enterprises (节水型企业评价导则) first published in 2006 or the new Water Efficiency Label System (水效标识制度) in 2018; regional or national policies on water conservation are often ambiguous, without specific targets for the quantity of water a region or an enterprise is supposed to conserve or for the increase in water use efficiency (pers. comm. with official from Beijing Water Authority, 21 August 2017) (Box 4.1).

Box 4.1 Water policy ambiguity

The ambiguity and inoperability of national water conservation policy is exemplified by the national program of 'Water Pollution Control Action Plan (State Council [2015]17 Reference Number: 000014349/2015-00042)', on industrial water conservation. It states that "We will formulate a list of water technologies, processes, products and equipment that the state encourages or discourages, and improve the water quota standards for water intensive industries. We will carry out water-saving diagnosis, water balance testing, and water efficiency evaluation, and strictly manage water consumption quotas. By 2020, electricity, steel, textile, paper, petroleum, petrochemical, chemical, food fermentation and other industries with high water consumption should meet the advanced quota standards. (This will be led by the Ministry of Industry and Information Technology and the Ministry of Water Resources, with the participation of the National Development and Reform Commission, the Ministry of Housing and Urban-Rural Development and the General Administration of Quality Supervision)". It can be identified here that there are three major tasks in industrial water conservation, 1) formulate a list, 2) carry out related tests and 3) implement water quota. However, in practice, the list as a national standard is marked as 'Recommended' (for details refer to Footnote 27), relevant water tests are selectively enforced; for example, in my field research, only 4 out of 30 interviewed enterprise have taken the required test (details refer to Figure 5.1 Water balance in Firm-24). As for the water quota, no sample firm reported conservation to adapt to the water quota (details refer to following illustration in this paragraph).

Therefore, the implementation of industrial water conservation in this policy program depends on local interpretations. In response to the national 'Water Pollution Control Action Plan', Beijing Municipality, for example, issued its own 'Water Pollution Control Action Plan in Beijing (Beijing Municipality [2015]66)' on industrial water conservation. It states that 'By 2020, the city's water consumption per 10,000 yuan of GDP will fall below 15 cubic meters, and the water consumption per 10,000 yuan of industrial added value will fall below 10 cubic meters. Electricity, petroleum, petrochemical, chemical, food fermentation and other high-water consumption industries should meet the advanced water quota standards. Still these sets of regulations have no impact on water conservation according to the 15 sample firms in Beijing.

Though there are national water intake norms for industrial products (工业用水定额), indicating desirable water use efficiencies by sector for current technologies, they are marked as 'recommended'[27], giving industry less incentive for water conservation. In addition, the available amount of water that an industrial facility can use for production is issued by local Water

[27] In China, national standards are categorized into 'Mandatory national standards (GB)', 'Recommended national standards (GB/T)' and 'Technical guidance document (GB/Z)' according to the enforcement level. Recommended standards refer to the standards that the state encourages to be adopted voluntarily, which have a guiding effect but are not suitable for compulsory implementation. In other words, the technical contents and requirements specified in the standards have a general guiding effect and allow the users to choose them flexibly according to their actual conditions. Source: China National Standardization Administration (http://www.sac.gov.cn/).

Authorities as a 'water quota'[28], which is calculated from historical water consumption. Table 4.1 shows the sample form in local Water Authority in A district in Beijing on water quota management[29]. Unless a facility is enlarging production and has to apply for extra quota, its industrial water consumption is routine. No sample firm reported being constrained by the 'water quota'.

> Every year, the enterprise will report their water plan, and we will distribute the quota according to industrial standard (water quota national standard)[30] and the consumption of the enterprise in the past three years. On the whole, we must control the total amount of water used in our region not to exceed the quota allocated by the state to this region. For individual enterprise, if you want to increase production this year, I can give you more water quota.
>
> – Official, Beijing Water Authority

[28] Water quota management is an institutionalized water governance instrument in China (Q. Liu & Sang, 2007; L. Ran, 2005). Water used by industrial users which are non-residential water withdrawal units, must not exceed the quota issued by local Water Authority (example in Table 4.1). All the 30 sample firms confirmed that they received water quota from local Water Authority on a yearly basis.

[29] For anonymity reason, pseudonym for the locality is used. The company names and addresses in the original document are not disclosed in Table 4.1.

[30] General principles of stipulation of water intake norm for industrial product (GB/T 18820-2011).

Table 4.1 Statistics of industrial water quota in A district in Beijing 2016

No.	Company name	Sector	National Standard	Compliance status in 2016	Water consumption in 2016 (ton)	Address
1		Pharmaceutical products	GB/T18916 Part 10	Y	110743	
2		Pharmaceutical products	GB/T18916 Part 10	Y	1850	
3		Dyeing and finishing of textile industrial product	GB/T18916 Part 4	Y	21387	
4		Pharmaceutical products	GB/T18916 Part 10	Y	27511	
5		Pharmaceutical products	GB/T18916 Part 10	Y	28843	
6		Wool textile product	GB/T18916 Part 14	Y	4721	
7		Dyeing and finishing of textile industrial product	GB/T18916 Part 4	Y	28560	
8		Dyeing and finishing of textile industrial product	GB/T18916 Part 4	Y	158	
9		Chinese spirits production	GB/T18916 Part 15	Y	1635	
10		Pharmaceutical products	GB/T18916 Part 10	Y	3816	
11		Pharmaceutical products	GB/T18916 Part 10	Y	3952	
12		Chinese spirits production	GB/T18916 Part 15	Y	8974	
13		Chinese spirits production	GB/T18916 Part 15	Y	600	

Source: Internal documents provided by Water Authority in A district, Beijing. Translated by the author.

Pollution control policies, on the other hand, are mandatory and in principle enforced by central and local authorities. Long before China started to tackle environmental problems in the 1970s, attention was initially focused on the treatment of wastewater. In 1999, the Circular on the Collection of Wastewater Treatment Fees (污水处理费) and the Establishment of Urban Pollution Discharge and Centralized Treatment (城市污染排放和集中处理) were issued. Industrial water users have long been confined by the Discharge/Emission Standards of Water Pollutants (水污染物排放标准), issued and updated by the former Ministry of Environmental Protection (2008-2018), now Ministry of Ecology and Environment (2018-); in 2016, General Office of the State Council released Plan for Controlling the Implementation of the Pollution Discharge Permit System (控制污染物排放许可制实施方案) and started to grant discharge permits for air and water pollutants to polluting firms.

During the field interview with industrial firms, when talking about water related policy, it was evident that enterprises were in general more concerned about pollution control-related regulations, which are subject to mandatory enforcement (Table 4.2, Entry-1, 4), severer violation punishment (Table 4.2, Entry-3), and therefore higher regulatory risks (Table 4.2, Entry-8). In addition, the pollution control regulations are often associated with the environmental protection campaigns and are endorsed with more government subsidies (Table 4.2, Entry-2). In addition, interviewees from enterprises are more vigilant and cautious when the issue of environmental protection is brought up during the interview, which are associated with the pollution control policies (example refer to Table 4.2, Entry-8). The differences between these two arenas of water policy result in different regulatory water risk for enterprises. Whether firms respond to these two major types of regulations differently will be illustrated in Chapter 5 and Chapter 7.

Table 4.2 Comments from interview correspondents on water policy distinction

No.	Correspondents	Comments
1	Official, Water conservation office, Beijing Water Authority	On water management, we are just allocating water quota. Others are routine matters. We encourage industrial users to recycle and reuse water (but it is not mandatory). The Water Authority is mainly in charge of water quantity while EPB oversees pollution control. Each region in Beijing follows the same protocol, in different locality, there may be differences in accountable departments though.
2	Official, Environmental Inspection, Beijing EPB	One the one hand, pollution control regulations come with financial subsidies. Especially in the early phase of implementation, the government gives subsidies to enterprises if they actively respond to the policy to adapt. On the other hand, when enterprises violate pollution policies and refuse our supervision, we can join forces with the Public Security Department and shut them down.
3	Official, Law Enforcement, Beijing EPB	Unlike Environmental Impact Assessment or environmental protection facilities, we do not have discretion over pollution violations, enterprises will be punished once a violation has been spotted. There is no room for negotiation.
4	Official, Hebei EPB	Water conservation is mainly driven by voluntarily behaviour. Companies are also willing to use less water, and people's awareness of water saving has

		increased. For pollution control, over the years, one of the major tools in Hebei is to shut down violating enterprises.
5	Firm-01	On water policy, we are mainly concerned with regional and industrial wastewater discharge standards.
6	Firm-02	In terms of water conservation, there are no big restrictions from government policies. National environmental protection standards and policies have a great impact on us. In terms of pollution, the main concern now is the new wastewater discharge permit system.
7	Firm-03	It is difficult to implement water-saving policies. For example, many enterprises here do not have a water meter installed. In the 'coal to natural gas' program[31] in Beijing, as early adapter, we received a government subsidy of 1.5 million yuan.
8	Firm-04	Policies related to water will be interpreted, mainly on emissions. In recent years, two major government policies are impacting on our water management, namely the 'Water Pollution Control Action Plan' and 'Beijing comprehensive drainage standard' in 2013. There is a lot of pressure related to environmental protection. We are afraid that if we disclose even if a little information, it will be magnified and cause negative impact to enterprises. The main concern is the risk of pollution control.
9	Firm-05	As long as you do not violate pollution emission policy, it is okay. (The bottom line for enterprises that are not capable of environmental upgrading.)
10	Firm-14	The major driving factor for water management is to cope with our production process. Government policy has certain impact. Wastewater treatment is the top concern and we have outsourced this task to Veolia.
11	Firm-15	Our major policy concern is the wastewater discharge standard, as we have high COD in our wastewater.
12	Firm-17	Local government is protecting water environment. Water related industries like us have to adapt to the new pollution control regulations. So far, there is no constraint from conservation policy.
13	Firm-24	So far, we have not felt pressure from current water policy; as SOE, we have been complying with government regulations.
14	Firm-26	We are more concerned with wastewater water discharge standards. As for water conservation, our current water use efficiency is already higher than the recommended standard by the government.
15	Firm-28	There is no pressure from government policy, as SOE, we are actively complying with policy, no administrative intervention is needed.
16	Firm-29	Devoted large amount of resources to reduce pollution emission violation.

In summary, there are differences between the two study regions Beijing and Hebei. Physical water supply is more abundant in Hebei, with Beijing imposing higher water prices (details in 4.5). Firms in Beijing face greater regulatory scrutiny, even though Hebei is under high regulatory pressure due to its proximity to Beijing.

4.3 South to North Water Transfer Project

An important context for this thesis is the SNWTP, the ambitious inter-basin water transfer project initiated by the Chinese government. This project aims to alleviate water shortage in the north by transferring an annual 25 billion cubic metres of water from the south. Domestic researches on SNWTP in China mainly rest on modelling water allocation, measuring water quality and identifying engineering issues during construction. International researchers tend to analyze political (Pohlner, 2016), governance (Barnett et al., 2015) or governmentality issues and

[31] One of the policy programs in China to reduce air pollution through diverting to cleaner energy.

question the necessity and cost effectiveness of this project (Crow-Miller, Webber, & Molle, 2017). "The hydrological and eco-environmental impacts of the South-to-North Water Transfer/Diversion Project in China and the corresponding long-term monitoring and conservation strategy have become one of the top topics of attention among research on inter-basin water transfer" (Liang Zhang, Li, Loáiciga, Zhuang, & Du, 2015, p. 279). Since the project has been used for no more than six years[32], studies on the effect of this project are scarce and further studies are needed.

One common factor about the research on adaptation to resource conservation is that it is generally focused on reductions in availability, whereas in this case the availability of water has increased in the study region. The water transfer project could have both increased the physical supply and the quality of the water in the case study area. So, in this sense, the physical water availability of industrial firms there might have increased despite the policy risks identified in the previous section. According to my research in Beijing and Hebei, industrial water prices have been raised several times since firms began to receive southern water. Understanding comprehensively this change in water availability and price is the first step in this thesis.

It is argued that SNWTP is a political tool (Crow-Miller, 2015) that reflects a powerful and controlling central government capable of pursuing its objectives (Moore, 2014). Beijing, the capital city of China, whose development has always been prioritized, is one of the water-receiving areas in the Middle Route of the project. Ever since the operation of the Middle Route began at the end of 2014, Beijing has been receiving an annual average of one billion cubic meter of southern water. It is claimed by the state that water coming from the south now accounts for more than 70% of the urban water supply in Beijing and the tap water quality is also alleged to have been increased after the transfer in various government media disclosures (X. Liang, 2016; M. Wei, 2017; Xi, 2015). Scholars suspect that the transfer may actually discourage water conservation, which is detrimental for water sustainability, quite apart from other socioeconomic and environmental costs of the project (Jianguo Liu & Yang, 2012). Whether these changes will truly benefit the destination region is yet to be discovered. Therefore, in this thesis, I investigate firm's resource adaptation in the hope that it could shed some lights on how the SNWTP influences the water receiving area through industrial water use.

Water supply

To understand the effect of SNWT, I will first introduce how southern water is used in Beijing. Beijing is the destination of the Middle Route of the SNWT project. The Beijing section of the SNWT starts from the North Juma River in Fangshan District. According to the Beijing Office of SNWT, when southern water first reaches the territory of Beijing, it flows through the waterhead

[32] The Middle Route began operating on 12 December 2014.

of Juma River in the Huinanzhuang Pumping Station, where the water is collected in a reservoir in front of the pumping station. To increase the flow rate, after being pressurized by 8 sets of pumps, the water is pushed into two water pipes with a length of more than 50 kilometres and an inner diameter of 4 meters (Figure 4.6).

Figure 4.6 Water pipes of the SNWT in Beijing

Source: South-to-North Water Diversion Construction Committee Office in Beijing

Then the pressure will be relieved at the Daning Detention Tank west of the Yongding River. Afterwards, the transferred water is divided into two routes. The first route passes through Fangshan District, crosses the Yongding River, goes through Fengtai District, continues north along the West Fourth Ring Road, and reaches Tuancheng Lake in the Summer Palace (Figure 4.7). There, the water will enter the regulation pool in Tuancheng Lake, which is connected to the Miyun Reservoir, the major drinking water reservoir in Beijing. In this way, the southern water can be used to replenish the Miyun Reservoir. However, according to my interview with Beijing Waterworks[33], no water has been transferred to Miyun Reservoir yet. The second route goes east into the south and east main canals, which run along the Fifth Ring Road in the south and east (Figure 4.8). Thus, a ring-shape water supply system is formed.

[33] Beijing Waterworks is a state-owned enterprise that operates most of the tap water plants in Beijing. Tunnels of the SNWT are incorporated into the Beijing Waterworks' network to use the transferred water. Interview date: 28/07/2017

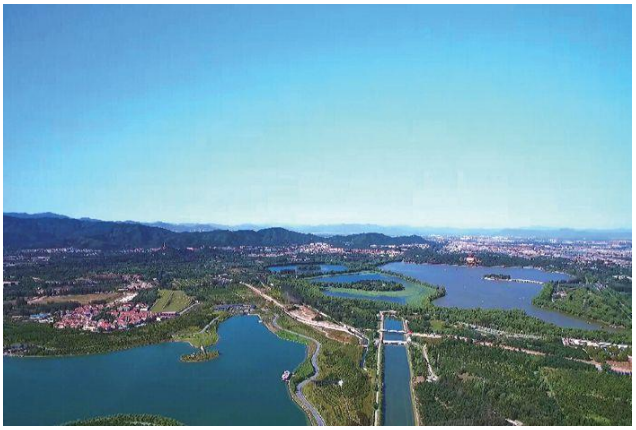


Figure 4.7 Water in SNWT and Kunming Lake in Summer Palace

Source: South-to-North Water Diversion Construction Committee Office in Beijing

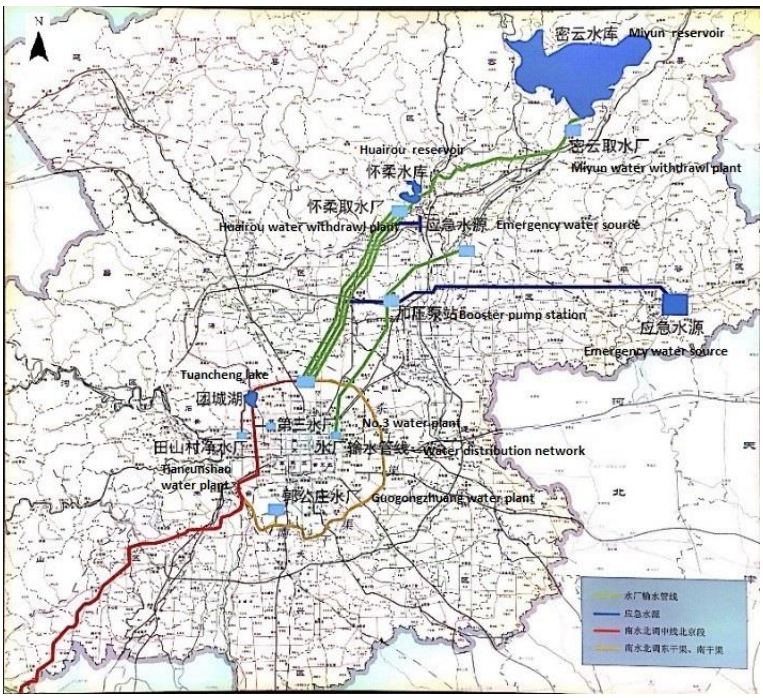


Figure 4.8 Routes in Beijing section of the SNWT

Source: Adapted from Beijing Museum of Tap Water

Legend from top to bottom: Water plant line, Emergency water source, Beijing section of middle route SNWTP, SNWTP east main canal and south main canal

The two routes (Figure 4.8) in Beijing are 80 kilometres long; all are underground tunnels, except for an 800-meter Tuancheng Lake Open Channel. The designed flow of the Beijing section is 50 cubic meters per second, and the annual water supply is planned to be 1 billion cubic meters. In April 2008, the Beijing section trunk line project was completed and officially opened in September. Beijing became the first city among the provinces and cities along the SNWT to benefit from the project.

When southern water reaches Beijing, it is distributed to tap water plants through water pipelines (Figure 4.9). After entering the water plant, southern water is supposed to undergo strict

purification treatment and become tap water that meets the national drinking water standards. It will then be distributed through the municipal water supply network for water users. The water supply range covers an area of 6,000 square kilometres, involving 15 districts, except for Yanqing District. To utilize southern water in Beijing, 11 water supply plants have been built or expanded with more water treatment capacity. Now, there are seven water plants in Beijing that take southern water. Southern water has become the major water source in Beijing. According to the Beijing Municipal government, 70% of the urban residents use water from the SNWTP, which directly benefited more than 11 million people (M. Wei, 2017).

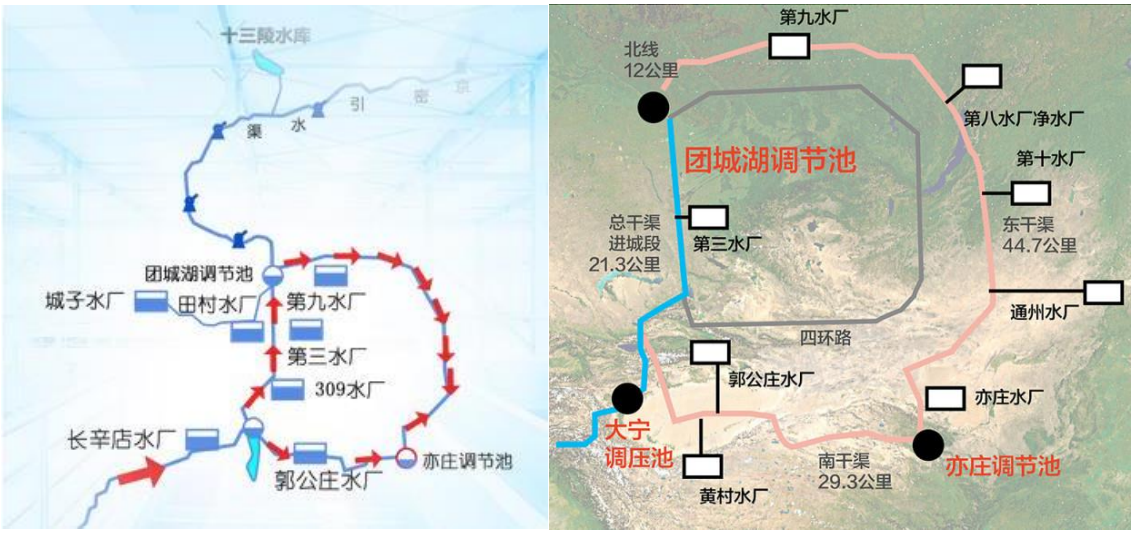


Figure 4.9 Waterworks in Beijing that take southern water

Source: Main Truck Canal Construction and Management Bureau of Middle Route Project

Extended water network

Propelled by SNWT, Beijing has gradually developed an extended water network that integrates combined dispatches from SNWT, Miyun Reservoir, Guanting Reservoir and groundwater. The water supply networks are connected to each other, allowing waterworks to have more than one water supply source[34]. For example, according to Beijing Waterworks, though No.9 water plant mainly uses transferred water, it is connected to the Huairou Reservoir as a back-up water source. With this new water source, there are decreased water supply risks. According to official news, southern water will eventually be stored in Miyun Reservoir. But for now, it has not reached Miyun.

> We have over-exploited Miyun Reservoir in the past (before the water transfer). There is no water. We are putting it at rest now.
>
> – Staff, Beijing Waterworks.

[34] Source: Interview with the Beijing Waterworks (Interview date: 28/07/2017).

By the time of my interview (June 2017) when water reaches Tuancheng Lake, all is allocated to different plants. In this way, Miyun's water is preserved. This whole project has lowered the water risk for Beijing.

> Southern water is mainly used for drinking. Before 2008, we are borrowing water from Hebei; after SNWT, we no longer need it from Hebei.
>
> – Staff, Beijing Waterworks.

With SNWT, Beijing has extended its water network and regulating capability of water supply for both the water works and the end of pipe users. Now, Beijing has bolder plans to keep constructing new infrastructures in the name of using SNWT. A diversified water transfer system is planned to increase the strategic reserve of water resources in Beijing. The goal is to realize the coordinated dispatch of Miyun Reservoir, groundwater and transferred water, forming a '26213' water supply landscape featuring two water routes, six major water plants, two hubs, one loop and three emergency water sources[35]. By then, the SNWT will be providing water for the 20 waterworks in Beijing. The water supply range will reach 6,000 square kilometres, covering all the urban area and becoming the main source of water in Beijing.

Potential Risk

Despite the complicated and often-neglected environmental risk, there remain risks from water supply in the source region and project operation. These risks are raised especially when the study region is relying on the water transfer as the major water source.

> The original rationale of SNWTP, turn waste into treasures. Risk mitigation. But it fails to consider the future trend of economic development. Future water supply, climate change, whether the risk of flood will still exist. Whether the project will provide stable water is still subject to climate factors. The socio-economic aspect is controllable, while the climate is not.
>
> Flow in the Middle Route is relatively stable, which is regulated by the dams to guarantee the support for the North. Will the water availability be influenced in the Danjiangkou[36] region? In extreme cases, I suspect they will still prioritize Beijing and compensate Danjiangkou in the form of financial aid.
>
> – Researcher 3, Beijing.

[35] According to the 'Overall plan of supporting project of Beijing South-to-North Water Diversion Project (北京市南水北调配套工程总体规划)'.
[36] Water source region in the Middle Route of SNWTP.

Whether water supply in the Danjiangkou Reservoir is sustainable in the long run poses future threat to this project. For now, as the Middle Route is in operation, there are still many operation risks threatening the quality and quantity of water delivered. The source region must be protected, so must the transfer route. Therefore, the whole route is guarded by restricted assess and a series of contingency plans.

> Water quality is monitored internally, and by an automated online system that reports to the government (the machines are under CCTV surveillance and cannot be tampered with), and there is also some other third-party monitoring. The SNWT project has increased 'pressure' to perform.
>
> For now, the main risk is precipitation. We have seventeen contingency plans in preparing for traffic accidents, precipitation, chemical leakage, drowning etc. For routine operation, we must make sure the electricity does not go out to make the water gate work. For that, we have standby generators.
>
> – Official, SNWT office in Hebei

These contingencies illustrated risks to the SNWT that other water sources do not have. During interviews with operators of the project, they often told me that they are well prepared for all kinds of contingencies to guarantee the quality and quantity of water sent to Beijing. From their narratives, it seems that the whole project is established to serve Beijing. With SNWT, the central government gained control over water allocation across regions and Beijing: the destination is the big winner.

It is understood that Beijing is one of the cities in China that is seriously short of water and has been seeking to divert water from other places[37]. Since the operation of SNWT in Beijing at the end of December 2014, it has been able to transfer 1 billion to 1.2 billion cubic meters of water to the capital per year, effectively alleviating the water shortage in the city[38]. However, Beijing's per capita water resources are still only 150 cubic meters, and the situation of a serious shortage of water resources in the capital has not been fundamentally reversed (L. Xie, 2017). The SNWT has increased water supply in both Beijing and Hebei, though without entirely eliminating the risks to that supply.

4.4 North China industrial cluster

In this section, the regional economic condition in the study region is introduced with a focus on local industrial clusters and industrial structure. Industrial relocation in this region guided by

[37] Source: Interview with Beijing Waterworks (Interview date: 28/07/2017).
[38] Source: SNWT Beijing Office.

national policy; I also indicate how restructuring and relocation could reshape regional economic geography.

Regional economy

The North China region, in which the two study areas of Beijing and Hebei are located, is often referred to as the North China Urban Agglomeration. It occupies an area of 216 thousand square meters and accommodates a population of 110 million people[39]. It is one of the rapidly growing regions in China with a high degree of openness and innovation. In 2016, 25% of foreign direct investment in the country landed in this region, and R&D expenditure accounted for 15% of the country total[40]. With a land area equivalent to 2.3% of China, North China carries 8% of the country's population and contributes 10% of the country's GDP[41]. However, the per capita GDP is lower than that of the Yangtze River Delta and Pearl River Delta. In terms of industrial structure, secondary industry in the Yangtze River Delta is well-developed, and the proportion of tertiary industry in the Pearl River Delta is high, while the North China region has the highest proportion of primary industry and the lowest proportion of secondary industry. Compared to the Yangtze River Delta and the Pearl River Delta economic circle, economic and industrial development levels in North China are generally low.

In secondary industry, mining and heavy manufacturing such as steel, electric power, automobile, chemical industry and petroleum processing in this region are nationally prominent. In 2015, the sales value of industrial enterprises above designated size in North China was 9014.71 billion yuan (USD 1280.79 billion), accounting for 8.2% of the national total[42]. The above-mentioned industries accounted for 48.5% of the region’s output, which was 16.3 percentage points higher than the national average. The sales value of ferrous metal mining and dressing industry and of the ferrous metal smelting and rolling processing industry accounted for 31.7% and 23.5% of national total respectively, and steel production accounted for 29.9% of the national total, reflecting that the two study areas are located in an important steel production base of China. Strategic industries such as electronics, pharmaceutical, special equipment and general-purpose equipment have developed rapidly in recent years and have gradually become the new leading industries in North China.

Since the Reform and Opening Up in 1978, the study region has achieved rapid economic growth, but gaps among the two regions are still relatively large. In 2015, the per capita GDP of Beijing was 2.64 times that of Hebei; the average disposable income of urban residents was 2.02 times that of Hebei; the per capita net income of rural households in Beijing was 1.86 times that of

[39] Data source: China Statistical Yearbook 2017.
[40] Data source: China Statistical Yearbook 2017.
[41] Data source: China Statistical Yearbook 2017.
[42] Data source: China Statistical Yearbook 2016.

Hebei[43]. In addition to intra-region disparities in economic development level, there are also difference in industrial structure within this region. In Beijing, high-end service industries and advanced manufacturing industries are competitively advantaged, whereas Hebei is still dominated by traditional industries.

As the capital of China, Beijing has incomparable technological and intellectual resources compared to other cities. Hebei is both advantaged and disadvantaged with its geographical closeness to Beijing[44]. Many cities in Hebei are in mountainous areas, and transportation and communication infrastructures are backward. For now, gaps within the study region are still large, which seriously affects the economic integration of this region. Another problem with economic structure in the study region is that the proportion of the state-owned economy is high, resulting in local governments exerting strong control over and interfering with enterprises.

Industrial development in the study region is also constrained by natural resources and environment. Beijing and Hebei are both water-scarcity regions with per capita water resources only one tenth of the national average. Though air quality in this region has improved over recent years, PM 2.5 concentration is still double the national standard. Regulating resource and pollution intensive industries is still a priority in regional environmental governance. At present, such industries account for a large proportion among industries in the study region; some are even leading industries. In Beijing, energy consumption in petroleum processing, coking and nuclear fuel processing industries accounted for 28.7% of the total industrial energy consumption[45]. In Hebei, the ferrous metal smelting and processing industry consumes more than half of the energy and 28.1% of water, and its added value accounts for 17%, making it the largest industry[46]. The heavy-manufacturing intensive industrial structure in Hebei exacerbates environmental deterioration. Among the 74 key air quality monitoring cities in China, the bottom six cities with the worst air quality are all from Hebei (Sheng & Tang, 2016).

Industrial relocation in Beijing and Hebei

Under the background of coordinated development of Beijing-Tianjin-Hebei region, the removal of general manufacturing industries is one of the strategies to relocate Beijing's non-capital functions (S. Zhou & Wang, 2017). Now industrial restructuring in the North China cluster remains under the guideline of the central government's 'Program Outline for Coordinated Development of the Beijing-Tianjin-Hebei Region (2015)', 'A Guide to Industrial Transfer in

[43] Data source: China Statistical Yearbook 2016.
[44] It is advantaged with preferential policies in the Coordinated Development of the Beijing-Tianjin-Hebei Region to boost economic development (Ren & Mu, 2005). However, being in the so-called Metropolitan Shadow Area (Pan & Yao, 2017), huge amount of resources and human capital are transferred out of Hebei, putting it at a disadvantaged place in resource allocation in this region.
[45] Data source: China Energy Statistical Yearbook 2017.
[46] Data source: China Energy Statistical Yearbook 2017, China Statistical Yearbook 2017.

Beijing-Tianjin-Hebei Region (2016)', and the municipal government programs of 'Catalogue of Prohibitions and Restrictions on New Industries in Beijing (2015)', and 'Catalogue of Polluting Industries, Production Process and Equipment Adjustment and Elimination in Beijing (2014)' [47]. Beijing is adopting a group transfer and cluster development approach to move general manufacturing industries (Appendix A) to development zones in Hebei.

Guided by the Catalogue of Prohibitions and Restrictions on New Industries in Beijing, since 2000, more than 1,000 companies have moved from Beijing to Hebei, most of which are manufacturing enterprises. Now, Beijing is launching a second batch of relocations. The to-be-relocated enterprises are mainly from manufacturing, cement, building materials, chemicals, furniture, home decoration and printing and dyeing sectors.

> A bunch of companies have moved out. There are several criteria. Firstly, in response to government policies, strict control should be exercised on general manufacturing and low-end industries, that is, strict control on increments. No new facilities or projects. Secondly, existing industries that do not conform to the capital's functions will be moved out. For example, for some industries with general technology, good revenue and little pollution, we will evacuate them to surrounding regions to drive their economic development. Thirdly, for enterprises with substantial pollution and low revenue. We are shutting them down. There is another category that is in line with the functional characteristics of our capital, but their technology needs to be improved. They can stay in Beijing, but technological transformation is required.
>
> Building materials, chemicals, textiles, printing and dyeing, as well as general steel processing industries, should not be in Beijing in principle. The garment industry is also restricted. We only keep some big brands, especially their headquarters and design departments and relocate their manufacturing facilities.
>
> – Official, Beijing Municipal Government

Spatial restructuring within the North China cluster features the relocation of general manufacturing from Beijing to surrounding areas. Hebei has accommodated relocated firms from Beijing and will continue to do so with the 'Coordinated development of Beijing-Tianjin-Hebei Region'[48], leaving them increasingly resource- and pollution-intensive. According to the Beijing Municipal Commission of Economy and Information Technology, from 2013 to 2016, the government relocated or closed 1341 polluting firms, while promoting green industries such as

[47] 《京津冀协同发展规划纲要》《京津冀产业转移指南》《北京市新增产业的禁止和限制目录（2018年版）》《北京市工业污染行业、生产工艺调整退出及设备淘汰目录》

[48] The Politburo of the Central Committee of the Communist Party of China approved the Program Outline for Coordinated Development of the Beijing-Tianjin-Hebei Region on 30 April 2015.

electronics, automobiles and healthcare services (You Li, 2017). By the end of 2016, 7.76 per cent of Beijing's enterprises (55250 enterprises) were engaged in mining and manufacturing, employing around one million people and contributing 19.26 per cent of local GDP[49]. Industries in Hebei now are led by steel and iron, chemicals and cement manufacturing (C. Wong & Karplus, 2017). At year-end 2016, 198 384 enterprises were in secondary industry, accounting for 25.26 per cent of all enterprises in Hebei, employing around 1.78 million workers and contributing 47.57 per cent to the provincial GDP[50].

As discussed in the previous section, the SNWT is raising water supply in the two study regions. These industrial relocations will change the water demand in the regions, raising it in Hebei and tending to decrease it in Beijing. In addition, one rationale for industrial relocation of Beijing is to push population migration to alleviate the population pressure in the capital[51]. Therefore, in addition to the shifted industrial demand, domestic demand may also shift[52].

4.5 Industrial water consumption

This section begins to elaborate industrial water consumption, the major quest of this thesis. Industrial water consumption in the study area is introduced, with a detailed account of industrial water supply in terms of quantity, quality and pricing. The use of industrial water is explained to better understand industrial water management. As an important aspect of water management for manufacturing industries, wastewater treatment for North China industry is introduced in this section.

Water supply

Industrial water in the study region is mainly supplied through municipal water supply networks. Generally, industrial users share the same water as household users or have a self-supply well (factories drill wells and pump water for their own use). Self-supply wells are common among rural industries, where there is no municipal water supply network, not even for domestic users.

[49] Data source: China Statistical Yearbook 2017.
[50] Data source: China Statistical Yearbook 2017.
[51] Ease Non-Capital Function of Beijing and Promote Coordinated Development of Beijing-Tianjin-Hebei (疏解非首都功能 推进京津冀协同发展), The People's Government of Beijing Municipality. http://www.beijing.gov.cn/ywdt/zwzt/sjfsdgn/ (Last accessed: 30 March 2020).
[52] For example, in 2018, 359 million m^3 of water was used by industrial firms in Beijing. In the same year, employment in firms above a designated size was 99.55*10000 persons. This equates to about 350 m^3 water per person. As a first approximation, relocation of enterprises from Beijing to Hebei might be expected to raise water demand in Hebei by 350 m^3 per job. If people relocate as well as firms, then their domestic use of water would need to be added to this (about 182 m^3 per person). 5 million persons are supposed to be relocated from Beijing to Hebei, according to the plan. If all of them were workers in industry, their relocation would bring an additional 2660 million m^3 water demand whereas the SNWTP increased water supply in Hebei in 2018 by 11941 million m^3. If some of the relocated workers were in service employment, their addition to the demand for water in Hebei would be lower.
Source: Hebei Statistical Yearbook 2018; Hebei Water Resources Bulletin 2018; Plan for Concerted Development and Industrial Transfer and Connection of Beijing, Tianjin and Hebei.

Some manufacturing facilities also use unconventional water sources; for example, some firms directly divert water from the SNWT and other firms in coastal regions have adopted seawater desalination techniques. Representative firms of each type were interviewed for this thesis and the results will be presented in the next chapter. Reclaimed water reuse is also considered to be an unconventional water source, and it will be studied in the following chapter on firm strategy, as reclaimed water reuse is an important technology that some industrial firms have adopted for water conservation. These water supply methods use either surface water from local water reservoirs, the SNWT or groundwater. After analyzing water supply methods in all the sample firms, Table 4.3 presents data about one industrial firm in Hebei (Firm-24) that uses multiple water supply sources to show the complexity of water supply sources in industrial entities. Firm-24 uses both ground water and surface water. For conventional water supply, Firm-24 is using water from 5 sources, including water from two other localities (FN and NP[53]), a self-supply well, a local reservoir and a local water plant. The water from these sources is either ground or surface water. In addition to conventional water sourced from a water plant and self-supply well, Firm-24 is also using recycled water in four different production processes to cut down cost and comply with zero liquid discharge policy in chemical sectors. Most sample firms have more than one water supply sources. There are also firms, including Firms 01 and 12 that only have one water supply source; they are either less water intensive and therefore do not need more water supply sources (Firm-01) or constrained by the locality (Firm-12 is located in an area where there is no access to the municipal water supply network, and so can only use self-supply well).

[53] Abbreviations are used to maintain anonymity.

Table 4.3 Company statistics on water supply sources

No.	Category		Water source	New water quantity(m^3/d)				Water quality (mg/L)				Use
				Plan	Water from the source	Water into facility	Pipe diameter specification (mm)*quantity	Water temperature	PH	Hardness	Turbidity	
1	Conventional water sources	Ground water	FN	15000	13375.8	13238	625					Production, domestic
2			NP	15000	11485	11316	625					
3			Self-supply well	200	176	176	150					Thermoelectricity for domestic
4		Surface water	Reservoir	45000		43549	DN900					Production
5			Water plant	5000		3183	325					Thermoelectricity for production
6	Unconventional water resources		Brine	35000		30287	DN900					Sodium carbonate production
7			Chloro-alkali pulp	8000		6350	420					Sodium carbonate production
8			Chloro-alkali recycle	10000		8224	450					Sodium carbonate production
9			Silicon recycle	3000		2196	300					Thermoelectricity for production

Source: Internal document from Firm-24, translated by the author.

Notes: FN and NP are location names. Pseudonyms are used for anonymity reason. DN is standard abbreviation for ‘Nominal Diameter’.

The total quantity of water a manufacturing facility can get is controlled by the local Water Authority in the form of water quota. The quota is based on historical water consumption and granted to enterprises annually. Firms file their water request before each new statistical year. The Water Authority assesses regional physical water availability and makes sure there is enough water for different water users. For individual industrial users they mainly refer to historical water consumption data; in addition, there is a national policy of 'Water intake norms for industrial products', indicating desirable water use efficiencies by sector for current technologies and 'Evaluating guide for water saving enterprises[54]'. The Water Authority also refers to these policy documents to ensure that enterprises follow the water conservation regulations. According to my interviews with firms in Beijing and Hebei, almost every firm reported that they normally ask for more water than they plan to consume just to reduce the risk of consuming more than the quota. No matter a factory is using tap water or self-supply well, there is metering device installed in the factory allowing the Water Authority to monitor water consumption. In well-developed regions, there are even online metering systems through which local authorities can monitor firms' water consumption continuously.

> One day the Water Authority called us claiming we have abnormal water consumption data. We don't even know that ourselves. So, we checked and found a leakage in an underground pipeline. In the end we were fined by the Water Authority for exceeding the water quota of that quarter.
>
> – Logistics Department Manager, Firm-08, Beijing.

If firms exceed the water quota granted by the local Water Authority, they will be punished in the form of fine. Currently, water conservation for industrial firms is mainly regulated by the local Water Authority.

The quality of industrial water depends on the water source. In some regions, groundwater users report high water hardness – alkalinity concentration is high in their local groundwater. Firms whose water comes from the municipal water network, especially if they are sharing the same network as household users, draw water for production that meets drinking water standards. Water quality matters to industrial firms, because water is used in different processes during production; for specific processes, there are specific requirements for water quality. For example, most industrial firms use water for cooling and in the boiler, and they must make sure the cooling and boiler water has low hardness to prevent pipe scaling or equipment fouling to reduce maintenance costs. As another example, often in food/drink manufacturing firms, a proportion of water goes into the final product, thus water has to be of a higher quality standard than other production water;

[54] First published in 2006.

in China such water is regulated by Food and Drug Administration. Therefore, if water supplied to the facility does not meet standard for a certain process, they will have to treat the raw water further, increasing their input costs.

In addition to process water, industrial water also includes water for ancillary production – water used to clean facilities and equipment and water used in the daily life of staff. Those forms of water bear some similarities to domestic water, which render it unlike the water for production, where technology is fixed, and a certain amount of water must be used to produce a certain amount of goods. But domestic water use is more flexible and has more room for conservation. However, for a manufacturing firm, the proportion of ancillary and auxiliary production water is small compared to production water, and therefore receives little attention from managers. Still, technological innovation in conservation does occur in firms – including water conserving taps or flush toilets, which will be further introduced in Chapter 5.

Water pricing

In China, the water pricing system is mainly divided into two categories: the domestic water price, charged to household users and the non-domestic water price, charged to secondary and tertiary sector users[55]. (For agricultural water consumption, there is a separate pricing mechanism, not discussed in this thesis.) In general, the non-domestic water price is higher than the domestic water price. Even if firms share the same water source as domestic users supplied by a municipal network, they have to pay more for water. This mechanism is regarded by the state as an incentive for industrial water conservation. In addition, among non-domestic users, special industries stand out with their own water price. Those industries include car washing, bottled water, golf courses and ski resorts, which are large water consumers and they are charged a high-water price. In Beijing, for example, special sector firms pay 160 yuan (USD23) per cubic metre of water, compared to 9.5 yuan (USD1.4) for urban manufacturing firms[56].

Firms in the study region started to use SNWT water in 2014; since then, the cost of water has increased given the huge cost of the construction and operation of this project. Now governments in this region are trying to increase water prices. In Beijing, since 2014, the water price has increased three times; the industrial water price rose from 7.15 yuan per cubic meter in 2014 to 9.5 yuan (urban user) or 9 yuan (suburban user) per cubic meter in 2016. Now urban industry is paying more for water than rural industry in Beijing.

In Hebei, in 2016, the provincial government issued a 'Notice on the Establishment of a Water Price Adjustment and Compensation Mechanism', targeting at making use of price to optimally allocate water resources, and to address the high cost of water use after the SNWT. According to

[55] Source: http://www.h2o-china.com/price/
[56] Interview with official from Beijing Water Authority (Interview date: 21/08/2017).

this plan, the water price will gradually be increased in 2017-2019, to meet the cost. Local governments responded to this policy. Baoding, for example, planned to adjust the water price in the main urban area from 2017-2019 (Table 4.4) and meet the final goal of having an average water price of 6.62 yuan per cubic meter. Baoding also declared that the city would mainly use SNWTP water in the future.

Table 4.4 Plan for water pricing adjustment in Baoding from 2017-2019

Year	Domestic	Non-domestic	Special Industry
2017	3.30	5.64	24.60
2018	3.88	6.69	28.30
2019	4.58	7.95	32.60
Goal	4.98	8.30	32.60

Unit: Yuan/m^3
Source: Internal document, Baoding municipal government.

Over the years, scientists, government officials, and water operators have advocated that China develop water markets and use pricing mechanisms to promote conservation (NDRC, 2018; H. Xie, Qiang, & Shen, 2018; Zhong & Mol, 2010). For industrial water management, a shift from pollution control regulations to market-based economic instruments is in progress (Boxer, 2001; M. Jiang et al., 2019; D. Shen, 2014). Among the many studies on optimizing industrial water pricing in China, research is focussed on designing a better pricing mechanism, for example, revising the level of the resource fee or the end-user rate (H. Xie et al., 2018), laddered water prices (Wenyong Zhang & Zhang, 2006) and optimizing price structure (T. Li & Shen, 2015). However, such designs all remain at the current rate level, 0.59-6.94 yuan per cubic meter (Geng, 2003; Xiaozhen Wang & Zhang, 2008; H. Xie et al., 2018), and they might have neglected a simple truth that given the current level[57], water represents a small proportion of the cost in industrial production, with the lowest being only 0.0001% (Z. Li, 2007). It is hard to stimulate water conservation in firms with such a pricing mechanism. Though there are empirical studies showing industrial sensitivity to water price change (S. Jia & Zhang, 2003; T. Li & Shen, 2015), these researches remain at sectoral or regional level.

In my fieldwork, at a facility level, industrial water users' perceptions of water pricing were investigated, with related questions including "What factors influence your water use? Is there any change in the water price in recent years? Have you taken any measures to change water use in your firm? And what are the measures? What factors drive you to take the action?"[58]. Among the 30 sample firms, only 1 firm from a special industry (Box 4.2) reported adaptation to water

[57] For water rate in China, refer to http://www.h2o-china.com/price/
[58] For detailed firm interview questions, refer to Appendix C.

Box 4.2 Context and adaptations in Firm-10

Firm-10 is a ski resort in Beijing, which is a special industry and has a water price of 160 yuan (USD23) per cubic meter. Every year, there will be 100 business days in winter. More than 90,000 tons of water are used every year mainly to make snow. One cubic meter of water makes two cubic meters of snow. When asked about the price of water, the company manager stated that the high price for their industry exerted pressure on water conservation. And they do not waste a drop. The major conservation measures in adaptation to the high price include rainwater harvest in summer, snowmelt harvest over the year and snow making time control. ("Snowmaking is subject to outdoor temperature, each year we start to make snow in November when it is getting cold in Beijing. However, in recent years, temperature is not stable in November and snow we made may melt. So now we wait until the temperature is stable to make snow. And in this way, a certain amount of water is saved.") They have built tunnels and tanks to facilitate rainwater and snowmelt harvest, which can contribute 14,000-15,000 tons of water each year. In terms of managerial institutions, they have regular employee training on water conservation and have arranged plumbers to inspect every water consumption link, including snowmaking, tap water, toilet etc. (Interview date: 23/08/2017).

pricing, while there are no adaptation measures in the remaining firms towards water pricing (Table 4.5). The reasons for this scant attention to water pricing include, for some firms (including Firm 01-06, 08-13, 15, 19-20, 28-29), the total water consumption is relatively low. Even for large water consumers (including Firms 07, 14, 16-18, 21-27, 30), given the current prices, the cost of water still constitutes a low share in their total production cost. Either way, the cost of water is a trivial part in production in the sample firms and has not been stimulating conservation (except for Firm-10).

Table 4.5 Comments/statistics from sample firms on water pricing

Firm	Comments
01	We use 20 tons of water a day. In 2016 water input only takes 0.00025% in total input cost, price is not one of the influencing factors in water management
02	We are aware of the water price increase in recent years, but this single factor has not changed our water use behaviour. [In our locality] water price regulation is not effective. [In our firm] the water cost for a whole year is equivalent to the electricity cost for a single day. We are not large water consumers, the water cost is less than 1/1000 of the total cost, 2%-3% of the total energy cost, it is a tiny part of production cost.
03	We use 40 tons of water a day. Water input accounts for around 10% of the total energy input. The water rate is 5 yuan per cubic meter regulated by local Water Authority. I managed to negotiate with them and got a price of 2-3 yuan per cubic meter. Water metering in this region is not flawless, there are still many firms here whose self-supply wells are not metered by local Water Authority.
04	The percentage of water cost is very low in our production. For example, one of our plants uses 200,000 tons of water a day, which is very low in our total cost. The main reason for water saving is not the cost, but the guidance of national policies and the constraint from laws and regulations.
05	Water consumption is small. We mainly use it in leakage test, there is no recycling process. Water is from our self-supply well, which is not metered.
06	Price is not one of the influencing factors in water management.
07	Water cost is around 0.003% of the total production cost.
08	The average cost for a piece of clothing is 20 yuan, where water accounted for 0.18 (0.9%). The increase in price has not changed our behaviour. We pay 30000 yuan for water a month. And only pay attention to water price when we pay the bill. In addition, we outsourced a lot of our production to other localities; in some of these places, water is not metered.
09	Water cost in total energy consumption (including water, electricity and gas): 7.24% in 2015, 9.09% in 2016, 8.94% in 2017.
10	Various adaptation measures, details refer to Box 4.2.

11	We use 400 tons of water a month on average. The cost is very low, therefore not calculated into the total production cost.
12	We have noticed the change in water price since the year before last. However, it does not impact on our total production cost much. Energy costs more than water, we tend to pay more attention to electricity.
13	Low water consumption, no incentive from water price.
14	Our large water consumption is mainly due to large production scale. We use about 80 million tons of water a year. There are water-saving reuse measures, mainly to save water costs. However, the cost for water in our production is low, I was not paying attention to the price.
15	Round-the-clock production consumes 40-50 tons of water per hour. Water cost is around 0.0048% of the total production cost.
16	The water consumption per unit of product is calculated in the cost. However, in power plant water cost is not mainly in the amount of water (price charged by water supplier), but cost for water treatment. Therefore, water pricing is not our major concern.
17	Water cost to production cost: 12/7500. It does not matter how high the price is because we use so little water (200 tons a day). We try to save water when the price is high. The cost of water is small. The original process used a lot of water, now the technology is advanced. In addition, we have bargaining power over the price with water supply agency.
18	Total cost not affected by water price increase, but new waste treatment regulations.
19	Low water consumption, do not pay specific attention to water price.
20	Less water consumed in production, more in everyday life for our staff. Not paying attention to industrial water pricing.
21	We have next to 0 water cost. Electricity accounts for 70-80% of the total production cost, which is our top concern.
22	In energy consumption, we pay more attention to coal consumption, which accounts for 60-70% of the total production input. Water rate is not fixed, the price is negotiated with local government and water supply company, usually 3.6-3.9 yuan per cubic meter. The cost of water is a minuscule part of the total cost of production. Still, we regard water conservation important in the production process.
23	We used to negotiate with external water supply body on pricing. Now we plan to use seawater desalination on a full scale to reduce the dependency on external organizations. Therefore, our water input cost is not determined by water pricing but the cost of our own seawater desalination. Right now, water cost accounts for 20% of total energy cost.
24	As the largest water consumer in this locality, we have bargaining power over water price. But as for its percentage in total production cost, it is small.
25	Have not paid enough attention to pricing.
26	We negotiated with the water plant about the price of water, did not follow the standard from the Price Bureau. Water accounts for a tiny part in total energy consumption, but still there are water statistics. Our production costs mainly lie in raw material.
27	Have not paid enough attention to pricing.
28	In water pricing, we have bargaining power with external supply organizations. We have various water conservation schemes, including our signature reclaimed water reuse system. To cut the water cost is one of the drivers, to increase CSR is the major reason.
29	Our energy consumption includes coal, electricity and water. The annual cost for electricity is 60 million yuan, while the annual cost for water is only 84000 yuan.
30	Price is not one of the influencing factors in water management.

In all the sample firms, water cost is calculated along with other energy cost, including, for example electricity and gas. Electricity consumption costs them 4-700 times more than water (e.g. Firm-02, 09, 12, 21, 22, 23, 29); sometimes other energy costs like coal consumption (e.g. Firm-22, 23, 29) were more of a concern given relative prices. However, in the case of Firm-10 in the special sector, water costs 14.4 million yuan (USD 2.06 million) per year, while electricity costs 0.984 million (USD 0.14 million) per year. When talking about water use in the special industry, the manager in Firm-10 noted that "now Beijing municipal government is strictly controlling the price of water in special industry. Still there are more newly developed ski resorts like us which

are still profiting despite high water cost; with local people having developed the habit of skiing, the market is getting large. Therefore, water price is not controlling the expansion of this particular industry, though it is encouraging water conservation in each firm. But with more ski resorts being built, the total amount of water used in this sector is still increasing, so the price is not reducing consumption on regional or sectoral scale. Now the government is resorting to measures other than pricing to restrict the development of special industries, such as shutting down golf courses to reduce regional water consumption." This also indicates that scale should be considered when designing water conservation policies including pricing. In summary, empirical evidence from this research showed that current water pricing acts as a misaligned incentive for industrial water conservation (except for the special industry at the facility level).

In addition, water metering remains a problem (comments from Firm-03, 05, 08), especially in rural areas of China. Without meters, water will not be truly marketized, therefore, could not act as an economic incentive. Furthermore, despite central or local government intentions to regulate use through pricing, in certain cases, especially for large corporations that have bargaining power over price (Firm-17, 22, 23, 24, 26, 28), it is more difficult to use price to change behaviour.

This evidence challenges the common belief by most economists that higher price leads to less demand. Such an economic instrument does not work for water conservation in Chinese industries, and the principle of 'promoting rational allocation of water resources through water pricing' by Chinese governments is nothing more than a good will. Further, I argue that the alleged water market is not a real market with fixed price and property rights, but rather a compensated water reallocation scheme. As Jiang *et al*. (2019) argued, state-market interaction in contemporary Chinese water governance is not in contradiction – the market is acting as a state proxy.

It seems that to promote the optimal allocation of water resources is what governments in China is always trying to do, but, that does not work well. Before, it was hard for water resources management authorities to collect the water resources fee due to insufficient institutional capability and enforcement even with low water rates (Fang, Xu, Wu, & Tan, 2002). This could still be true now. And not only in fee collecting, but in policy implementation in general. For the moment, it is still hard to realize water right exchange, so the government is only relying on pricing for demand management. However, empirical evidence in this study showed that industrial users (special industry users excluded) are not sensitive to water price. In the interview with local industry in Beijing, only one company from special industry report water constraint in pricing. Therefore, I conclude that now in industrial water management in the study area, pricing failed in regulating consumption.

Wastewater treatment

Unlike domestic water users who just pay sewage charge and emit wastewater to municipal wastewater network, industrial water users are faced with wastewater treatment regulated by environmental policies. Industrial water users have long been confined by the Discharge/Emission Standards of Water Pollutants issued and updated by the former Ministry of Environmental Protection (2008-2018), now Ministry of Ecology and Environment (2018-); in 2016, General Office of the State Council released Plan for Controlling the Implementation of the Pollution Discharge Permit System and started to grant discharge permit for air and water pollutants to polluting industries.

Previously, China used a conventional centralized wastewater treatment technology wherein municipal wastewater treatment plants take domestic and industrial wastewater, treat it to meet national standards and then emit it to a natural water body. (Before that, there was a time when there were no environmental regulations in China; wastewater from firms was randomly discharged into the natural environment.) Now with the tightening of environmental regulations and enforcement in China, industrial firms, especially large wastewater emitters, are required to develop on-site wastewater treatment facilities to treat their wastewater themselves first before it is emitted to municipal wastewater treatment plants or (if their treatment standards are high) to the natural environment. The rationale for this change is that for some industries, for example pharmaceutical, the wastewater they generate contains specific pollutants that a regular centralized waste treatment plant is not capable of handling. Other large water consumers, discharge so much wastewater that exceeds the treatment capacity of municipal waste treatment plant. China's government in this way is seeking to prevent contaminated water from entering natural environment. Though China started wastewater treatment late, it now hosts some of the few cities worldwide that have integrated on-site water recycling technology. Beijing is playing a leading role in on-site water recycling, using corresponding industry and related knowledge bases (Binz, Truffer, & Coenen, 2015).

Wastewater treatment in industrial firms is strictly monitored in the study region by local Environmental Protection Bureaus[59]. EPBs visit firms regularly or randomly to supervise their waste treatment, making sure that no wastewater is polluting the environment[60]. In addition, with the advance of monitoring techniques, many large polluters are required by EPB to install an online monitoring system, that automatically samples and tests wastewater to make sure that there

[59] Interviews with sample industrial firms and EPB officials, 2017-2018.
[60] Interviews with sample industrial firms and EPB officials, 2017-2018.

is no emission violation and that the enterprise has no access to the monitoring system (preventing data fabrication)[61].

Governments at central and provincial levels have issued 'Lists of key monitoring firms' in their jurisdictions. Pollution-heavy firms, which are often named on national or provincial lists, are under scrutiny by EPBs at all levels. Manufacturing firms in Beijing and Hebei, whether on the list or not, reported general pressure to control pollution, pressure which exerts an important impact on their waste treatment behaviour (Chapter 5). Pollution control regulations as an institutional factor that influences industrial water management will be elaborated in Chapter 7.

4.6 Conclusion

This chapter responded to the first research question in this thesis. "What is physical and regulatory water availability in northern China?" Key background information regarding water and industry in the study area was introduced, along with some findings derived from my field work covering the study period of 2012-2017. General background of the study area was first introduced. Physical and regulatory water availability in Beijing and Hebei were then reported, with a specific section covering the SNWT and how it has changed water availability in the study area. Then industry development and structure in the study area were introduced and industrial water consumption in the study region was explored. I find that North China industries face both physical and regulatory water stress. At the firm level, there are more pressures from environmental regulations than from physical constraints. Industrial water pricing was also examined to shed light on the industrial water availability. Results showed that price in the study region is not constraining industrial water use and current water pricing acts as a misaligned incentive for industrial water conservation (except for the special industry at the facility level).

In terms of regulatory water risk, which directly impact firms' responses to ecological modernization, a major finding is the distinction between water conservation and pollution control policies. Water conservation related policies are often not mandatory; regional or national policies on water conservation are often ambiguous, without specific targets for the quantity of water a region or an enterprise is supposed to conserve or for the increase in water use efficiency. Such water conservation-related policies are soft regulations. Pollution control policies, on the other hand, are hard regulations – mandatory and in principle enforced by central and local authorities. Whether this distinction in the language of policy leads to distinctions in compliance will be presented in the following chapters.

In terms of physical risk, regional physical water scarcity has been alleviated by the SNWT to some extent. Currently in Middle Route of the SNWT, southern water is mainly for municipal use

[61] Sample firms that have an online monitoring system installed include Firm-04, 07, 09, 13, 14, 16, 20, 22, 23, 24, 25, 26, 27, 29.

due to its high cost and quality. The impact of SNWT has been mainly exerted at the regional level, in terms of regional water availability. The impact of the SNWT on water quality is adapted through drinking water treatment plants, because no matter the quality of the raw water they use, the quality of the water they produce should be consistent with unified national treatment standards. Individual industrial users are not substantially influenced by the water transfer. The government has restricted the development of new factories and promoted industrial relocation, to guarantee water supply for existing factories, making them less constrained by water resources. In other words, regional scarcity does not necessarily generate entity behaviour change; the government in this case plays a moderating role. And as scarcity has not stimulated conservation behaviour, regulations need to be designed to transmit regional scarcity into a signal to individual firms.

Having effectively abandoned binding quotas for firms and households, the government can only rely on pricing for demand management. However, the current price fails to regulate industrial consumption, especially at the firm-level. Industrial relocation in Beijing and Hebei also prioritized the needs of Beijing, transforming its economy from resource-driven to efficiency-driven, partly for reasons of environmental protection as well as water demand management in Beijing. However, under current environmental and institutional circumstance, firms in both Beijing and Hebei are faced with the need for environmental upgrading.

In summary, in terms of water availability in the study region, the local physical environment is relatively dry, with no big rivers; the long history of pollution reduces availability even more. The SNWTP is supposedly allowing some recharge of groundwater and increasing supply of clean water. However, such an impact is mainly exerted on the regional level. The relocation policy, as one of the regional responses to physical water constraints, simply shifts the burden out of Beijing and onto Hebei, while regulatory pressures are the tools to regulate firms. However, there is the issue of the distinction between conservation and pollution policy. Conservation policies are weak, water in practice is not really constrained for firms, except that heavy users are being driven out of Beijing; and pricing is so far not a tool that affects water availability for firms either. The study region, as one of the fast industrialising and urbanizing regions in China, is faced with water resource constraint. How will industries in this region cope with both physical and regulatory water risk? What are the common strategies in water management and what factors affect their behaviour in water management? These questions will be answered in the following chapters.

Chapter 5 Firms' Water Management Behaviours

5.1 Introduction

This chapter introduces firm strategies in water management, in response to research question 2 of this thesis: "What do industrial firms do to manage water?". To be specific, this chapter examines the strategies that pattern firms' adaptation to water resource constraints and environmental regulations in Beijing and Hebei. Cases are from different types of firms – different scales, ownership, histories and industrial sectors. Following Warren *et al.*'s (1999) category, I named these reactive, proactive and resistive firm behaviour. One of the most adopted measures observed in the study region is innovation, which in this study is defined as reactive and sometimes proactive environmental behaviour with high degree of policy compliance. But resistive behaviour, such as regulation avoidance and rule breaking, are also seen. In this chapter, I will first describe firm behaviour based on the case study firms and then describe representative cases in each strategy along with brief comments on firm and locality contingencies that shaped firm behaviour (detailed analysis of firm characteristics and locality factors impact will be presented in Chapter 6 and 7). While this chapter focuses on firm strategies, the following Chapter 6 and 7 will disentangle the influence from firm character and locality.

Water use in industrial enterprises is found to be more affected by pollution control than water resources consumption, concluded Chapter 4. As water is the precondition for production – no water, no firm – so if firms are allowed to manufacture, a water quota will be allocated to them (see Section 4.5). Also, industrial water has a low price elasticity (though there is price discrimination against special industries), so among general manufacturing firms in this study pricing does not regulate use[62]. Water conservation and pollution treatment behaviour in firms are instead driven by government regulations. Though water withdrawal by industry is huge, consumption is not necessarily large: if pollution control is of high standard and reuse is realized, firms could consume less water while obeying the government's pollution control regulations.

As indicated in Chapter 2, firms employ various strategies in CEM. Different typologies are used to classify strategies. In this chapter, I adopt a typology that reflects the behavioural outcome and classifies firms' in water management into three types: innovation, avoidance and rule breaking. In the following section of this chapter, I introduce in detail these different adaptation behaviours (Table 5.1), their effect and the explanations given by firms that lead to each specific behaviour. Innovation will be firstly introduced with specific cases of both technological and institutional innovation. Then the avoidance behaviour of firms is described; it features relocation, outsourcing and factory closure. Finally, opportunists and government-enterprise collusion exist, permitting

[62] For details refer to Chapter 4: 4.5 Industrial water consumption on 'Water pricing'.

rule breaking behaviour. This chapter concludes with major findings about corporate water management behaviours and suggestions for both firm and government to improve corporate environmental performance and strengthen environmental governance.

Table 5.1 Behaviours of sample firms

Firm	Innovation[63]		Avoidance			Rule breaking	
	Technology	Institution	Relocation	Outsourcing	Factory closure	Opportunist	Collusion
1	√	√					
2	√	√					
3	√					√	√
4	√	√					
5					√	√	
6	√	√					
7	√	√					
8	√	√		√			
9	√	√					
10	√	√					
11	√						
12	√		√				
13	√	√					
14	√	√					
15	√						√
16	√	√					
17	√						
18	√						
19	√						
20	√	√					
21	√		√				
22	√	√					
23	√	√	√				
24	√	√					
25	√	√					
26	√	√					
27	√	√					
28	√	√					
29	√	√					
30	√						

[63] In this study, innovation in a firm is the production or adoption of a value-added novelty: either the renewal and enlargement of products, services, and markets; or development of new methods of production or new management systems. For example, the adoption of new water technology or water management system.
Reference: A Dictionary of Geography (5 ed.). Oxford, UK: Oxford University Press.

5.2 Innovation

To tackle the physical risk of water shortage and regulatory risk on water conservation and pollution control, firms initiated technical and managerial innovations to improve environmental performance. Almost all the firms initiate innovation, either voluntarily or involuntarily, in response to stringent environmental regulations in the study area (Table 5.1). The only firm that did not innovate in some way (Firm 5) was forced to close. Innovation features reactive behaviour – regulatory compliance – and some firms adopted proactive innovation to gain competitive advantage through reduced regulatory risk and compliance cost (i.e. Firm-02, 04, 17, 23, 24, 28, 30). Specific innovation practices are introduced in this section. Innovating firms make positive changes to strengthen CEM.

Technological innovation

Technical innovations identified in water management practices are mainly grouped into three categories (Table 5.2) with eight common behaviours. These behaviours can be grouped into water conservation- or pollution control-specific innovations in compliance with related water regulations, and technological innovations in the main production process that are initiated to serve other purposes, for example, to cut production cost for other raw materials (Box 5.1), or to produce competitive product (Box 5.2), but having the extra benefit of increased water use efficiency or reduced wastewater emissions. The third category of technological innovation not specifically targeted at water management, has generated both water conservation and pollution control effect; therefore, analysis of them will be incorporated into the analysis in the following two subsections on water conservation and pollution control. Table 5.2 gives an overall picture of the technological innovation adoption status in all the sample firms. In the following subsection, I introduce different technological innovations and describe representative cases.

Box 5.1 Context and adaptations in Firm-26

Firm-26, a chemical fibres manufacturing company, whose production cost mainly lies in the raw material fibre (raw fibre cost is 15000 yuan per ton of final product, while water cost is 150 yuan per ton of final product). Technological innovation in the main production process was initiated to use less raw fibre; water consumption was also reduced in this innovation (Interview date: 07/11/2017).

Box 5.2 Context and adaptations in Firm-17

Firm-17, a paper manufacturing firm having the best production line in this industry in China had its main production process upgraded to produce paper of higher quality with lower cost. As an extra benefit, water use efficiency in Firm-17 is 4 cubic meters of water per ton of paper, while the national sectoral average is 20 cubic meters of water per ton of paper (Interview date: 21/09/2017, for detailed context of Firm-17, also refer to subsection 'Water conservation').

Table 5.2 Technological innovation in sample firms

Firm	Water Conservation Specific				Pollution Control Specific		Main Production Process	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Recycle and reuse	Reclaimed water reuse	Alternative water source	Water saving equipment	Wastewater treatment	Pollution prevention	Production process upgrade	Routine technology reform
1	√			√	√	√	√	√
2	√	√		√	√	√	√	√
3					√		√	
4	√			√	√	√	√	√
6					√	√	√	√
7	√			√	√	√	√	√
8					√		√	
9	√			√	√	√	√	√
10	√		√	√			√	
11	√			√	√	√	√	√
12					√		√	
13	√			√	√	√	√	√
14	√		√	√	√	√	√	√
15					√	√	√	√
16	√			√	√	√	√	√
17					√		√	
18					√		√	
19					√			
20	√				√		√	√
21							√	
22	√			√	√	√	√	√
23	√		√	√	√	√	√	√
24	√			√	√	√	√	√
25	√			√	√	√	√	√
26	√			√	√	√	√	√
27	√			√	√	√	√	√
28	√	√		√	√	√	√	√
29	√			√	√	√	√	√
30					√	√	√	

Note: Firm-05 is not listed in this table as there was no innovation in this firm.

Water conservation

Technological innovation is not unusual for industrial firms. Specifically, in terms of water use in production, firms added recycle and reuse processes in manufacturing to consume less water (Table 5.2 Column 1). This is a common practice in manufacturing firms, designed into the main production process to conserve water, and therefore constrained by the main process. The sample firms without 'recycle and reuse' programs[64] do not recycle and reuse water in the main

[64] Except for Firm-03 and 12 who are in Food and Wine sector whose water is subject to quality control by Food and Drug Administration.

production process and are not incentivized economically or through regulation to adopt this type of innovation either. As when firms try to change the way they use water, in most cases it is inevitable that they renovate infrastructure, to reroute or update pipelines, which increases the adaptation cost.

> For energy conservation, we changed all the lighting lamps into LED lights. It is viable. But water does not work that way. They are fixed, it's hard to change the water equipment and pipelines. For example, the water coming out of our own treatment plant is of high quality. Can we reuse it to flush the toilet? Yes, we can. But who is going to install the pipes? No one. You did not take this into consideration when you first build this plant. Now you want to change. On the one hand, the input of such adaptation is too high, and the saved cost of water won't make up for it. On the other hand, in most cases, we don't have the physical condition. There is no room to install new pipes. It is all built up, all the lines are in our facilities. We can't just tear them down. So, water adaptation is constrained.
>
> – EHS manager, Firm-01, Beijing.

This cost is one of the many reasons why firms are reluctant to adopt new water conservation techniques. Like Firm-01, despite recycling and reusing water in the original production process, they would not further adapt because of the infrastructure constraint. This point has also been remarked on by Firms 06, 08, 11, 17, 18, and 19. Water adaptation in manufacturing firms can be a process path-dependent on previous technological conditions. Furthermore, with the distinction in water conservation and pollution control policies in China, characterized by soft conservation and hard pollution control, there is limited regulatory incentive or pressure for water conservation [65]. Economic incentives to conserve water are also inadequate to trigger technological innovation, since the cost of water for a manufacturing firm is normally a minor part of total input costs (<1/1000) [66]; the savings are thus insufficient to overweigh new infrastructure costs. When it comes to the adoption of environmental practices, firms tend to base their decisions on the cost-benefit framework, refusing to take a proactive step if it is not under hard regulations nor economically beneficial.

Thus, improved water conservation performance often comes as a side effect of technological innovation that is initiated to improve manufacturing techniques, to produce competitive products or to cut the cost of other raw materials (Table 5.2 Column 7). With improved technology, water use efficiency is increased as a by-product. Consider for example, Firm-17 in Hebei, a private enterprise in a water-intensive and pollution-heavy sector. The industrial region in which Firm-

[65] For empirical evidence, refer to Chapter 4: 4.2 Water in North China on 'Regulatory water risk'.
[66] For empirical evidence, refer to Chapter 4: 4.5 Industrial water consumption on 'Water pricing'.

17 is located has many similar small enterprises manufacturing the same product. This region has a long history of manufacturing in this sector and now has competitive advantage over its counterparts in the same sector country wide.

> When the inspectors from the central environmental protection agency come here, they don't even believe we can use so little water and generate so little pollutant.
>
> – General manager, Firm-17, Hebei.

This performance derives from technological innovations in manufacturing techniques. Over the years Firm-17, along with its peers in the same area, has remained at the cutting-edge of technology in this sector. "The machines that we are using now are purchased from Japan, the best you can find in our country. Even the equipment that we eliminated is still better than that in other parts of China." The industry in this region started from small family workshops. When people saw how profitable such workshops were, many families in the same area got into this business, creating a regional industrial hub, which formed a benign competitive environment. Due to the special social setting, every individual enterprise is familiar with every other, and when one company adopts new technology to boost production, every other company adopts the same new technology[67]. In this case, physical proximity as well as informal inter-firm relationships promoted collective efficiency and knowledge spill-overs (Breschi & Lissoni, 2001; Schmitz, 1995; S. Zhu, He, & Luo, 2019). With constant innovation, scope exists to invest in water saving technologies alongside other technologies.

In large enterprises, regular technological innovation is routinely initiated (Table 5.2 Column 8). Firm-25 in Hebei for example, is a state-owned enterprise (SOE), a leader in its industry nationwide. The manager in its technical centre (the department that oversees all technological innovation in this firm) told me:

> Water-related technical reform involves mechanical sealing water reuse etc. Most water reuse and conservation techniques are to serve the main production process. The technical reforms are for economic benefit to cut the cost of production. Technical reform is routine work. We also constantly send staff out to conferences or other companies in the same industry to exchange experience and learn from them. Our technique is the best in the east. While in the west, there are more advanced technologies, we are still learning from them. Also, we are constantly enlarging our production, with the enlarged production, the water use efficiency is also increasing.
>
> – Manager, Technical Centre, Firm-25, Hebei.

[67] Interview with Firm-17 (Interview date: 21/09/2017).

Such commitment to R&D equips firm with capability of continuous innovation, contributing to firms' capability of environmental adaptation with reduced compliance cost.

Furthermore, water use efficiency can be increased when a facility is operating at its full capacity:

> We use a tank of water to wash our product; either when we wash one or two, it is the same tank of water, so the more product that we are producing the less water is embodied in each product. Our output is subject to seasonal variation and so is the water consumption per unit of product.
>
> – EHS manager, Firm-02, Beijing.
>
> That is the perk of scale. When you produce more, the supporting public utilities are being taken full use of.
>
> – Manager, Technical Centre, Firm-25, Hebei.

This can also be true for other sectors (confirmed in Firm-01, 04, 07, 08, 14, 15, 20, 23, 24, 26, 27, 28, 29, 30). When the amount of water is constrained by techniques and machinery conditions, the more product is manufactured, the more efficiently water is being used.

However, technological innovation that specifically targets water conservation is also observed, including the adoption of reclaimed water reuse technology[68], building new water reclaiming facilities and pipelines to collect wastewater and distribute the reclaimed water for reuse (Table 5.2 Column 2). It can be viewed as an advanced mode of recycle and reuse; what differentiates it from common recycle and reuse is that additional water treatment is required to raise the water quality to production standards. Firm-02 in Beijing and Firm-28 in Hebei (both SOEs) are among the firms that have adopted the reclaimed water reuse system. The main reason that prevents other firms from adopting the same technology is the quality of the reclaimed water, especially for firms that have high standards for production water quality (Firm-03, 09, 11, 12). Given the high cost of operating a water reclaim system, if the recycled water cannot be used in production, it seems pointless to do this. Firm-02 reported that it has used reclaimed water for cooling during production.

> Our reclaimed water system technology is advanced. The quality of our reclaimed water is even better than tap water in terms of 'hardness[69]'. In cooling water, we try to decrease the hardness of the water to prevent scaling in our pipes and equipment.
>
> – EHS staff, Firm-02, Beijing.

[68] "Reclaimed water reuse 中水回用" is a standard engineering term in China, meaning to save wastewater, treat it with a simple process and then reuse it.
[69] Hardness refers to the amount of dissolved calcium and magnesium in water.

Again, however, infrastructure construction is unavoidable, in addition to the initial cost of water treatment equipment, deterring small firms in taking such action. The two firms that did adopt reclaimed water technology are both SOEs. According to them, cost did not get in the way of innovation: when they were planning such reclamation, they were thinking more about "responding to national policies" and "setting a good image for SOEs" (Box 5.3).

Box 5.3 Interviews on reclaimed water reuse

Environmental performance is related to the evaluation of our general manager, which concerns his/her political career, even if it (referring to the reclaimed water system) is not profitable, they'll still do it.

- EHS staff, Firm-02, Beijing.

Our reclaimed water system is advanced, water is reused in our production. We even have an extra amount of reclaimed water that we cannot consume. Now we donate it to the city. They use it for cleaning, irrigation and other municipal purposes. This is also part of our CSR scheme.

- Director, Public Utilities Management, Firm-28, Hebei.

Firm-02 is a newly constructed plant, built in 2011, in which the water reclaim system is designed from the start of construction. Therefore, the firm did not have to pay for infrastructure reconstruction. When firms were asked about whether they would like to adopt the water reclaim system, Firms 04, 07, 14, 24, 25, 26, 27 and 29 stated that they would rather do it in new facility than through reconstructing existing facility.

The third water conservation-specific behaviour is to adopt alternative water sources (Table 5.2 Column 3). This is exemplified in stormwater harvest and reuse in Firm-10 (Box 4.2), Firm-14[70] and seawater desalination in Firm-23[71]. Like the reclaimed water reuse system, this also requires extensive infrastructure construction. It is only adopted by large scale, high water consumers, that are driven by high water demand[72] and financially capable[73] of initiating such change.

The last common water conservation-specific behaviour is to adopt water saving equipment (Table 5.2 Column 4). This is under the guidance of 'Catalogue of the Industrial Water Saving Process, Technology and Equipment Encouraged by the State' issued by the Ministry of Industry and Information Technology and Ministry of Water Resources. However, as a non-mandatory policy, this is not implemented by every firm. As illustrated by the previous water conservation adaptation behaviours, changes in the main production process requires extensive changes in previous technological and infrastructure conditions and remain a path-dependent process.

[70] For detailed context of Firm-14 refer to Box 6.1.

[71] For detailed context of Firm-23 refer to section 5.3 Avoidance on 'Relocation' and to Chapter 7: 7.2 Infrastructure-Alternative water sources, where there is a detailed account of seawater desalination in Firm-23.

[72] Firm-14 consumes 80 million tons of water annually and Firm-23 consumes 30 million tons of water annually. (Interview year: 2017)

[73] For Firm-14, its quarterly revenue is 1 billion yuan (USD 143 million) in 2017. For Firm-23, its revenue in 2016 is 700 million yuan (USD 100 million). (Interview year: 2017)

Without mandatory regulations, firms will not change the main production process (Firm-03, 06, 08, 12, 15, 17, 18, 19, 20, 21, 30). By contrast, in addition to process water, industrial water also includes water for ancillary production – water used to clean facilities and equipment and auxiliary production water (water used in the daily life of staff). Those forms of water bear some similarities to domestic water, which renders it unlike the water used in production, where technology is fixed, and a certain amount of water must be used to produce a certain amount of goods. But domestic water use is more flexible and has large scope for conservation. However, for a manufacturing firm, the proportion of ancillary and auxiliary production water is small compared to production water, and therefore receives little attention from managers. Still, technological innovation in conservation does occur in some firms – including installing water conserving taps or flush toilets (e.g. in Firm-01, 02, 04, 10, 13, 28).

In summary, water conservation-related technological innovations are path-dependent on previous technological conditions in the main production process because there are no mandatory government regulations for upgrading and such innovations are costly in comparison with the benefits. The increased performance mainly came along with upgrades to the main production process, driven by factors other than merely water conservation.

Pollution control

After water passes through production process, it becomes wastewater. In wastewater (pollution) control, there are also technological innovations. Most sample firms reported that they were under pressure from local EPB to treat wastewater being emitted to the natural environmental or to municipal wastewater treatment plants[74]. In this sample, 27 out of 30 firms have wastewater treatment equipment or facilities installed in response to the pollution regulations (Table 5.2 Column 5). Exceptions are Firm-10 (in Beijing) and 21 (in Hebei) which do not produce wastewater and Firm-05 (in Beijing) which is an example of a non-compliant firm that is forced to close by the government because of this non-compliance. This limited number of exceptions shows there is a high degree of compliance in pollution control regulations in Beijing and Hebei in comparison to water conservation regulations. As pollution control policy is mandatory and supervised by environmental authorities, firms that generate wastewater must engage in wastewater treatment to meet emission standards[75].

[74] For evidence, also refer to Table 4.2 Comments from interview correspondents on water policy distinction.

[75] In China, there are three set of emission standards, national, reginal and sectoral; enterprises are required to enforce the strictest standards. The emission standards are the major code of conduct in firms' water management (for evidence also refer to Table 4.2), supervised by EPB at different levels.

Table 5.3 Wastewater treatment in sample firms

Firm	Wastewater treatment			
	Facility			Outsourced
	Equipment	Workshop	Plant	
1		√		
2	√		√	√
3		√		
4	√		√	√
6		√		
7	√		√	
8		√		
9	√		√	
11	√			
12		√		
13	√		√	
14	√		√	√
15			√	
16	√		√	
17		√		
18		√		
19	√			
20		√		
22	√		√	
23	√		√	
24	√		√	
25	√		√	
26	√		√	
27	√		√	
28	√		√	
29	√		√	
30	√		√	

Note: Firm-05, 10 and 21 are not listed here.

Waste treatment behaviours are categorized into four types in the case study (Table 5.3). Some firms are regulated into adopting wastewater treatment facilities including equipment installed at the production unit, sewage treatment workshop or plants built within their factory depending on the wastewater quantity and pollutant types[76]. Other firms outsourced their sewage treatment business to reduce water treatment pressure (Firm-02) and shift regulatory risk (Firms 04 and 14).

Wastewater treatment, as an end-of-pipe process is less path dependent than water conservation innovations (introduced earlier) and pollution prevention innovations (to be introduced in the next paragraph). Unlike other technological innovations that need to substantially change the original

[76] Whether to build wastewater treatment workshop or plant depends on the quantity of sewage, with wastewater treatment plants having higher treatment capability. And for wastewater coming from different production process, there may be pollutants that need to be pre-treated before they enter the wastewater treatment workshop/plant. In that case, wastewater treatment equipment is installed in the production unit to pre-treat the pollutants.

water use infrastructure, waste treatment requires additional end-of-pipe collection and treatment equipment and/or facilities, without extensive change to the original water network.

There also exists pollution prevention (Table 5.2 Column 6), in which manufacturing techniques[77] are chosen so as to generate less polluted water in the first place. Now, for industrial firms in the research area, pollution control has a high degree of compliance, but no firm reports that such innovations offset compliance costs, except for the firms that use reclaimed water. Building extra wastewater treatment facilities is viewed by all firms as an additional operating cost.

As a late industrialized country, Chinese industries have gone through an extensive development period during which wastewater was emitted to the environment without treatment, causing serious pollution to both surface and groundwater body. It was not until 1984, that China started to regulate industrial emission and hold pollutant discharging units accountable for water pollution, by issuing the 'Technological principle and methods for enactment of local water pollutant emission standard (GB 3839-83)'. In 1985, China issued the first regulation on industrial waste for specific industry, the 'Emission standards for pollutants from shipbuilding industry (GB 4286-84)' setting the maximum permissible discharge of pollutants from shipbuilding industry. From then on, new wastewater emission standards have been formulated targeting different industries, especially pollution intensive industries, such as 'dyeing and finishing of textile industry', 'iron and steel industry', 'pulp and paper industry', 'pharmaceutical industry' etc. In 2017, the former Ministry of Environmental Protection also issued the 'Self-monitoring technology guidelines for pollution sources', supervising enterprises' water pollution governance. Now, for water pollution-heavy industries, their wastewater discharge is regulated by national, local and industrial standards, and enterprises should obey by the strictest standard when there is inconsistency among standards at different levels.

Firm-30 in Hebei, a pulp and paper manufacturing firm, like many other manufacturing firms in the study region used to emit its effluent into a nearby river. However, with the tightening of environmental regulations, in 2005, Firm-30 invested over 70 million yuan (USD 10 million) to build a new sewage treatment plant with a daily treatment capacity of 40,000 tons and advanced waste treatment technologies were adopted. Now the wastewater that comes out of Firm-30's own treatment facility is of good quality and could be emitted to a natural water body. To demonstrate the high quality of their wastewater, the firm keeps fish and ducks in the wastewater pool. Like Firm-30, industries in China started adopting wastewater treatment late, under policy pressure, but have developed high sewage treatment levels.

[77] This is also a benefit from upgrading the main production process (Table 5.2 Column 7 and 8), which not only reduces water consumption but also produces less waste. For example, the case of Firm-17 introduced in the previous subsection.

Now pollution control in Beijing and Hebei industries is mainly driven by state regulations (also refer to Table 4.2 Comments from interview correspondents on water policy distinction). Firms reported that they have delegated staff to interpret new environmental policies to reduce the risk of regulation violations.

> We manage water according to governments' regulations. We also have our own standards. They are stricter than the state's standards. For example, in wastewater treatment, our COD concentration is lower, just to reduce the risk of emission violation. Since there are still errors in manual monitoring. Whenever the government issued new regulations, we will check our current standard: if it meets new regulation, business as usual, if not, we will notify the corresponding department to make adaptation to meet with new rules.
>
> – EHS manager, Firm-04, Beijing.

In addition to Firm-04, firms including Firms 01, 02, 07, 09, 14, 23, 24, 25, 26, 27, 28, 29 and 30 also reported resources devoted into reducing emission violation risk with advanced waste treatment facilities and higher waste treatment standards[78].

In summary, technological innovations to promote industrial water conservation and pollution control specifically target compliance with environmental regulations or occur in the main production process. Innovations for conservation are costly because of fixed infrastructure, with no mandatory targets often rendering conservation a side-benefit of other changes. But some large corporations do regularly innovate, and others adopt the reclaimed water reuse system, the driving factors of which will be further explored in the next chapter. Results on firm technological innovations in different categories showed that differences of water policy (mandatory targets or not) led to different responses from firms.

Institutional innovation

There are also institutional innovations in firms' water conservation, including the adoption of standardized environmental management system (EMS), like the ISO system, accurate metering and statistics, establishing accountability, reward system, commitment to employee training and CSR initiatives (Table 5.4). However, the frequency of institutional innovations is less than that of technological innovation, indicating the tecno-centric features of industrial water management to a certain extent with so many technical innovations caused by production technology decisions

[78] As waste treatment is an externality for manufacturing firms, firms originally do not have treatment standards, they have to comply with government standards (explained in Footnote 75) imposed by mandatory pollution control regulations. For firms that have internalized this environmental externality, they set up their own stricter wastewater treatment standards to reduce emission violation risk. This issue will be further explored in Chapter 6 in discussing what kinds of firms tend to internalize the environmental externalities, and consequently setting their own standards on this matter.

and by pollution control mandates. This subsection gives details of institutional innovations in representative cases.

Table 5.4 Institutional innovation in sample firms

Firm	Standardized EMS	Metering and Statistics	Establishing Accountability	Reward System	Employee Training	CSR Initiatives
1	√	√			√	
2	√	√	√		√	√
4	√	√	√		√	√
6	√					
7	√	√			√	√
9	√	√				
10			√		√	
13						
14	√	√	√	√		√
20	√					
22	√	√	√	√		
23	√	√	√	√	√	√
24	√	√	√	√	√	
25	√	√				
26	√	√				
27	√	√				
28	√	√	√		√	√
29	√	√				√

Note: Sample firms without institutional innovation are not listed.

Tangible institutional innovations include adopting a standardized environmental management system, accurate metering and statistics, and establishing accountability and reward systems. These internalize environmental externalities by adding accountability and incentives to water management.

Standardized EMS is a protocol in listed environment-sensitive enterprises that institutionalize environmental practices and incorporate international standards. For example, as Firm-04 recounted, "we adopted the ISO environmental management system. They send inspectors here last year, one of the suggestions from them is to change the landscape plants in our factory into drought-tolerant species to use less water, we have not thought about this before." (pers. comm. in Firm-04, 12 August 2017). Firms that established EMS are shown in Table 5.4 Column 1. Among them, firms include Firm-02, 07, 09, 14, 22, 23, 24, 29 also established extra energy management systems with water as an integral part. Firms that have specific water management system include Firm-07, 14, 24. These are commonly large or medium listed enterprises who have established formal management institutions.

Good managerial practices start from accurate metering and statistics of water consumption.

> Accurate metering is the start of better management. You have to know where the problem originated from.
>
> – EHS manager, Firm-29, Hebei

Table 5.5 is an example of statistics on water consumption in a pharmaceutical company in Beijing. Water for different purposes in different workshops is monitored. Such metering and statistics help firms visualize their water consumption situation and discover potential sites for conservation, which is beneficial for both water resources conservation and pollution control.

Table 5.5 Statistics on water consumption in Firm-09

Water consumption details in 2016													
Water consumption unit		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Power workshop	Purified water	2815	1412	2460	1822	2272	1992	2908	931	2302	2306	2911	2195
	Sewage shed	28	17	50	26	148	498	221	20	22	25	553	240
	Pressure pump water	405	80	650	402	874	2103	280	293	219	153	186	0
	Vacuum pump water	188	19	164	158	158	245	832	64	127	61	250	7
	Boiler	1087	418	1012	644	929	760	801	177	683	805	1446	1331
	Desulfuration												
	Subtotal	4523	1946	4336	3052	4381	5598	5042	1485	3353	3350	5346	3773
Administration office	Bathroom	282	88	203	154	216	153	193	28	138	173	214	221
	Service centre	1329	834	307	219	504	1219	486	406	611	106	73	156
	Laundry	29	10	45	39	40	35	28	5	35	27	39	33
	Canteen	102	38	110	182	106	942	199	192	134	120	131	138
	Office building	93	468	296	378	296	393	368	189	112	110	110	454
	Subtotal	1835	1438	961	972	1162	2742	1274	820	1030	536	567	1002
QI section	Quality inspection	34	13	39	39	60	90	63	417	5	51	66	76
	Microbial laboratory	2	0	15	16	11	20	4	0	5	6	10	13
	Subtotal	36	13	54	55	71	110	67	417	10	57	76	89
Extraction workshop		760	13	1141	507	1124	943	1297	54	668	800	545	2494
Oral liquid workshop		13	8	17	15	15	13	18	9		33	17	31
Packing workshop		60	16	55	22	43	37	69	110	44	50	66	68
Injection purified water		0	0	0	1430	2473	687	718	632	3026	2400	2911	2195
Injection water					1	2	0	1	1	2	1	2	1
Injection vacuum					6	10	0	0	0	1	4	1	0
Injection AC					7	8	3	4	5	6	3	5	4
New injection workshop		350	416	142				0			2544	3032	2347
New injection recycled water		0	0	0	227	420	1014	718	0	203	136	113	147
Total		7579	3850	6721	6269	9700	11164	9207	3527	8339	9912	12673	12146
Company water		9627	4374	7914		11717	8889	11548	4553	10023	10054	11549	10995
Expense		78460.05	35648.1	64499.1		105453	80001	103932	40977	90207	90486	103941	98955
Metering rate (%)													
Error		2048	524	1193		2017	-2275	2341	1026	1684	142	-1124	-1151
Annual output value (10 thousand yuan)													
Water recycling (ton)		194400	0	194400	131160	243600	215600	245520	36000	352800			

Source: Internal document from Firm-09, translated by the author

Water balance testing[79] is encouraged by the state. Firm-24 in Hebei, a chemical company did a water balance test in 2016. Figure 5.1 demonstrates the overall water balance of Firm-24. After the test, several adaptations were identified, including the use of desalinated water in certain processes, cooling water recycling, employee training in water conservation and metering devices innovation, as well as maintenance of water network and equipment to prevent incidental water leaking[80].

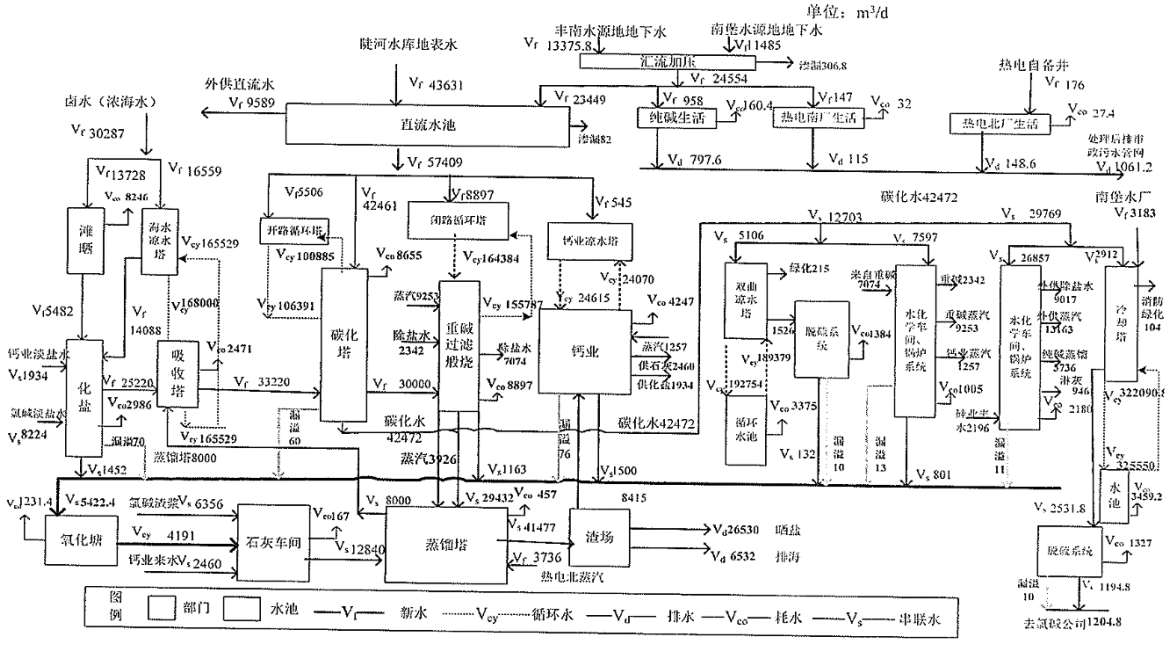


Figure 5.1 Water balance in Firm-24

Legend: □department/water tank; —water flow

Source: Internal document from Firm-24

Based on accurate metering, some firms go further to establish accountability. Several of the interviewed firms, mostly large scale SOEs and COEs (collectively owned enterprises) or FIEs (foreign-invested enterprises) hold individuals accountable for water conservation as water consumption along with other resources consumption data is monitored at different levels.

[79] According to 'The general principles of water balance test in enterprises (GB/T 12452-2008)' water balance testing is an effective method for scientific management of water use units and the basis for further water conservation. In water balance tests, enterprises are expected to explore the water network status and water use by each unit, generate a water balance map, figure out water balance and reasonable consumption quotas based on water data from this test and come up with corresponding measures to increase water use efficiency. The overall goal of water balance testing is to strengthen water management and raise the level of rational use of water.

[80] The issue of incidental water leaking involves more than water conservation. One of the protocols in clean production in China is to prevent '跑冒滴漏 (leakage and venting)', which is not confined to water, but also other raw materials to cut production cost and prevent production incidents.

> Just in recent years, we have a big change in managing energy and water resources, we adopted a well-formulated system. Data are reported daily with a specific person responsible for each section. Now we are planning to build up our own big data analysis system. Our advantage in doing this is that we started reforming our management system early [previous institutional adaptation schemes were implemented]. The decision is made by party committee (this is a SOE), because this [management system reform] costs a lot of money.
>
> – EHS manager, Firm-02, Beijing.

However, such a monitoring system is a part of the energy management system, primarily targeting electricity or gas conservation, which concern firms more than water[81]. In addition, as recounted by Firm-02 in the previous comment, their new institutional change [the big data system] will be facilitated by the previous adaptations [energy and water management system], indicating that institutional innovation is also a path-dependent process on firms' previous institutions and attention from management [decision made by party committee]. Some firms even designed reward systems to incentivize the accountable individuals or units.

> Water consumption quota is allocated to each workshop and linked up with our performance pay, it influences our salary (laughs).
>
> – Chemical engineering manager, Firm-22, Hebei.

With the adoption of standardized environmental management systems, accurate metering and statistics, established accountability and reward systems, firms set up formal institution for water management. However, these systems do not specifically target water conservation, with most driven by energy conservation and pollution control[82]. Such institutional innovations increased water use efficiency and played a role in water pollution control, which is made tangible with the metering and statistics.

Less tangible are the institutionalization of environmental norms and values by individuals and organizations. These include employee training and CSR initiatives. Some firms hold regular environmental education events for staff. These are more common in SOEs where the CCP plays a major part in management and organizes teambuilding activities to promote state policies.

> This month [June 2017] is our Safety Production Month, we held a series of activities including resource conservation education.

[81] For evidence, also refer to Table 4.5 Comments/statistics from sample firms on water pricing.
[82] This finding is not confined to water pollution control, but also applies to other environmental elements, for example, air pollutant control in Firm-29.

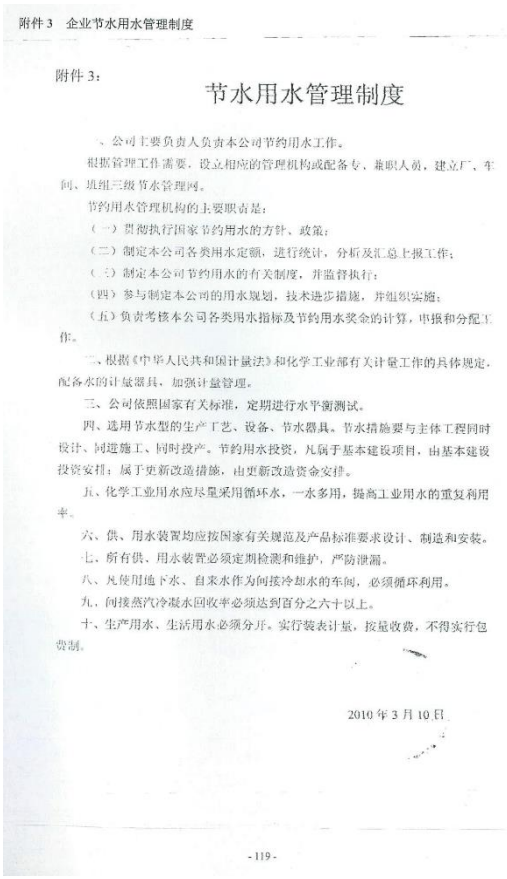
– EHS manager, Firm-02, Beijing.

Such institutional innovation is easier to initiate than technological innovation, but the effect is uncertain, since "it is easier to change management style but takes long to change people's perceptions" (pers. comm., Firm-02, 06 August 2017). Moreover, in SOEs, such training programs are often viewed by employees as political tasks, which damages their uptake and the corresponding internalization of environmental norms and values.

In addition to the commitment to employee training, in some reputation-sensitive firms, water management is also part of CSR initiatives (e.g. in Firm-02, 04, 28, 29). Still such institutional innovations were only briefly mentioned by firm managers during the field interview, while large emphases were put on technological innovations in water management.

Water management institutions: Case of Firm-24

Here, I present the case of water management institution in Firm-24 (Figure 5.2) specifically targeting water conservation. Innovations, including water recycle and reuse, adoption of water saving equipment, production process upgrading, metering and statistics, and establishing accountability and reward systems, are institutionalized in Firm-24. It first identified the principal person accountable for water-saving in the firm and the major responsibilities for water-saving management. The first task was to implement relevant government regulations. The other provisions in this institution were also in response to the government standards or guidance on water metering, water balance testing (GB/T 12452-2008), cataloguing of industrial water saving process, technology and equipment, water recycling and reuse policy in the Chinese chemical industry. As introduced before, in addition to standardized EMS certified by the International Standards Organization and specific energy (including water) management system, Firm-24 also has this water conservation management system, indicating the importance of water management in Firm-24. With this case, I illustrate what water specific institutions are like in industrial enterprises in this study.



附件 3 企业节水用水管理制度

附件 3：

节水用水管理制度

一、公司主要负责人负责本公司节约用水工作。

根据管理工作需要，设立相应的管理机构或配备专、兼职人员，建立厂、车间、班组三级节水管理网。

节约用水管理机构的主要职责是：

（一）贯彻执行国家节约用水的方针、政策；

（二）制定本公司各类用水定额，进行统计、分析及汇总上报工作；

（三）制定本公司节约用水的有关制度，并监督执行；

（四）参与制定本公司的用水规划，技术进步措施，并组织实施；

（五）负责考核本公司各类用水指标及节约用水奖金的计算，申报和分配工作。

二、根据《中华人民共和国计量法》和化学工业部有关计量工作的具体规定，配备水的计量器具，加强计量管理。

三、公司依照国家有关标准，定期进行水平衡测试。

四、选用节水型的生产工艺、设备、节水器具。节水措施要与主体工程同时设计、同进施工、同时投产。节约用水投资，凡属于基本建设项目，由基本建设投资安排；属于更新改造措施，由更新改造资金安排。

五、化学工业用水应尽量采用循环水，一水多用，提高工业用水的重复利用率。

六、供、用水装置均应按国家有关规范及产品标准要求设计、制造和安装。

七、所有供、用水装置必须定期检测和维护，严防泄漏。

八、凡使用地下水、自来水作为间接冷却水的车间，必须循环利用。

九、间接蒸汽冷凝水回收率必须达到百分之六十以上。

十、生产用水、生活用水必须分开。实行装表计量，按量收费，不得实行包费制。

2010 年 3 月 10 日

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1.The main person in charge of the company is responsible for the company's water conservation.
According to management needs, set up corresponding management agency or configure full-time/part-time personnel to establish a three-level (facility, workshop, class) water-saving management network.
Main responsibilities of water conservation management agency include, 1) Implement state policies in water conservation. 2) establish water quota for different usages in the company, monitor consumption, analyze data and report statistics. 3) establish water saving institution in this company and supervise the implementation. 4) Participate in the water consumption and technological innovation plans of this company, oversee the implementation. 5) Evaluated water conservation performance and grant bonus, report and delegate conservation targets.
2.Manage water metering according to 'Metrology Law of the People's Republic of China' and other state regulations on metering.
3.Run regular water balance test in accordance with relevant state regulations.
4.Use water-saving production technology, equipment, water-saving appliances. Water-saving measures must be designed, constructed, and put into operation simultaneously with the main project. Investment in water conservation comes from capital construction fund or renovation fund according to the nature of the project.
5.Chemical industry should recycle water as much as possible. Encourage reuse.
6.Water supply and water usage equipment shall be designed, manufactured and installed in accordance with relevant national standards and product standards.
7.All the water supply and usage equipment must be regularly inspected and maintained. Strictly prevent leakage.
8.Workshops that use groundwater or tap water as indirect cooling water must recycle the water.
9.Recovery rate for indirect steam condensate water must be more than 60%.
10.Domestic water and production water must be separated. Metering must be carried out, and the fee shall be charged according to the usage.

Figure 5.2 Water-saving management institution in Firm-24
Source: Internal document from Firm-24, translated by the author

Discussion of innovations in water management

In summary, innovation demonstrates reactive and proactive environmental management resulting from policy compliance and voluntary endogenous technical change. Common practices include risk reduction, water reuse, water conservation, less water-intensive product, commitment to research and employee training on environmental preservation. Such innovations can add to firms' competitive advantage with competitively valuable organizational capabilities. In general, firms reported that adaptation costs for water conservation could be offset by technological innovation[83], which is consistent with the ecological modernization theory:

> Technical reform targeting water conservation we have done – including changes in pumps, circulating water and steam water. The costs of such adaptations are usually recovered one or two years afterwards. We have the technique of four-rounds of water

[83] Still such innovations are part of the main production process upgrade and initiated not only to conserve water, which does not contradict my previous claim that the price of water is not high enough to induce conservation innovations. To reiterate, water conservation regulations including water pricing are not enough to trigger firm innovation.

cleaning. The water reuse can save our cost. Every year, we will organize all kinds of technical reform projects, water conservation is only a small part.

– Manager, Firm-26, Hebei.

In pollution control, however, wastewater treatment imposed by pollution regulations is economically unprofitable, except for reclaimed water reuse. This finding provides an intriguing contradiction to the ecological modernization theory ethos: innovation stimulated by environmental regulation does not always guarantee economic profitability. The corollary of this finding is that purely profit-driven decisions do not always guarantee good environmental behaviour. Still, there is a higher degree of compliance in pollution control than in resource conservation in the case study firms, indicating that water management is driven by high-power regulations in the study region. The hard pollution control regulations in Beijing and Hebei are driving environmental upgrading here.

The results also show that both technological and institutional innovation are highly path dependent processes, for firms' previous techniques and infrastructure as well as management institutions, staff uptake of environmental norms and values all play crucial roles in firms' decision making for water adaptation and their subsequent performance.

Results indicate that firms' own characteristics play a major part in innovation decisions. Large scale firms, often SOEs/COEs, or FIEs, perform better in policy compliance and innovation than smaller firms. As such firms are listed on the stock market and are reputation-sensitive, their environmental performance is related to their financing; therefore, they are eager to reduce environmental regulatory risks. Detailed illustrations on how firm characteristics drive styles of water management are presented in the next chapter.

5.3 Avoidance

Firms that do not initiate environmental upgrading circumvent the issue. They resist environmental regulations to different degrees, depending on the form of avoidance. In general, firms avoided physical or regulatory water risk through relocation, outsourcing or factory closure (Table 5.1). However, as the sample firms are mainly existing firms, I have few examples of this particular type of behaviour; this does not mean, however, that this type of behaviour is not common in this region[84]. In the 30 sample firms, Firm-05 is incapable of environmental upgrading and was forced to close by the local government. Firm-08 outsourced its water intensive manufacturing to other localities. Firms 12, 21 and 23 relocated.

[84] In recent years, with the policy-guided manufacturing relocation and environmental protection campaigns in the Beijing-Tianjin-Hebei region, relocation and factory closure are common in both Beijing and Hebei (Duan, 2018; Xinhuanet, 2018).

Relocation

Firm relocations are propelled by various reasons. I specifically consider the implications of water resource constraints and environmental regulations for firm relocation. Such relocation followed a common path, with firms in Beijing relocating to Hebei, where there are relatively abundant water resources and less strict water regulations as well as weaker enforcement. This path is facilitated by the 'relocation of general manufacturing from Beijing to surrounding areas' strategy in the study region.

Does this render Hebei the pollution haven[85] of Beijing? Previous studies show that on a regional scale Hebei is not only a pollution haven but also a resources haven[86] (S. Zhang, 2018), which hurts firms' incentive for pollution control and constrained resource use. While most research neglects the impact of such relocation schemes at the firm level, Zhou and Wang (2017) studied the impact of firm relocation from Beijing to Hebei and found that institutional innovation in the relocation played a mediating role in reaching both environmental and economic targets in Beijing and Hebei. Moreover, I also find that relocation may have stimulated technological innovation that leads to better environmental and economic performance in individual enterprises. Firm-23 is an SOE, that relocated from Beijing to Hebei, following Beijing's industrial relocation scheme. As Firm-23 is both resource and pollution intensive, a large water user, the water supply in Beijing does not meet its needs. The local conventional water sources (water from self-supply well or municipal tap water) in Hebei are not enough either. Therefore, when Firm-23 relocated, it built new facilities to use unconventional water sources. Now, more than 60% of the water it uses comes from seawater desalination, thanks to the new water treatment technology that was adopted after the relocation.

> During the production process, water is recycled and reused. Recycling and reuse are designed when we built this plant. Now there are new techniques, but it is less likely that we would adopt them, unless we construct new projects. There is large space for water conservation in domestic and landscape water. While for conservation in production, the adoption cost is too high. And now production is stable, water use efficiency is improving.
>
> – Energy & Environment manager, Firm-23, Hebei.

This comes to the issue of innovation and path dependence again. Firms are generally inclined to adopt new technology in new establishments rather than by renovating old facilities. On top of

[85] According to Pollution Haven Hypothesis (Copeland & Taylor, 2004), polluting industries will relocate to jurisdictions with less stringent environmental regulations. Countries with slack environmental regulations are likely to become production platforms and pollution havens for pollution-intensive industries (Copeland & Taylor, 2004; Walter, 1982).

[86] Following the idea of pollution haven, what 'resources haven' means here is that Hebei is absorbing the resource demand from Beijing through industrial relocation.

that, local governments in Hebei also raise requirements when they grant licenses to new establishments: the standards for new plants in terms of water management are higher than those for renovating old facilities, which stimulates technological innovation during firm relocation.

> If you want to establish a new plant, your water use efficiency should reach a standard that is normally higher than an existing firm. Other than that, Firm-23 is consuming too much, we won't offer them that large an amount of fresh water. But the physical condition here is suitable for this alternative water source [seawater desalination].
>
> – Official, Industrial Zone Management Committee, Hebei.

Overall, relocation within the study region exerted extra pressure on regional water consumption in Hebei and introduced new pollution sources. However, at the firm level, relocation breaks the lock-in of technology and creates a new path, which leads to innovation in water use. Therefore, relocation of manufacturing plants in the study region, though coerced by the state most of the time[87], provides opportunities for new path creation. In addition, another externality brought by relocation is the environmental and industrial policy shift. One of the features of Chinese industrial policy is the distinction between existing facilities and newly built facilities. In general, the environmental requirements for new facilities are stricter than that for existing facilities in recognition of the path dependence in adaptation of existing firms. For example, for a steel manufacturing firm like Firm-23, according to the 'Norm of water intake - Part 2: Iron and steel complex (GB/T 18916.2-2012)', in existing plants, water withdrawal should not exceed 4.9 cubic meter per tons of steel, while in newly built plants the norm is 4.5m^3/t. This means that after the relocation, as Firm-23 became a newly built factory, the standard for water conservation is higher, creating more regulatory pressure on Firm-23. This is also true for other sectors. As the government is pursuing industrial and environmental upgrading, it has stricter requirements for new manufacturing facilities. Therefore, relocation changes the regulation standards for firms, forcing firms into innovation. But on large scale, Beijing is still redistributing resource demand and pollution to neighbouring cities in Hebei.

Outsourcing

For enterprises in a global production network (GPN) or a global value chain (GVC), outsourcing is another behaviour to alleviate resource constraints and reduce water-related regulatory risks. China used to be the destination of global outsourcing, which introduced new pollution sources but also better collaborations on corporate environmental management through business supply chain partnerships.

[87] Though there are no sample firms that voluntarily moved to Hebei in this study, this does not mean that on a large scale there is no voluntary firm relocation from Beijing to Hebei. After all, firm's location choice is subject to complex reasons that this study does not aim to cover.

Firm-08 in Beijing used to be the destination of global outsourcing in the 1980s. Now its Beijing factory is under pressure from customers, who have specific water quality requirements, giving the firm an incentive to better manage its water; this is consistent with the ecological modernization theory's argument about the benefits of international integration. However, with increased labour and raw material costs, Beijing is no longer suitable for such manufacturing.

> We take a maximum order of 20 million units a year. This facility only does 1 million, 2 million at most. The rest, we do in Cambodia. There we won't be constrained by water. Now we use 400 thousand cubic meters of water a year. The local Water Authority won't grant us more. But the main reason for going to Cambodia is the cheap labour.
>
> – Manager, Logistics Department, Firm-08, Beijing.

So now the firm is outsourcing its production again to the next pollution haven. China used to be the low-cost supplier in the global production network; now with increased labour costs and stricter environmental regulations, Chinese manufacturing is also 'going out'. This is another global manufacturing shift, the implications of which for resource and environment are yet to be discovered. More research can be done on this.

Firm relocation and outsourcing shift resource demands, with varied implications for resource conservation and pollution control. Going out does not necessarily mean going down. On the one hand, for some firms, going/outsourcing to pollution havens reduces the incentive for environmental behaviour as suggested by Pollution Haven Hypothesis; on the other hand, relocation brings new investment, which stimulates innovation with reduced adaptation cost for new water technology. In these cases, relocation creates a new path to make firms less dependent on previous technology and infrastructure. Furthermore, relocation within the study region is guided by specific industrial policies, sometimes with specific technological instructions (Box 5.4). These policy constraints co-shaped innovation by relocated firms.

Box 5.4 Relocation of Firm-23

In the case of Firm-23, after relocation, as a newly built plant, not only does it have to obey new water intake norm as introduced before. The production technology and equipment in the new plant must also conform to the 'Catalogue of the Industrial Water Saving Process, Technology and Equipment Encouraged by the State' and the 'Evaluating Guide for Water Saving Enterprises'. In the case of Firm-23's relocation, new water technological innovations include, 'seawater desalination' and 'water quality classification, cascade use technology'(to classify industrial water, desalination, soft water, drainage in each circulation system, reclaimed water, sewage according to the corresponding water quality, use water in a cascading style according to the quality requirements in each production process, in this way to minimize total sewage).

Factory closure

Over the years, the study region witnessed numerous plants being shut down during environmental campaigns and industrial upgrading. Though devastating for individual firms, this

does raise regional environmental standards. After all, many small firms lack adaptation capability: a firm's innovation to meet environmental regulation is constrained by its capability.

> For a small enterprise, the revenue of the whole year won't even cover the environmental protection cost. So, now that environmental inspections are tight, many small businesses have closed their doors. They are forced to close; they won't make money.
>
> – Practitioner, water service sector, Beijing.

And prior to closure, firms might make the final struggle by defying the rules. They will take advantage of the institutional deficit, make the last bucket of gold and wait for the government to shut them down.

Firm-05 is a forced-to-close firm that was not capable of environmental upgrading. Established in 2007, Firm-05 was engaged in equipment manufacturing. The wastewater that Firm-05 produced was high in COD concentration (above emission standards) with no treatment facility or equipment. The general manager recounted that they consulted an environmental service company in 2014 when the local government start to strengthen environmental enforcement in local enterprises. However, the upgrading would cost more than their annual revenue. Therefore, they did not initiate the upgrading. During 2014-2015, whenever there was environmental inspection by local EPB, they closed the factory door and pretended there was no manufacturing. In 2016, with central environmental inspection team arriving at their locality, inspections were stricter than ever, and the local government shut down the factory's electricity supply and closed the factory for good. This is the only such case in this study.

In recent years, both Beijing and Hebei are enforcing strict rules to shut down dispersed, disrupted/violative and polluted (SanLuanWu 散乱污) enterprises (Zhi, Qiao, Li, Meng, & Zhao, 2019). It is one of the strategies adopted by the Ministry of Environmental Protection to enforce its environmental regulations. SanLuanWu (SLW) enterprises are under the radar of central and local EPB inspections. When such enterprises were spotted, they are required by local EPB to initiate environmental upgrading. If enterprises lack upgrading capability and therefore fail to comply with stringent regulations, administrative measures are taken to close such enterprises. In 2016 alone, Hebei regulated or shut down 53000 SLW enterprises (Hebei Province Environmental Protection Hall, 2017); Beijing regulated 4477 SLW enterprises in the same year (Peoples Network, 2017). Such mandatory environmental upgrading is also a sign of industrial upgrading to phase out backward production capacities but requires institutional capacity to implement such command and control policy.

In sum, currently in the study region, when firms fail to innovate to comply with environmental regulations, they are forced to relocate or be closed. For firms in a GPN, there is another

alternative to avoid regulatory compliance – outsourcing resource and pollution intensive manufacturing to other countries. China used to be a pollution haven for early industrialized countries, but the global manufacturing landscape will be changed as China moves up the global value chain. Such a change of economic activity will lead to changes in resource consumption and the pollution landscape as well (H. Wu, Guo, Zhang, & Bu, 2017). Further large-scale studies are needed to explore its global environmental implication.

5.4 Rule breaking

Among the resisting behaviours observed in Beijing and Hebei, there are also firms that defied the rules. Rule-breaking mainly comes in two forms: opportunists that take advantage of deficiencies in regulation enforcement; and firms that have bargaining powers with local governments over environmental matters. Though there are not many firms that are directly engaged in this type of behaviour in my sample (Table 5.1), this does not mean that it is uncommon in the study region. One of the major environmental campaigns in China targets the regulation of these rule breaking firms' (SLW enterprises)[88] governance. In regulating SLW enterprises in Beijing, 6194 enterprises were regulated in 2017; 4833 of them were involved in emission violation. Now, Beijing has ambitious goals to shut down or relocate 1000 manufacturing enterprises in 2020 and extinguish SLW enterprises by then (Xinhuanet, 2018). In Hebei, in 2017 more than 108000 SLW enterprises were investigated: 68747 were closed, 899 were relocated, and 38785 rule breaking firms were forced to adopt technologies to comply with local environmental regulations (Duan, 2018).

However, such schemes rely heavily on the command-and-control tool and local enforcement capability in regulating enterprises. Where there are weak institutional capabilities or corruption, opportunists or collusions emerge. In my field research, three firms were found to have engaged in rule breaking, either as opportunist (Firm-05) or through collusion (Firms 03, 15) nature. Firm-05 was introduced in the previous section: it was forced to closed when its rule breaking behaviour was spotted by local EPB. By contrast, rule-breaking in Firms 03 and 15 were assisted by government-enterprise collusion.

[88] This policy campaign started as part of air pollution control in the Beijing-Tianjin-Hebei region as one of the enforcement schemes of the Action Plan for Air Pollution Prevention and Control (2013) (Peng, Yu, Ma, & Yang, 2018). It was later spread across the country and broadened beyond air pollution control to other environmental elements including water (Z. Chen & Le, 2018).
According to the official definition, SLW enterprises refer to those enterprises that do not conform to national industrial policies, do not conform to local industrial layout plans, have not gone through the examination and approval procedures of industry, information technology, development and reform, land, planning, environmental protection, industry and commerce, quality supervision, safety supervision, power and so on, and cannot meet the emission standards.

Opportunist

Rule breaking occurs when opportunists are facilitated by institutional deficit. Due to the lack of labour power in environmental or water authorities, the enforcement of regulation and monitoring of firms are inadequate, resulting in a 'grasp the large, let go of the small' (Hsieh & Song, 2015) strategy, leaving a bunch of miscreant enterprises.

> When it comes to environmental protection in small and medium scale enterprises, they are fooling the government. They just want to spend less money. They come to us, we design a process and equipment and report the budget. [But they just] ask about the price, [and] even give up environmental upgrading.
>
> – Manager, environmental service company, Beijing.

Such evasion is especially severe in rural areas, which lack monitoring capacity. "Local enterprises are not secretly discharging the untreated wastewater, they are doing that openly, don't even bother to cover their track" (Practitioner, water service sector, Hebei, 14 August 2017). This represents a failure of regulation: enterprises are not properly supervised when enforcement resources in the local EPB are limited. Among such reputation-insensitive firms, what constrains their behaviour is not policy itself, but how the local government implements it. If there is chance that they will not be spotted, they will seize it. This reveals one shortcoming of the still predominant command-and-control environmental policies in China, when there is not enough control.

With limited labour force, governments primarily regulate large and medium scale enterprises, leaving small enterprises more space for violation. In the regulation of large enterprises, there are also regional disparities within the study area. In Beijing, where central policies are well implemented, major water consumers and wastewater emitters are tightly regulated (commented by Firms 01, 02, 04, 07, 09, 14, 16)[89]; local EPBs pay regular and random visits to inspect compliance with environmental regulations. In some regions of Hebei, large enterprises are protected against environmental compliance (refer to the case of Firm-15 in the following 'Collusion' subsection): supervision is a formality.

Collusion

Rule breaking also results from government-enterprise collusion, in which governments turn a blind eye to misbehaving firms. Not only small firms, but also large firms are involved. Firm-15 in Hebei is perceived as the local pillar industry, according to a field worker:

[89] In addition, other academic research (C. Wong & Karplus, 2017), news coverage (Xinhuanet, 2018) and government reports (J. Zhang, 2018), as well as government environmental investment (P. Zhang, Zhu, & Zhu, 2012) show the stringency of environmental enforcement in Beijing.

> We have all the environmental protection equipment required by the government; I just seldom see it operating.
>
> – Field worker, Firm-15, Hebei.

The city government tolerates the polluting behaviour of Firm-15 as a form of local protectionism, because the firm contributes a lot of local tax revenue. When the local EPB initiates a spot check, Firm-15 is tipped off. The firm then operates the required environmental protection equipment or ceases production (pers. comm. in Firm-15, 17 September 2017).

In addition to collusion over waste emission, some firms also have bargaining power over water supply. Like Firm-15, Firm-24 is also the pillar enterprise in its locality. It is in a special economic zone, using 70% of the total industrial water in this zone. Every year, Firm-24 negotiates with the local Water Authority about the amount of water it can acquire. Firm-24 receives a discount on its water price from the government: while other large enterprises pay 3.97 yuan per cubic meter of water, Firm-24 pays 3.76 yuan. Of course, this does not violate any rule, though it does show the bargaining power of large enterprises. In other cases, such negotiation is not entirely legal. The general manager of Firm-03 in Beijing privately bragged to me that he/she knew someone from the local Water Authority and had been paying the domestic water price for the water withdrawn from its self-supply well (in Beijing, domestic water costs less than industrial water). The origin of collusion lies in a social structure that is based on network. You must know someone to do business, and if you do, then everything is negotiable, including environmental regulations. But recent institutional reforms make it risky for government officials to collude with enterprises when those officials[90] are held accountable for water pollution in their administration.

During field work in Beijing and Hebei, I also spotted government-enterprise collusion over punishment when enterprises are sanctioned for rule breaking. According to an official from a local EPB in Beijing, when violating enterprises are fined, EPB officials have discretion over the amount of fine and tend to favour enterprises that are protected by the local government or have a personal relationship with the EPB official.

In addition to collusion in supervision of polluting industry, there is also collusion between government and environmental service companies[91]. Stringent environmental regulations

[90] Local officials are now appointed as River/Lake Chiefs, whose performance is added into their overall official assessment ("Water pollution prevention and control law of the People's Republic of China (2017 revision) [effective]," 2017).

[91] Environmental service companies are companies that provide environmental protection or resource provision or conservation services. Their customers can be enterprises or governments. In this research, there are seven water service companies interviewed, including three water supply companies that work for the municipal government to provide domestic and industrial water for their locality; two wastewater treatment companies that work for the municipal governments as well as local enterprises to collect and

represent an opportunity for service companies. An investor from the water service sector in Beijing told me at an Industry Conference in Beijing:

> What is policy, it is a government subsidy, it is money.
>
> – Investor, water service sector, Beijing.

Cynical his/her claim may sound, this can be true[92]. He/she also told me the reason why he/she attended this conference was to network with government representatives to gain favour in government bidding. If they do win the bid, they will have to reward the official with a substantial amount of their profit from the very project they get from the government.

In summary, defiance of water regulations, especially of pollution control regulations, is not uncommon in the study area. This can be attributed to, on the one hand, poorly designed policy caused by non-participatory policy making and central-local politics; on the other hand, enforcement gaps derived from institutional deficits as well as governance-enterprise collusion/local protectionism. In respect of policy, China used to be accused of lacking strict environmental regulations; my evidence shows that in the ecological modernization of China, current standards are simply too high for some small enterprises to comply, and due to restricted enforcement power, small firms can ignore the rules and wait until the government spots them and closes them. Until then, they just keep making profits. This exposes a defect of non-participatory policy making in China. Fragmented central-local relations also add to the making of impractical environmental policies (Habich-Sobiegalla, 2018; Kostka & Nahm, 2017)[93]. In respect of enforcement, the lack of labour in environmental or water authorities leaves inadequate monitoring and enforcement of regulations, leaving a large number of small enterprises effectively unregulated. Large enterprises are more involved in government-enterprise collusion, as they have more bargaining power over a wide range of issues including environmental compliance. To prevent rule breaking, the state could adopt diversified enforcement instruments, rather than heavily rely on policy instruments that require strict monitoring.

5.5 Conclusion

In answering research question 2 'What do industrial firms do to manage water?', this chapter investigated firms' adaptation to resource constraints and environmental regulation under current

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treat domestic and industrial sewage; and two water service companies that work for manufacturing enterprises to develop client companies' water technologies and build/manage on-site wastewater treatment facilities in client companies.

[92] What s/he means is that in China, with policy programs, there is supporting funding allocated by central or local governments to implement the policy. For example, in water pollution control, municipal governments will allocate funding to build municipal wastewater treatment plant. Water service companies can bid to get the government funding and run the wastewater treatment plant for the government. This is just one case, there are various other projects in water management.

[93] For evidence from this study, also refer to Box 7.3.

ecological modernization process in China characterized by large-scale industrial transformation through industrial upgrading, technological advancement or developing new industries. Firm-level adaptations that feature either upgrading or downgrading are identified in this case study. Behaviours include innovation, relocation, outsourcing, factory closure and rule breaking, depending on firm-specific factors, such as ownership, size/scale, histories and sectoral characteristics, which will be analyzed in the following chapters. Innovations, both technological and institutional, help with policy compliance, and some firms even go beyond compliance towards proactive environmental behaviour through innovation. However, this process is constrained by firm capability and depends on routine practices. Relocation features involuntary relocation from Beijing to Hebei imposed by the state, which introduces higher demands for water consumption and new pollution sources to Hebei. At the firm level, such relocation (a form of creative destruction (Schumpeter, 1947)) breaks technological lock-in, as new investment stimulates innovation and improved water use performance. Outsourcing is another means to reduce water risk for enterprises in global production networks. For some firms, especially small size/scale firms, the lack of adaptation capability leads to factory closure. Resistance through rule breaking is also observed, facilitated by institutional deficit and government-enterprise collusion.

Environmental upgrading in Beijing and Hebei industries follows both top-down and bottom-up patterns, with the state playing a major role in enforcing pollution control behaviour. Even so, voluntary innovations are also observed in firms, promoting their environmental behaviour. Innovation capacities differ within the cluster. Increasingly strict environmental regulations promote innovation and make compliance costs less relevant, while the constraints of firm capacity indicate path dependence. Firm relocation and outsourcing shift resource demands, with varied implications for resource conservation and pollution control. Going out does not necessarily mean going down. On the one hand, for some firms, going/outsourcing to pollution havens reduces the incentive for environmental behaviour as suggested by Pollution Haven Hypothesis; on the other hand, relocation brings new investment, which stimulates innovation with reduced adaptation cost for new water technology. In these cases, relocation creates a new path to make firms less dependent on previous technology and infrastructure. Furthermore, relocation within the study region is guided by specific industrial policies, with sometimes specific technological instructions. These policy constraints co-shaped innovation by relocated firms.

Defiance of environmental regulations exists, due to institutional deficits and government-enterprise collusion. Institutional deficit leads to ‘grasp the large and let go of the small’ policy enforcement. A large proportion of air pollution in China derives from unauthorized and uncertificated companies that fail to meet environmental standards (E. Wong, 2017); my evidence shows that large enterprises under scrutiny are performing well, while small and sometimes illegal

plants are behaving poorly. Wang *et al.*'s (2008, p. 648) research on rural industries and water pollution in China concluded that "the control of rural water pollution is not simply a technical problem of designing a more appropriate governance system or finding better policy instruments or more funding. Solutions lie in changes in the model that underpins rural development in China". This also proves to be true in the study area. The gap in environmental regulation does not lie in the lack of strict standards: the standards are too high for many small enterprises to comply, and due to restricted enforcement power, small firms are encouraged to ignore the rules and wait for the government to spot them and die. Otherwise, they will just keep profiting without change.

In other words, the model of environmental governance needs to change in this region to promote innovation and environment-friendly behaviour. In one direction, environmental governance should depend less on top-down (command and control) instruments, which require an already-insufficient supervision force; bottom-up instruments, including economic incentives and voluntary agreements, could encourage the uptake of environmental norms and values by individuals and firms. In another direction, improved public awareness of water conservation and pollution (repeatedly mentioned by interviewees) and increased use of public reports on firm behaviour could reduce the supervision burden.

Environmental performance includes both resource consumption and pollution production (Gauthier, 2005; Q. Zhu & Sarkis, 2004). Among firms in the North China region, more attention has been paid to pollution control than to resource conservation. On the policy level alone (discussed in the previous chapter), resource conservation policies are often marked as 'recommended', while pollution control policies are mandatory and in principle enforced by central and local authorities. Such policy distinction resulted in differences in firm behaviour by locality (Chapter 7). This finding contributes to the ecological modernization theory in its application in water management by distinguishing between resource conservation and pollution control.

This chapter also contributes to the application of evolutionary concepts in enterprise-level environmental management in China. Water management in Chinese industrial firms is highly path dependent. Regular industrial users pay scant attention to water, with the water quota system as the primary institution managing water supply. Industrial consumption is routine unless firms are enlarging production and therefore need to apply for extra quota. Adaptations to regulatory risk are also dependent on previous technological and institutional conditions. In the end, environmental performance is often improved as a by-product of production technological innovation, while relocation, on the other hand, breaks the lock-in of technology and creates a new path, which leads to innovation in water use. Therefore, relocation of manufacturing plants in the study region, though coerced by the state most of the time, provides opportunities for new

path creation. More implications of this involuntary relocation will be discussed in Chapter 7 when making regional comparisons across the study area.

Chapter 6 Firm Characteristics

6.1 Introduction

While Chapter 5 introduced firm behaviours in water management, this chapter will explore the internal firm characteristics that shape those behaviours, in response to research question 3. Specifically, firm ownership, size/scale, financial status, market position, and sector are identified through the empirical evidence as influencing firms' water management behaviour. Following the behaviours identified in firm's water management in Chapter 5, I categorized sample firms into three group, namely proactive, reactive and resistive according to their compliance status to water regulations[94]. While the behavioural typology in Chapter 5 is mainly in terms of behavioural outcome, the typology in this chapter is mainly in terms of behavioural orientation/intention, or strategy. Proactive firms are those that demonstrate behaviour or adaptations that exceed what the regulations require, for example, firms that actively respond to the non-mandatory conservation policies or firms that have higher wastewater treatment standards than the government compulsory standards. Reactive firms are those that follow the basic requirements in the regulation, but do not adapt further. Resistive firms are those that fail to comply with compulsory regulations; in the sample, Firm-05 that was forced to close because of non-compliance to environmental protection regulations. In sum, there are 20 proactive, 9 reactive and 1 resistive firm. However, with limited sample and the snowball sampling method, this composition could not represent the overall compliance status in Beijing and Hebei. With this case study, I am mainly aiming at water adaptation strategies taken in Beijing and Hebei industries and the impacting factors; this chapter explores firm characteristics that promote environmental adaptations in the sample firms that may drive environmental management in firms with the same characters. To identify those characteristics inductively from the sample cases is the major goal in this chapter. Table 6.1 lists the basic characteristics of the sample firms that affect firm strategy in water management as revealed by the field interviews. For instance, reputation sensitivity is not listed as a characteristic in Firm-01. This does not necessarily mean that Firm-01 is not reputation sensitive. It is just that this specific characteristic does not affect Firm-01's water strategy.

[94] This typology is based on Warren *et al.* (1999)'s classification of corporate environmental strategies.

Table 6.1 Characteristics of sample firms

Firm	Strategy	Ownership	Scale	Listed	Others
1	Reactive	PE	Medium	Y	
2	Proactive	SOE	Large	Y	Reputation sensitive, customer integration, manager perception
3	Reactive	PE	Small		
4	Proactive	FIE	Large	Y	Reputation sensitive
5	Resistive	PE	Small		
6	Reactive	FIE	Large	Y	
7	Proactive	SOE	Large	Y	Sectoral characteristic (water intensive), reputation sensitive
8	Reactive	PE	Small		Customer integration, supply chain integration
9	Proactive	SOE	Medium	Y	
10	Proactive	PE	Small		Sectoral characteristic (special industry, water intensive)
11	Reactive	PE	Medium	Y	
12	Reactive	PE	Small		
13	Proactive	SOE	Medium		
14	Proactive	SOE	Large	Y	Sectoral characteristic (water intensive, ZLD)
15	Reactive	PE	Large	Y	
16	Proactive	SOE	Large		Sectoral characteristic (water intensive)
17	Proactive	PE	Small		Sectoral characteristic (water intensive), industrial peers
18	Proactive	PE	Small		Sectoral characteristic (water intensive), industrial peers
19	Reactive	PE	Small		
20	Reactive	SOE	Large	Y	
21	Proactive	SOE	Medium	Y	Sectoral characteristic (water intensive)
22	Proactive	SOE	Medium	Y	Sectoral characteristic (water intensive), reputation sensitive
23	Proactive	SOE	Large	Y	Sectoral characteristic (water intensive), reputation sensitive
24	Proactive	SOE	Large	Y	Sectoral characteristic (water intensive, ZLD), reputation sensitive, corporate environmental ethics,
25	Proactive	SOE	Medium	Y	Sectoral characteristic (water intensive, ZLD), industrial peers
26	Proactive	SOE	Large	Y	Sectoral characteristic (water intensive, ZLD)
27	Proactive	SOE	Large	Y	Sectoral characteristic (water intensive, ZLD)
28	Proactive	SOE	Medium	Y	Manager perception
29	Proactive	SOE	Medium	Y	Environmental sensitive, reputation sensitive
30	Proactive	SOE	Medium		Sectoral characteristic (water intensive), reputation sensitive

Note: PE stands for private enterprise. ZLD stands for Zero Liquid Discharge (In China, there is a zero liquid discharge policy in chemical sectors, the wastewater from which is complex in pollutant component and highly toxic). Criteria for firm scale: refer to Appendix B Classification of Large, Medium, Small and Miniature Enterprises. 'Water intensive' is determined by sector. In China, according to the "China Census for Water", major water intensive manufacturing sectors include Manufacture of textiles, Manufacture of paper and paper production, Processing of petroleum, coking, processing of nuclear fuel, Manufacture of chemical raw materials and chemical products, Manufacture of non-metallic mineral products, Smelting and processing of ferrous metals, Smelting and processing of non-ferrous metals.

In terms of ownership[95], there are state-owned enterprises, foreign-invested enterprise and private enterprises in the sample. The environmental externalities faced by different types of firm are analyzed in the following section. The scale of firms is determined according to the National Bureau of Statistics in China (Appendix B) by revenue and employee number; there are small, medium and large enterprises in the sample. The impact of firm scale on environmental adaptation will also be analyzed in this chapter. It is noteworthy that there are no small SOEs in the sample. This has to do with the SOE development trajectory in China: small SOEs have been sold off or closed along with the privatization of Chinese enterprises that started from 1992. Now, large and medium SOEs play important role in major industries[96] controlling the lifeblood of the Chinese economy (Weiying Zhang, 2014). In addition to ownership and scale, whether a firm is listed on stock market also determines its environmental and reputation sensitivity and will be duly analyzed in this chapter. As stated before, though there are more proactive firms in this study, this does not represent the regional status of corporate environmental behaviour. After all there is a large proportion of large-scale, listed SOEs in the study sample, that tend to produce proactive environmental behaviour.

Other characteristic factors that affect sample firms' water management identified in this research include sectoral characteristics[97], reputation/environmental sensitivity, manager perception, industrial peers and corporate environmental ethics. In addition, there are also overlaps of these characteristics; for example, SOEs or listed enterprises are found to be more reputation sensitive; firms in the chemical industry (sectoral characteristic) are more environmentally sensitive. Therefore, in the following section, while focusing on analyzing the impact of the two major firm characteristics, namely ownership and scale, this study tries to capture as many firm characteristic driving factors whether endogenous or exogenous to the two major factors.

As indicated in Chapter 2, firm characteristics affect the environmental position they take, and consequently their approaches to compliance. Therefore, in this chapter, I examine firm

[95] Types of ownership in China and their environmental governance status: for domestically invested enterprises (contrast Foreign-invested and Hong Kong, Macao and Taiwan-invested), ownership mainly involves state-owned enterprises, collectively owned enterprises (aka. township and village enterprises) and private enterprises. SOEs largely represent urban economies, and township and village enterprises (TVEs) reflect their rural counterparts. The urban-rural economic disparity results from China's distinctive development trajectory where state sectors are prioritized, and also leads to the distinction between environmental performance of urban and rural regions. Although both are under the control of government, SOE and TVE also bear distinct features in environmental governance due to different state priorities. Firms with capital from outside mainland China are subject to not only domestic regulations in China but also international standards and norms.

[96] SOEs play a crucial role in key industries such as energy, raw materials, and equipment manufacturing; and even hold monopoly positions in financial systems, telecommunications, oil and gas, and major public utilities (Weiying Zhang, 2014).

[97] Different sectors are subject to various peculiarities. Here in Table 6.1, I only selected some common sectoral characteristics (water intensity, special industry, sector specific regulations like the zero liquid discharge policy in chemical industries) that impact on firms' water management.

characteristics to explore their capability and orientation, and the environmental management practices they lead to. While this chapter mainly discusses how different kinds of firms react to ecological modernization differently, the next chapter will examine the impact of different types of regulations as one of the locality factors.

In the following sections of this chapter, I will first introduce various firm characteristics and then explore how they affect firm strategies. The state-owned enterprises, in particular, will be analyzed, which tend to possess various internal factors that drive corporate environmental management in China's current ecological modernization. This chapter concludes with implications for corporate environmental management and state environmental governance.

6.2 Firm characteristics that matter

In addition to ownership and scale, which is the major firm characteristic in my analysis, other factors are also influential in driving CEM. Other characteristics that current Chinese SOEs commonly possess, for example, large-scale, stock market listed, in environmentally sensitive sector, co-shape their environmental performance. Moreover, external locality factors were also diagnosed to examine the articulation between territorial institutions and firm attributes; these will be presented in Chapter 7. Again, as introduced before, with limited cases, this chapter does not aim to pattern behaviour according to characteristics and reach conclusions like, for example, large firms are doing better than small firms in water management. The sample is not large enough to reach such conclusions. And there are still proactive small firms (i.e. Firm-10) and reactive large firms (i.e. Firm-01), as small firms may be subject to other drivers (i.e. sectoral characteristics in Firm-10) for proactive water management. Therefore, this section identifies the firm characteristics that matter in water management with inductive case analysis.

Ownership

With case study firms in state-owned, private and foreign-invested enterprises, I am able to compare strategy in firms with different ownership types (Table 6.2). Firm interviews showed that state-owned and foreign-invested ownership status lead firms to proactive initiatives in water management – they adopted new water conservation techniques that were not compulsory (i.e. Firm-02, 28[98]) and responded to pollution control regulations with higher standards (i.e. Firm-04, 07, 09 etc.). This is attributable to their specific status and their nature of state or international integration.

[98] Refer to Box 5.3, which indicates that state-ownership status has driven Firm-02 and 28 to adopt costly and non-mandatory reclaimed water reuse system.

Table 6.2 Ownership and firm strategy

	Proactive	Reactive	Resistive	Sum
SOE	16	1	0	17
PE	3	7	1	11
FIE	1	1	0	2
Sum	20	9	1	30

Among the 17 SOEs in this study, 16 adopted proactive water management strategies, except Firm-20, which is still in close compliance with government regulations[99]. Moreover 9 of these SOEs are large [all but one listed] and 8 are medium [all but 2 listed]. Whether the firm size and share listing status are co-promoting water management in SOEs will be analyzed in the following parts. When asked about internal drivers for water management, among the 16 proactive SOEs, 2 reported attention from management due to their SOE status (Firm-02 and 28), and 7 reported their reputation sensitivity as an SOE (Firm-02, 07, 22,23, 24, 29, 30)[100] is driving water management. It can be seen that the behaviour of SOE is subject to their unique status. They can be regarded as local representatives of the state, but they are also subject to regulation. SOEs used to be accused of resisting environmental regulations through their stronger bargaining power over local governments than private enterprises (C. He, Zhang, & Rui, 2012). However, as China proceeds towards ecological modernization, the performance of SOEs in my interviews during 2017-2018 in Beijing and Hebei is generally better than that of private firms. As senior managers in SOEs often assume political positions within the state, such external incentives are what private firms do not have in promoting environmental upgrading. And state integration in SOEs is driving proactive water management (Box 5.3). As a semi-state actor, the behaviour of transformed SOEs also exemplifies the state's greater resolution in ecological modernization. In addition, among the 16 proactive firms, 12 are in water and pollution intensive or environmental sensitive sectors; the impact of sector characteristics will be discussed in the later section.

There are only 2 FIEs in this study (both large and listed); they illustrate that international integration in FIEs is helping with firm's environmental management. Firm-04 reported that its waste treatment technology is aided by the overseas parent company, which is up to international standards. Such international integration in terms of extra standards and technological aid helped the FIE reduce regulatory risk in China (pers. comm. in Firm-04, 12 August 2017). But just as with SOEs, foreign-invested ownership structure does not guarantee proactive strategy: the reactive FIE Firm-06 which is less pollution intensive has taken no proactive water management

[99] As for the reasons why Firm-20 did not go beyond compliance in water management: as an equipment manufacturing enterprise, water is mainly used in a rain proof test to check the leakproofness of the equipment they produce. Water will not be contaminated in such process and can be reused; therefore, water consumption is not the manager's major concern in Firm-20 (Interview date: 15/10/2017).

[100] This does not mean other SOEs are not reputation sensitive. It is just this nature was not specifically brought up when talking about their water management during the interview.

strategies. However, SOEs and FIEs in China, which are often listed (and reputation sensitive)[101], large and profitable (capable of environmental upgrading), at least comply with environmental regulations.

For the 11 PEs in this study, 8 are small [none of them listed], 3 are medium / large [all listed]. Three take proactive strategies, 7 is reactive and 1 is not in compliance with environmental regulations. Though there are 3 proactive PEs, this does not result from their private ownership[102], as this type of ownership is not giving firm extra incentive in environmental management judging from this case study[103]. In addition, in the SLW campaign in Beijing and Hebei, the huge numbers of non-complying firms are all small private enterprises[104].

Here I present a case in which environmental behaviour changed along with ownership change. Firm-29 in Hebei is a cement manufacturing firm. Established as a private enterprise in 1998 and flourishing in the cement cluster in Hebei, Firm-29 has an annual production capacity of 600,000 tons of cement grinding. In 2013, Firm-29 was purchased by a local SOE in Hebei, and in 2016 experienced another ownership change. Now Firm-29 is controlled by a large SOE in Beijing. Along with the ownership change, environmental behaviour altered accordingly. Before 2013, when Firm-29 was still a private firm, it had no supporting environmental protection facilities or equipment. After the first ownership change in 2013, it built a waste treatment facility and invested in a new comprehensive resource recovery project. In 2016, after the second ownership change, the new shareholder is a more reputation sensitive SOE and put more effort in environmental management in Firm-29.

> Now the headquarters is making environmental protection oriented technical reform a routine. They have strict requirements for us. The whole group is investing one billion in resource conservation and pollution control. We (Firm-29) have some six and seven million. The cost of ammonia (used in waste gas treatment) alone has added more than 2 per cent of our total production cost. Private firms will try all means to cut such environmental protection cost. Right now, we have no advantage in production cost at all.
>
> – EHS Manager, Firm-29, Hebei.

[101] SOEs or FIEs are more reputation sensitive than private enterprises, being more concerned about their public image (pers. comm. in Firm-29, 10 July 2018); some such firms exceed compliance and have higher standards of wastewater treatment to reduce regulatory risk (i.e. Firm-04, 07, 09 etc).
[102] Firm-10 is mainly driven by its special industry status (details refer to the 'Sectoral characteristics' part) and Firms 17 and 18 are driven by industrial peers (details refer to the 'Miscellaneous' part).
[103] None of the 3 proactive PEs reported drivers for water management from their ownership type. In addition, other researches also showed that Chinese PEs have bad performance in water pollution abatement (H. Wang & Jin, 2007); have not received much incentive in environmental governance (Z. Yu & Huang, 2020); and are less responsive to environmental policies than SOEs (X. Wu, Gao, Guo, & Maqbool, 2019).
[104] For more details on the regulating SLW campaign, refer to Chapter 5 on 'Factory closure' and 'Rule breaking'.

The ownership change in Firm-29 is a clear demonstration of the improved environmental behaviour of the SOE. What happened to Firm-29's ownership is not unique. This is a common trend in China: once a TVE or private enterprise is well developed, it will be merged into an SOE or become state holding. The implication of such ownership structure change on the geography of corporate environmental performance also needs investigation.

In summary, state and international integration in SOEs and FIEs in China is driving their environmental adaptation. PEs do not have an incentive, unless they are subject to other driving characteristics, for example, PEs in a GPN/GVC are affected by international integration[105], without any change in ownership status. Other characteristics possessed by SOEs and FIEs, including large/medium scale, share listing, reputation sensitivity, in environmental intensive sectors etc. co-promote their environmental behaviour and will be elaborated in the following subsections.

Size/scale

There are 12 large, 10 medium and 8 small scale enterprises in this study (Table 6.3). Of the 22 large and medium firms, 17 are proactive and 5 are reactive in water management. Of the 8 small enterprises, 3 are proactive, 4 are reactive and 1 is resistive. Though the sample size is not large enough to pattern behaviour according to firm size, still in the firm interviews several factors were identified that are likely to constrain the adaption capability and orientation in small firms compared with large and medium scaled firms. They are profitability, technological and institutional path dependence, economies of scale and government monitoring strategies.

Table 6.3 Size and firm strategy

	Proactive	Reactive	Resistive	Sum
Large	9	3	0	12
Medium	8	2	0	10
Small	3	4	1	8
Sum	20	9	1	30

Profitability directly affects the financial capability of tecno-centric environmental adaptations in Beijing and Hebei manufacturing firms.

> For a small enterprise, the revenue of the whole year won't even cover the environmental protection cost. So, now that environmental inspections are tight, many small businesses have closed their doors. They are forced to close; they won't make money.
>
> – Practitioner in water service sector, Beijing.

[105] Refer to the case of Firm-08 in this chapter on 'Market and international integration'.

There are few non-compliant firms in this sample. But according to an environmental service company that offers environmental innovation service to local enterprises to help them comply with government policies,

> When it comes to environmental protection in small and medium scale enterprises, they are fooling the government. They just want to spend less money. They come to us, we design a process and equipment and report the budget. [But they just] ask about the price, [and] even give up environmental upgrading.
>
> – Environmental service company, Beijing.

As introduced before, in the SLW campaign, large numbers of small enterprises were shut down because of non-compliance. Firm-05 in this study is one example of such enterprises, which was financially incapable of adaptation[106].

The second factor is technological and institutional path dependence. As concluded in the last chapter, water adaptation in industrial firms is both technologically and institutionally path dependent. When comparing large-scale and medium-scale enterprises with small enterprises, innovation capability stands out in large firms, accelerating their environmental adaptation (Table 5.2 and Table 5.4), by offsetting the adaptation cost through technological innovation[107]. As discussed in the previous chapter, technical reforms including environmental oriented reforms, are routine in large enterprises (Table 5.2 Column 8 Routine technology reform)[108]. Among the 9 sample firms that do not have routine technologic reform, 7 are small enterprises, 2 are medium enterprises. As discussed before, adopting a single pollution treatment facility might simply bankrupt small enterprises. As SOEs are mostly large and medium scale firms, they are institutionally more capable of innovation and consequently yield better environmental performance than private enterprises. While ownership has more to do with the incentive for CEM, scale adds to the capability of CEM. Moreover, economies of scale also affect water use performance. Both the water consumption and waste treatment facility efficiencies are increased with the increase in production scale (pers. comm. in Firm-25, 7 November 2017)[109].

While the previous three factors influence adaptation capability, the last factor – government monitoring strategies – affect the adaptation orientation. Both the command-and-control water and pollution regulations and the regulating SLW campaigns are highly reliant on government monitoring capability. Institutional deficit, which will be further explored in the next chapter,

[106] For details, refer to the case of Firm-05 in Chapter 5: 5.3 Avoidance on 'Factory closure'.
[107] For example, refer to the quotation from Firm-26 in Chapter 5: 5.2 Innovation on 'Discussion on innovation in water management'.
[108] For routine technological innovation, also refer to the example of Firm-25 in Chapter 5: 5.2 Innovation-Technological innovation-'Water conservation'.
[109] For evidence of increased in efficiency with scale, also refer the example of Firm-02 and 25 on Page 86.

often makes small firms in China into outlaws. Enforcement is compromised by the lack of labour in environmental or water authorities; the consequence is a 'grasp the large, let go of the small' (Hsieh & Song, 2015) strategy.

> We are mainly monitoring large emitters. We seldom go to firms that do not produce large amount of waste — not enough labour. Additionally, for some small firms that contribute pollution, they are not registered with the Industrial and Commercial Bureau, we don't even know of their existence.
>
> – Official, EPB, Hebei.

Under the current institutional background, small firms are encouraged to ignore the rules and wait for the government to spot them and die[110]. Otherwise, they just keep profiting without change.

In summary, environmental innovation, no matter whether from policy compliance or voluntary endogenous technical change, is influenced by the size/scale of firms. Here in this subsection, I identified four factors originating from firm size/scale – including profitability, technological and institutional path dependency, scale economies and government monitoring strategies – that affect their water management performance. Large firms, often SOEs or FIEs, perform better in policy compliance and innovation than smaller firms. In addition, large firms are often listed on the stock market and are more reputation-sensitive, so their environmental performance is related to their financing; they are eager to reduce environmental regulatory risks. Large and medium enterprises are capable of environmental adaptation and at the same time subject to other characteristics (ownership, share listing etc.) that tend to reorient their environmental stands. By contrast, among small firms, both compliance capacity and incentive seem lacking.

Over the years, both Beijing and Hebei witnessed numerous plants shut down during environmental campaigns and industrial upgrading. Though devastating for individual firms, this does raise regional environmental standards. After all, small firms lack adaptation capability: a firm's innovation to meet environmental regulation is constrained by its capability. And prior to closure, some firms might make the final struggle by defying the rules.

Others

In addition to ownership and scale, other firm characteristics including financial status, market and international integration, sectoral characteristics etc. also drive water management in firms.

[110] Demonstrated in the case of Firm-05.

Financial status

Stock-market listed firms tend to be more reputation sensitive than non-listed firms (Zeng et al., 2012), as environment-related CSR performance exerts impact on their financing (pers. comm. in Firm-29, 10 July 2018). Especially when firms apply for public listing or refinancing in the stock market, they are required to disclose environmental information (Zeng et al., 2012).

> Now environmental protection is mainly relying on SOEs and listed companies. A record of environmental violations will hinder our financing. We are doing everything we can to reduce this risk. The requirements from the headquarters are even stricter than those from the government. Just to reduce such risk.
>
> – EHS Manager, Firm-29, Hebei.

This often occurred in listed SOEs or multinational corporations (also confirmed in Firm-02, 04, 07, 14, 28). Their specific financial status urged those enterprises to internalize the environmental externalities. Other empirical studies also show that listed firms are sensitive to environmental violations (X. Xu, Zeng, & Tam, 2012).

In addition to maintaining financing capability and good reputation by restraining from environmental violations, international integration in listed enterprises in terms of adopting international standards, for example, standardized environmental management system like the ISO 14001 certification (Chao, Yin, & Ma, 2009) or pressure from international customers or partners, acts in the same direction. There is no direct evidence showing that international integration in listed enterprises does have an impact on their water management from this case study[111]; this deserves further research.

Market and international integration

Market integration – in terms of customer integration, supply chain integration and international integration when firms are playing in the global market – affect water management. Examples are Firm-02 and 08. Firm-02, a listed large-scale, car manufacturing SOE indicates that a need to demonstrate CSR behaviour to their customers has driven them to take proactive water management strategies (pers. comm. in Firm-02, 6 August 2017). Firm-08, a small-scale private garment manufacturing enterprise, which is one link in the global garment production network, reported pressure from their international partners and customers in the garment supply chain on water management (pers. comm. in Firm-08, 23 August 2017).

[111] Indirect evidence in this research includes, in terms of adopting international standards, 16 firms that adopted standardized EMS, all of them listed enterprises (Table 5.4). Firms that have experienced pressure from international customers on water management will be reported in the next part, in the case of Firm-02 and 08, though only Firm-02 is a listed firm.

> In water quality regulation, we are monitored by The Centers for Disease Control and EPB. In addition, we have one customer company that came here to test our water quality every year to see whether there is toxic substance in the production water to guarantee the quality of the products we manufactured for them. All our customers are foreign companies.
>
> – Logistics Department Manager, Firm-08, Beijing.

This indicates that international integration in Firm-08 comes with integrating international standards. The previously introduced Firm-04 is also affected by international integration in water management by receiving international aid through technological transfer facilitated by its foreign-invested status[112]. This shows that the previously discussed characteristic including 'ownership', 'share listing' status and whether in the GPN all contribute to international integration of firm's water management. In addition, other research also indicated that when a firm is in a global production network or is seeking to enter a global market, it also tends to be reputation sensitive and have more incentive for environmental management than other firms (Kuo et al., 2012). Such firms also face pressure from their international customers to improve their environmental performance (as in the case of Firm-08). Previous studies also showed that when firms seek to enter the global market, they initiate proactive self-regulation to meet international environmental standards (Zeng et al., 2005). As more Chinese firms (not only SOEs) compete in a global market, their environmental performance is gradually improving to guarantee them a passport into a GPN.

In ecological modernization theory, international integration drives institutional and economic change at a national level. For individual firms, international standards and interactions are also driving corporate environmental management. Being part of a global production network has been found to have a positive impact on Chinese firms' environmental self-regulation (Christmann & Taylor, 2001; S. Zhu & He, 2016). Though large- and medium-sized SOEs play an important role in the Chinese economy, it was not until the 2000s that they began to green their behaviour and take environmental concerns into account when they sought to enter the global market (Q. Zhu & Sarkis, 2006) – another form of regulatory and economic pressure from the market on listed SOEs (Rowe & Guthrie, 2010).

In other words, despite strict state regulation, the market and international integration play significant roles in corporate environmental behaviour. The better environmental performance of most enterprises does not rely only on policy compliance. To guarantee their reputation in the international or capital market is sometimes the ultimate reason to comply with environmental

[112] For evidence, refer to the description of Firm-04 in 'Ownership' on Page 115.

regulation or even go beyond compliance to reduce risk. Proactive firms in my study are not only distinctive in ownership, but also are often large scale, stocked market listed and in major sectors of China that are in a GPN (Table 6.1)[113].

Sectoral characteristics

The fact that Chinese government has put effort in regulating environmentally sensitive firms, like oil and gas, chemical and paper products (H. Wang et al., 2004) causes such industries to face more social and political pressure over environmental management (i.e. Firm-14, 24, 25, 26, 27 in the chemical industry are subject to stricter regulations). Here, I define an environmentally sensitive industry as a resource and pollution intensive industry, which is strictly regulated by the government; for example, a 'zero emission' rule is imposed on the chemical industry by the state, indicating that such industry should not emit waste into natural environment. The waste should either be recycled in the facility or treated before being emitted to external environment. Here I give two examples of environmentally sensitive firms (Box 6.1 and Box 6.2).

Box 6.1 Context and adaptations in Firm-14

Firm-14 in Beijing is a large scale SOE established in 1993, specializing in petroleum manufacturing. Being a large water user, Firm-14 consumes an annual 80 million cubic meters of water, which is beyond the regional water supply capacity, so for now water in Firm-14 is partially supplied by the SNWTP. Due to the constraint on water supply, Firm-14 has initiated various technical reforms including water recycle and reuse, boosting its wastewater treatment capacity. Those measures mainly serve production purposes. The firm also initiated diversion of rain and sewage water in response to government order.

Box 6.2 Context and adaptations in Firm-23

Firm-23 was originally established in 1919 in Beijing, specializing in metal manufacturing. As it is both resource and pollution intensive, the local resource and environmental carrying capacity could no longer sustain the development of Firm-23. It was relocated from Beijing to Hebei in 2010. The relocation broke the lock-in of technology and created a new path. When Firm-23 relocated, it built new facilities to use unconventional water source. Now more than 60 per cent of the water it uses comes from seawater desalination.

In addition to the water or pollution intensive sectoral characteristics, other sectors also face contingencies that might drive proactive water management; an example is Firm-10, which is in the special industry with higher water price to regulate use (Box 4.2).

In summary, firm strategies are dependent on sector characteristics. In the Chinese regulatory environment, different sectors are subject to different levels of regulation, but the sample size in this study is insufficient to draw explicit conclusions on sectoral impact. What can be identified from this field research though is that sectoral characteristics do affect CEM. However,

[113] For the 20 proactive firms in this study, are 16 SOEs, 17 are large or medium scaled, 14 are listed and 15 are in water/environmental sensitive sector.

comparison across sectors (or dynamics within a certain sector) need large samples to draw inclusive conclusions on broader sectoral dynamics.

Miscellaneous

The impact of profitability is discussed in the analysis of firm size. Like size/scale, profitability is mainly impacting the capability of firms to adapt. However, without large or medium firms that are not profitable in this sample, I cannot go further into the analysis of the impact of profitability on CEM.

Environmental and reputation sensitivity are discussed in all of the previously mentioned characteristics. Such sensitivity is here understood as an adjunct of other characteristics rather than as a starting point of analysis as in other research (Kuo et al.,2012; Zeng et al. 2012).

Evidence also shows that industrial peers drive firm environmental adaptations, altering both their orientation and capability. As introduced in Chapter 5, the environmental adaptations of Firm-17[114] are influenced by innovations in its industrial peers. Firm-18 is also one of the peers of Firm-17 and learning from its peers on advanced technology and managerial practices (pers. comm. in Firm-18, 21 September 2017).

Another firm characteristic that drives environmental adaptations is manager perception, which affects the adaptation orientation. Examples are shown in Firm-02 and 28's proactive strategy, which both received attention and support from management[115]. The attention from managers derives from Firm-02 and 28's state-ownership. However, there might be other contributors to manager perception, not identified in this case study. Still, this is consistent with the attention-based view in organizational behaviour.

In addition, corporate environmental ethics also appeared to be one of the influencing characteristics, demonstrated in the case of Firm-24[116], a path dependent process of industrial water management, in which the firm's water conservation ethic originated from its water scarce past.

Chinese SOEs: the assemblage

Due to their special development path, Chinese SOEs are normally large and in critical sectors, which are often resource and pollution intensive, stock market listed and part of a GPN. Some are even the leader of its GPN, for example, Firm-23. The fact that SOEs in China often possess all

[114] Refer to the case of Firm-17 on Page 84-85.
[115] For evidence, refer to Box 5.3.
[116] For evidence, refer to the description of Firm 24 in Chapter 7: 7.2 Infrastructure on 'Regional water availability' on Page 138.

the characteristics that tend to promote a firm's environmental behaviour mean that SOEs often yield good environmental performance. Currently in the study region, SOEs take the lead in CEM.

As a special institution, SOE environmental management decisions are influenced by Party leaders at firm level. SOEs are efficient in executing state orders in environmental governance. Other studies also showed that in China, governments play a prominent institutional role in CEM (Rowe & Guthrie, 2010) and I find such influence is even more profound in SOEs in the sense that SOEs in this case study are more responsive to government environmental regulations[117]. Therefore, I identify SOEs as a 'state agent' in China's current environmental governance.

As a state actor, SOEs are taking the lead in CEM. The special political status of SOEs motivates their environmental managers to comply with environmental regulation and even go beyond compliance for the firm's economic benefit. SOE behaviour in environmental management appears to have evolved, since previous studies found the problematic enforcement of environmental rules in SOEs (X. Ma & Ortolano, 2000; Rowe & Guthrie, 2010) and defined them as resisting environmental governance (C. He et al., 2012). The new role of SOEs demonstrates both the evolved capacity of SOEs and the changing state orientation to environmental crisis.

SOEs, with their outdated technology, used to be accused of contributing more pollution than none-state enterprises (Johnson, Liu, & Newfarmer, 1997). However, with SOE reform in China and elimination of excess output capacity, the competence of SOEs has improved and they are more capable of handling environmental issues. In addition, governments, especially local government agencies used to turn a blind eye to SOEs' polluting behaviour, since the economic performance of localities is a major criterion in the cadre evaluation system. Now, since environmental performance is added to the criteria for cadre evaluation, 'protection' of these SOEs is less direct. Therefore, as a state representative, the change in SOE orientation in environmental management indicates the state's dedication to environmental governance. Before, the Chinese government was accused of lack of environmental enforcement, attributable to its prioritization of economic development over environmental preservation (Jianguo Liu & Diamond, 2005). Now the government's resolution in tackling its environmental problems is shown in new regulations, stringent enforcement and various regulatory instruments.

The mode of environmental governance in China has, in this sense, shifted, bringing diversified approaches (Mol & Carter, 2006) and new non-state players (Guttman et al., 2018). Guttman *et al.* (2018) identified nonstate actors that are active in current Chinese environmental governance, including NGOs, enterprises CSR, business associations and public service units and emerging E-platforms. But those nonstate actors, though adding social pressure to polluting industries, still

[117] Also refer to Box 5.3 on the state influence on SOEs' proactive environmental management.

play a marginal role. What drives polluters most are still those regulatory pressures and economic pressures from the market (through listing and reputational effects) (Rowe & Guthrie, 2010).

In summary, this section examines how firm characteristics encourage or discourage firms' environmental behaviour. I classify the environmental behaviours that different types of firms have taken, shedding light on firm strategies and firm characteristics. Within a limited qualitative research sample, this research sought to include many different types of firms, in terms of scale, ownership, sectoral characteristics and so on to explain the impact of firms' characteristics. In general, environmental upgrading results from policy compliance and voluntary endogenous innovation, in both of which firms' own characteristics play a major part. Firm strategies including innovation, relocation, outsourcing, factory closure and rule breaking, depend on firm-specific factors, such as ownership, size/scale, histories and sectoral characteristics. In the next section, the mechanism of how characteristics influence behaviour will be explored.

6.3 Bridging firm characteristics with firm strategies

Using a resource-based view, in this section, I illustrate how firm capability (resource) mediates the relationship between firm characteristics and firm environmental management behaviour and explore how different types of firm internalize external environmental pressures and generate various proactive, reactive or resistive environmental practices. This is achieved by the analysis of organizational capabilities through which firm characteristics influence firm behaviour. On the resource-based view, from the capability perspective, firm characteristics influence organizational capabilities, then capabilities influence environmental strategies and subsequent behaviours. In short, characteristics impact behaviour through the development of organizational capacities.

The competitive advantage of a company is the "condition under which competitors are unable to replicate its competitive strategies" (Y.-S. Chen, 2008, p. 278; Porter, 2008). According to RBV, competitive advantage is the result of the key resources and capabilities of a firm (Barney, 1991; Orsato, 2006). Environmental social responsibility is a key capability[118] that leads to a sustained competitive advantage and proactive environmental strategies that strengthen a firm's competitive advantage (Hart, 1995; Sharma & Vredenburg, 1998). Environmental forces – including stakeholder activism and environmentalism, competitive pressures, national environmental policies, and international environmental regulations – affect firm behaviour and performance (Rugman & Verbeke, 1998). Therefore, from the RBV, environmental management as an important element of a firm's strategies, is considered a unique capability of firms (Hart, 1995).

[118] Environmental social responsibility can be viewed as a behaviour, as well as a capability.

In the following subsection, I examine various organizational capabilities, and then illustrate which kind of firms are most sensitive to environmental competitive advantages.

Organizational capabilities and competitive advantages

Sharma and Vredenburg (1998) noted that the capabilities that firms develop for environmental management include stakeholder integration, higher-order learning and continuous innovation. These are the capabilities that give firms competitive advantage. I examine whether these three types of competitive capability have emerged from proactive environmental strategies in the case study firms.

Firstly, in terms of stakeholder integration, this study observed integration of state/regulators, investors, customers and consumers in firm's water management. State as the major regulator in firms water management in this case is seen from firms' pressure from and compliance to mandatory environmental regulations, in this case pollution control[119]. Firms in the study region, especially the SOEs, are integrating state regulators in the sphere of water management to reduce policy risk, exemplified in the state integration of SOEs discussed in the previous 'Ownership' part[120]. Investor integration in this study is shown in the influence from domestic or international parent firms. For example, in the case of Firm-04 in 'Ownership' section, where integration with its overseas parent firm promoted technological transfer which strengthened Firm-04's water management; domestic firms like Firm-02[121] and Firm-29[122] also reported headquarter integration in their water management. In addition, listed firms' environmental sensitivity are also subject to investors integration, for details, refer to the previous section on 'Financial status'. Customer and consumer integration are discussed in the previous section on 'Market and international integration'[123]. The findings on stakeholder integration from the RBV are consistent with the ecological modernization theory on state-market relations and international integrations in environmental reforms, though the role of civil societies as projected by ecological modernization are not observed in this case study.

As for higher-order learning, demonstrated in this research in firms' technological and institutional innovation[124] to cope with environmental constraints, based on their interpretation of the environmental issue and decision making on adaptation strategies; institutional pressure

[119] For more evidence, refer to Chapter 4 and 5.
[120] Also refer to Box 5.3 on state integration in SOE environmental management.
[121] For evidence, refer to the details of Firm-02 on Page 140 indicating headquarter involvement in Firm-02's wastewater treatment business.
[122] For evidence, refer to the interview quotations from Firm-29 on Page 116 and 120.
[123] In addition, other empirical studies also show that customer and supplier involvement has positive effects on green product innovation in Chinese enterprises (Y. Zhao, Feng, & Shi, 2018) and that environmental attitude plays a moderating role promoting environmental innovation through customer and competitor orientation (Liao, 2018b).
[124] Refer to Chapter 5: 5.2 Innovation.

affects environmental innovation through knowledge acquisition (Liao, 2018a), demonstrated in this research in the impact from international and industrial peers. Examples are technology transfers in Firm-04[125], Firm-17[126] and Firm-25[127]. And for continuous innovation, it is often large scale firms which can devote more resources to form these competitive advantages, for those firms with routine technological reform, which increased environmental adaptation capability[128]. Both the capability of higher-order learning and continuous innovation in driving proactive corporate environmental management are consistent with the ecological modernization theory.

The dynamic capability of a proactive environmental strategy will reduce the uncertainty at the business-nature interface (Aragón-Correa & Sharma, 2003) and enhance competitive advantage in the environmental arena. Environmental strategies contribute to competitive advantage, but which kind of firms are more sensitive to environmental adaptation? Previous research shows that factors including global market, innovation, social legitimization, and financial performance contribute to the linkage. From the resource-based view, 'it pays to be green' (Russo & Fouts, 1997). Therefore, the profitability of a firm determines the available resources it can devote to environmental management. The evidence here also shows that large scale profitable firms are more capable of environmental management[129]. Another important factor is firms' environmental sensitivity, as it costs environmentally sensitive firms more to conform to environmental norms (Berrone & Gomez-Mejia, 2009); firms in sensitive sectors are compelled to proactive environmental management, especially under the strict regulatory environment in this region[130]. In addition, firms in a global market or global value chain are faced with extra international environmental regulations; developing environmental strategies will help them reduce complexity and uncertainty in international markets[131].

In summary, through the RBV firms in this case study have developed capabilities including stakeholder integration, higher-order learning and continuous innovation in proactive environmental management and would further promote their environmental adaptation with the competitive advantaged derived from those capacities. The empirical results in this chapter also showed that large scale, profitable, listed SOEs or multinationals tend to integrate the pressure from various stakeholder, and are more capable of environmental innovations. The findings are also consistent with the interpretations from the ecological modernization. In combining RBV with ecological modernization, while this subsection focused on firm capability in environmental

[125] Details refer to Page 114.
[126] Details refer to Page 83-84.
[127] Details refer to the interview quotation from Firm-25 on Page 86.
[128] For more evidence, refer to Chapter 5 on routine technology reform and 6.2 Firm characteristics that matter on the impact of scale.
[129] Refer to the evidence on 'Size/scale' in the previous section.
[130] Refer to the evidence on 'Sectoral characteristics' in the previous section.
[131] Refer to the evidence on 'Market and international integration' in the previous section.

adaptation, the next subsection focuses on firm orientation, and explains how firm characteristics affect the adaptation orientation.

Firm orientation and environmental position

In addition to firm capability, the orientation of firms also influences the environmental position they take and their response to environmental policies – which are also shaped by firm characteristics. The previous section (6.2) showed that ownership, financial status and market as well as sector position tend to orient the environmental position that firms take and generate proactive environmental management practice or compliance with policy. It showed that organizational differences influence compliance orientations across firms. Table 6.4 lists reasons provided by each firm when asked "what factors drive you to take the action (measures to change water use in your firm)?" (Appendix C Interview Question). The table identifies the major reasons for choosing a specific environmental management strategy. The most commonly-mentioned reasons include reputation sensitivity (from special ownership type or share listing status), water use intensity (therefore under high/low regulatory constraints), knowledge, technological spill-over from industrial peers and financial capability.

Table 6.4 Orientation of sample firms

Firm	Strategy	Key drivers
1	Reactive	Reputation sensitivity as listed firm, financially and technologically capable of initiating changes to comply with government policies
2	Proactive	Reputation sensitivity as listed firm and SOE, customer integration, manager perception, gain competitive advantage through reduced regulatory risk
3	Reactive	High quality requirement for water, under extra supervision
4	Proactive	Reputation sensitivity as listed firm, reduce regulatory risk, international integration
5	Resistive	Financially incapable of adaptation, reputation insensitive
6	Reactive	We are not pollution intensive, so we just follow the rules
7	Proactive	Water intensive, reputation sensitivity as listed firm and SOE, financially capable of establishing standardized management institution
8	Reactive	Customer integration, supply chain integration, shift the risk away through global outsourcing
9	Proactive	Highly institutionalized water management as we are SOE and financially capable
10	Proactive	Special industry wants to save water cost, water intensive
11	Reactive	We are not pollution intensive, so we just follow the rules
12	Reactive	We just follow the rules
13	Proactive	Reputation sensitivity as SOE
14	Proactive	Reputation sensitivity as listed firm and SOE, water and pollution intensive
15	Reactive	As local leading enterprise, has bargaining power with local environmental state over compliance
16	Proactive	Reputation sensitivity as listed firm, financially capable of environmental adaptation, water intensive
17	Proactive	Water intensive, technology spill-over from industrial peers
18	Proactive	Water intensive, technology spill-over from industrial peers
19	Reactive	We are less water and pollution intensive, so we just follow the rules
20	Reactive	We just follow the rules
21	Proactive	Water intensive
22	Proactive	Water intensive, reputation sensitivity as listed firm and SOE, financially capable
23	Proactive	Water intensive, reputation sensitivity as listed firm and SOE, our technological innovations help save water input

24	Proactive	Water intensive, reputation sensitivity as listed firm, corporate environmental ethics
25	Proactive	Water intensive, technology spill-over from industrial peers
26	Proactive	Water intensive, financially and technologically capable
27	Proactive	Water intensive, financially and technologically capable
28	Proactive	Manager perception, set a good example for SOE
29	Proactive	Environmental sensitive, reputation sensitivity as listed firm
30	Proactive	Water intensive, reputation sensitivity as local pillar firm

As indicated in the Chapter 5, the orientations of firm strategies differ, ranging from innovation (reactive or proactive compliance) to avoidance and rule breaking (purposeful non-compliance). The orientation of firms is also the outcome of their characteristics. In addition, the interplay of firm capability and orientation produces the internal driver for environmental innovation. Accordingly, a good regulatory approach should acknowledge and incentivize firm orientation with regard to their capability. State subsidy is the often-used approach to direct their orientations; in this region, the state is incentivizing compliance to a certain extent[132]. However, other mechanisms such as positive publicity might engage more stakeholders, such as consumers, socially responsible investment investors and civil society[133].

The fact that firm characteristics determine firm capability and orientation in environmental management suggests that regulation should be individualized, tailored to the characteristics of different types of firm to encourage compliance. The traditional one-size-fit-all environmental policy (List & Gallet, 1999) may not actually fit all regulated agents. Regulation diversification in China now is mainly demonstrated in sector-specific regulation – for example, the zero emission/ZLD policy in the chemical industry, targeted at resource and pollution intensive sectors. However, other firm characteristics impacting firm environmental position are not considered in state policy making, which resulted in, for example, the closure of small-scale factories for not being capable of adapting to new environmental regulations. For firm-level policy compliance, good regulation should be able to increase resource productivity and competitiveness.

Empirical evidence in this chapter (6.2) showed that firm characteristics including ownership, financial status, market and international integration, sectoral characteristics, industrial peers, manager perception all impact on the adaptation orientations of firm. The findings are consistent with the resource dependent theory of firms in that firm adaptations are dependent on external stakeholders including state, market, international, industrial community stakeholders etc. And the impact from manager perception also indicate the attention-base view of organizational behaviour. While analysis of firm characteristics from the organizational behaviour theories indicated firm capability and orientation directly influence the adaptation strategies they took. It is also consistent with the ecological modernization theories in state, market and international

[132] For evidence, refer to Table 4.2, Entry-2 and Entry-7.
[133] In this case study, firms with environmental information disclosure are all listed firms, including Firm-02, 04, 07, 14, 16, 23, 24, 29.

integration in shaping firm's capability and orientation in ecological modernization. Therefore, this study achieved the combination of organizational behaviour and ecological modernization theories in analyzing firm-level adaptation to environmental constraints.

6.4 Conclusion

Research question 3 asks how firm characteristics exert influence on water management strategies. This chapter distinguishes strategies taken in different types of firms, in terms of ownership, size/scale, financial status, market position, sectoral characteristics and so on; these characteristics affect the incentive and capability of their adaptation behaviour. The major internal firm characteristics driving factors identified in this research are ownership and scale. While ownership has more to do with the incentive for CEM, scale add to the capability of CEM. Other factors are also found to be linked to firms' adaptation capability and orientation. Therefore, environmental policy making should be individualized considering the characteristics of firms in determining compliance capability and orientation. This also indicates that bottom-up behaviour research like this is necessary to inform policy implementation. This chapter contributes to the ecological modernization theory in exploring the internal factors that affect firm response, indicating that it is imperative to consider firm characteristics when designing environmental regulations, and take the heterogeneity of characteristics into consideration to avoid the one-size-fit-all type of policy.

In the literature review chapter, Table 2.1 lists the firm characteristics that are found in previous researches to have an impact on CEM, and which this study also found to be relevant. There are overlaps among factors found in different studies; for example, profitability is often associated with firm size and share listing status, and in China with ownership status. Firms listed on stock markets can be reputation sensitive and firms in certain industrial sectors (sectoral characteristics) are more environmental sensitive. Firms' ownership might impact on manager perception (i.e. state impact on SOE or international impact on FIE). In this thesis, I mainly elaborated on the major firm characteristics that impact on firm strategies in water management and responses to ecological modernization with my own classification. I first analyzed the impact of firm ownership type and scale on water management strategy. Firms with different ownership type are subject to different drivers, some of which overlap with other drivers discussed in this chapter. The scale of firms mainly impacts on their adaptation capability. Others firm characteristics include firm's share listing status, market and international integration, sectoral characteristics and some of the more sophisticated drivers[134] including reputation and environmental sensitivity, profitability, industrial peers, manager perception and corporate environmental ethics. Moreover, among these characteristics, while firm size/scale, and profitability mainly affect environmental

[134] Those drivers may be related to other major characteristics. For example, for firms driven by reputation sensitivity, Firm-29 is reputation sensitive due to its SOE ownership, stock market listed status, while Firm-02's sensitivity is also subject to customer integration.

adaptation capability, other characteristics (including, ownership, share listing, environmental and reputation sensitivity, international integration, customer integration, supply chain integration) mainly impact firms' adaptation and compliance orientation.

Following the analytical framework of this research, firm characteristics that matter in CEM are identified. I also find that Chinese SOEs now own most of the characteristics that drive CEM; therefore, I argue that SOEs in the study region now take the lead in CEM. Empirical results show that some SOEs are reactive and some are proactive in response to environmental regulations; both technological and institutional innovations were initiated to reduce resource consumption and produce less pollution. SOEs in this region had internalized environmental externalities. In addition, this chapter also shows the distinction between state and non-state actors in China's ecological modernization. In environmental governance, the role of SOE is quite ambiguous, being state representative and enterprise, regulator and regulated. From this evidence, I argue that SOEs are now acting as a state actor taking the lead in CEM. This does not mean that I am taking a state-centric view in analyzing the dynamic of SOEs' environmental management though: in addition to state intervention and the peculiar political status of SOE, the market also plays a significant role in this dynamic: the better environmental performance of SOE does not rely only on policy compliance. To guarantee their reputation in the international or capital market is sometimes the ultimate reason for complying with environmental regulation or even going beyond compliance to reduce risk. Since SOEs in China are not only distinctive in ownership, but also are often large scale, stock market listed and in a GPN, there are various other firm characteristics that drive corporate environmental behaviour that are not confined to SOEs.

From a resource-based view, analysis in this chapter explained how firm capability (resource) mediates the relationship between firm characteristics and firm environmental management behaviour and explored how different types of firm internalize external environmental pressures and generate various proactive, reactive or resistive environmental practices. In addition, firm orientation which is co-shaped by firm characteristics also impact on the adaptation strategies firms took. Where the resource dependent theory and attention-based view are also found useful in analyzing firm adaptations. Moreover, the analysis of firm capability and orientation from the organizational behaviour theories are also consistent with the ecological modernization of firm, making such combination one of the theoretical contributions of this research.

The chapter also contributes to the literature on environmental governance in developmental states by distinguishing state from non-state actors. I explored the role of SOEs, which now act more like a state actor in China's ecological modernization. This chapter also contributes to the CEM literature in identifying the internal firm characteristics that drive corporate environmental behaviour. Some practical policy implications are also proposed. Firstly, with the state dedication

to combating environmental pollution, regulations are being strengthened; the current problem lies in the effective enforcement of strict environmental policies. With institutional deficit, opportunists exist, which hurts the competitive advantage of firms that bear the extra environmental management cost of complying with policy. Secondly, in addition to policy instruments, economic instrument should be promoted to facilitate firms' internalization of environmental externalities. As environmental protection, especially in pollution control, is not financially profitable, economic incentives could be given to firms to encourage environment-friendly behaviour. Finally, industrial transformation can weed out low-end resource- and pollution-intensive manufacturing to increase the efficiency of resource consumption and pollution control.

Building on the analysis in Chapter 5 on firm strategies and in this chapter on internal firm characteristics, the next chapter will examine the external locality factors that affect firm environmental strategies while co-shaping firm characteristics. Thereafter, a comprehensive understanding of firm strategy and its driving factors will be constructed.

Chapter 7 Locality

7.1 Introduction

Chapter 6 mainly investigated the internal firm-specific factors that exert influence on corporate water management strategies. In this chapter, attention will be given to how external locality factors impact firm behaviour. I argue that locality factors not only directly influence firm strategies but also have an indirect impact on them through shaping firm characteristics. I identify several locality factors, both physical (infrastructure) and institutional, that co-shape firm strategies and generate different patterns of firm behaviour across localities in the study region. In the following sections of this chapter, I introduce the locality factors shaping firm behaviour in water management from both physical and institutional aspects. Regional disparities within the study region resulting in the differences in firm behaviour in different localities are also reported. The chapter concludes with comments on the implications of the findings for regional water governance.

In Chapter 2, Table 2.2 shows the locality or external factors that have been found in the literatures to influence corporate environmental management. Among them, environmental institutions are mentioned frequently, as indicated in Chapter 4 when introducing the regulatory risks in the case study areas, in which environmental regulations play a major role in the internalization of environmental externalities in enterprises. The institutional context (i.e. monitoring stringency, social pressure, market condition) for environmental enforcement is also affecting firm compliance. In addition to the institutional factors, environmental resource availability and

physical infrastructure are also impacting CEM. The 'severity of environmental problems' factor can be understood in this case as regional water availability (as the severity of water scarcity and pollution), while it may also influence the strictness of environmental policy and enforcement.

7.2 Infrastructure

In this section, I identify the infrastructural locality factors that affect firm water management behaviour, which lead firm to adopt different strategies or not adopt them. While Table 7.1 is an overview of these impacts, the remainder of this section details those impacts with examples from sample firms.

Table 7.1 Infrastructure and firm strategy

Infrastructure	Strategy	Example
Regional water infrastructure	Technological innovations including building and adapting water withdrawal and wastewater treatment infrastructures, reclaimed water reuse	Firm-03, 10, 12, 14, 22-27
Regional water availability	Water conservation, specific technological and institutional strategies	Firm-01, 24
Recycled water	Technological innovations including recycle and reuse, reclaimed water reuse	Firm-02
Alternative water sources	Technological innovations, including seawater desalination and stormwater harvest	Firm-14, 23

Regional water infrastructure

Firms' water use and performance improvements heavily depend on the water infrastructure within the facility (Chapters 5). The physical infrastructure in a firm's locality also has an impact on firm's water use behaviour, which will be described in the following paragraphs of this section. From the field interviews and observations, I also found that currently in the study region, there is an obstacle from infrastructure for clean water supply and wastewater control that affect firm water management behaviour. I further concluded that on a regional scale it is important to increase water supply performance by separating domestic water pipelines from industrial water pipelines, in pollution control by separating stormwater from sewage in the drainage system and by building municipal reclaimed water systems. The field evidence for these conclusions will be presented.

First, from the perspective of water supply, regional infrastructures have an impact on firms' water use behaviour. Firms in the study region either use tap water supplied through the municipal water supply network or have self-supply wells from which they withdraw groundwater[135]. Tap water comes from the same network as domestic water, except for some remote areas where there is no network[136] or newly developed industrial areas (i.e. Firm-24, 25, 26, 27) where the industrial water network is separated from the domestic water network (this saves the extra treatment of

[135] For more evidence, refer to Chapter 4: 4.5 Industrial water consumption on 'Water supply'.
[136] For example, in Firm-12 self-supply wells need to be built to withdraw water.

water that domestic user requires while industrial water does not). In some regions in Hebei, industrial water is cheaper than local domestic water because of its lower treatment cost (i.e. Firm-24, 25, 26, 27); in Beijing, industrial firms are charged more for water than domestic users even if they share the same source.

> The domestic and industrial water are coming from the same network. We have done conductivity[137] test. They are the same. Our neighbour factories are also using water from the same municipal network. However, quality requirements in different industrial sectors and production processes are different. Like us, our production water quality requirement does not have to be as high as domestic water quality.
>
> – EHS manager, Firm-01, Beijing.

Regional water supply infrastructure directly affects firms' water supply, in terms of whether they will have to devote resources to build their own infrastructures to complement for the deficiency in regional infrastructure or the price of the water[138]. And with different quality requirements, it might be cost-effective to separate the domestic water network from industrial water networks in future infrastructure development.

Secondly, for water drainage, the separation of stormwater from sewage discharge is also imperative for protecting the water environment. All the cities in the sample report incomplete rain / sewage diversion (Box 7.1)

Box 7.1 Interviews on regional water infrastructure

In the city pipe network, stormwater and sewage share the same pipe in certain nodes. In regular days, this is okay. Stormwater also helps dilute sewage, reducing our sewage treatment pressure. But when the rainy season comes or there is sudden burst of precipitation, large amounts of water rush into the municipal sewage treatment plant, which is beyond our processing capacity. We have no choice but to emit it all into the environment without treatment.

- General Manager, Wastewater treatment plant, Hebei.

The infrastructure is flawed. Some sewage pipes are open-air. When there is heavy rainfall, the sewage will be flushed out of the channels into the environment, causing pollution.

- Official, EPB, Beijing.

These examples expose the problem of inadequate infrastructure in regional water governance. However, just as within firms, the constraint of historical regional infrastructure and the large scale of this public utility add to the cost of adapting municipal water infrastructure. And this deficiency of regional infrastructure in drainage also affect individual firm behaviour, for example, Firm-14 reported that one of the water infrastructure adaptation they were doing during the

[137] One of the quality indicators of water.
[138] In this study, firms including Firm-03, 10, 12, 22-27, have to build their own water withdrawal infrastructure no matter self-supply wells or water delivery pipes.

interview time is to separate stormwater from sewage discharge within their facility boundary, "for newly build facilities there are complementary regional water networks for this, however, as we are old facilities, we will have to adapt the infrastructure ourselves, build stormwater harvest pipelines etc." (pers. comm. in Firm-14, 31 August 2017).

Another example of how regional infrastructure might affect firm behaviour is that in Chapter 5, it was observed that firms are reluctant to adopt large scale reclaimed water reuse systems, considering the huge initial investment and its uncertain return. But when asked about whether they are willing to use reclaimed water if it were supplied by a municipal network, the responses were largely positive, especially for firms in Beijing and cities receiving SNWTP water in Hebei, where industrial water prices have risen in recent years[139]. Also, for large consumers of industrial water, which do not have high quality requirements for some or all the water they use (for example cooling water that does not go directly into the product), reclaimed water could well serve their purposes with relatively low cost (confirmed in Firm-01, 04, 06, 07, 13, 14, 15, 19, 20, 23, 24, 25, 26, 27). Therefore, supporting regional reclaimed water reuse system would promote the adoption of alternative water use in industrial firms. And this is supported by local policies though still constrained by regional infrastructure.

> We are working on projects to build a reclaimed water system in Beijing. It is supported by current policies and the cost to use reclaimed water is low. But supporting infrastructure must be built for wide use of it.
>
> – Practitioner, water service sector, Beijing.

Centralized wastewater treatment facilities in localities are indeed useful for small firms which lack the ability to adapt infrastructure. However, for manufacturing facilities with large water consumption and waste discharge or industries that generate special pollutants, it is usually out of the municipal treatment plants' capacity; on-site treatment and recycling is more appropriate for such enterprises. On-site treatment is regarded as a clean-tech industry with disruptive potential to the dominant development logic of the wastewater sector (Truffer, Binz, Gebauer, & Störmer, 2013). Without extended networks and centralized treatment facilities, on-site treatment is more flexible and could be diversified. Beijing hosts a considerable on-site treatment industry (Binz et al., 2015). For on-site treatment in the studied firms (refer to Table 5.3), all the wastewater generating firms (except for one non-compliance firm) initiated on-site treatment. Among them, Firm-02, 04, 07, 09, 13-16, 22-30 have to build their own sewage treatment plants as their sewage

[139] Also refer to Box 7.2, where it is indicated that firms in Beijing are willing to use reclaimed water if it is provided by municipal network.

is beyond the treatment capability of municipal wastewater water treatment plant in terms of quantity or particular pollutant.

In between water supply and drainage, there is 'reclaimed water', also called 'middle water'[140] in Chinese, which is promoted by the Chinese government and requires corresponding infrastructures. In the next part of this section, I identify how recycled water could add to regional water availability; in the third part, I elaborate on recycled water and the implementation gap of such a regional strategy, mainly in infrastructure and public trust.

Infrastructure remains a major obstacle in regional water governance in both water supply and waste treatment that impact on firm behaviour as discussed before. In addition, the condition of both water supply and wastewater infrastructure differs among regions. In the study region, I observed distinctions of infrastructure between rural and urban areas (rural regions lack infrastructure in general[141]); between newly developed areas and old areas (new areas are equipped with relatively advanced infrastructure[142]); and between rich regions and poor regions (rich regions are financially more capable of infrastructure adaptation[143]).

With regional infrastructure being one of the obstacle, it is found in this research that currently, in China's water sector, the public–private partnership (PPP) mode (K. Feng & Wang, 2019) stands out in developing infrastructures. PPP is a government and social capital cooperation, as a project operation mode in public infrastructure. Under this model, private companies and capital are encouraged to cooperate with the governments and participate in the construction of public infrastructure. The PPP mode is utilized as an innovative procurement or project delivery alternative in developing public infrastructures in China over the past two decades, along with the burgeon of the country's environmental initiatives. It is widely applied in water supply and

Box 7.2 Interview on PPP project in water sector

In both water supply and wastewater treatment, there are PPP projects. Sometimes, we bundle them to a same company. The private partner is more concerned about the pricing and when can they recover the initial cost. They negotiate with us [the government] on pricing, for example, if a company wants to build and operate a water supply plant, they will negotiate with us on the price of the water they can charge to the end-user. And when their profit could not cover the cost, we will have to subsidize them. And for water project, we have to provide supporting pipe networks. For example, now in A district in Beijing there is a PPP municipal reclaimed water plant, many factories in this region want to use the reclaimed water, however, there is no water distribution network. We will have to build regional network for reclaimed water reuse for them. In the past two years, PPP has been applied to various projects, not only water projects, but also municipal engineering and landscape engineering projects.
–Official, Beijing Water Authority

[140] In China, water supply is identified as 'upper water', while drainage is identified as 'lower water'.
[141] For example, in the case of Firm-12 in Footnote 136.
[142] For example, in locality where Firm-24 is, it is a newly developed industrial area, where the industrial and domestic water networks are separated, allowing Firm-24 to get cheap industrial water.
[143] This is a general observation during the field work that in rich regions visited, regional water infrastructures are better developed.

sewage treatment, expanding regional water supply networks and centralized wastewater treatment capacities. In my study, many tap water plants, or centralized wastewater treatment facilities are PPP projects, which help water infrastructure development with marketization in this sector (Box 7.2). Though this is not the primary focus in this study, the institution and implication of PPP in water sector in China deserve further investigation with more empirical evidence.

In summary, sufficient supporting regional water infrastructure will ease the burden on water infrastructure development in enterprises, reducing firm's adaptation cost and facilitating certain technological innovations (for example, wastewater treatment). In clean water delivery, there is in general enough water with varied accessibility, price and quality[144]. While in wastewater treatment, regional infrastructure conditions also differ among regions (rural and urban, old and new, rich and poor distinction) exerting pressure on firm's own pollution control to different degree. It was found in Chapter 5 that firms' adaptation in water management is dependent on water infrastructure in their facilities. Here in this chapter regional water infrastructures are also found to exert an impact on firm's water use.

Regional water availability

In addition to local water infrastructure, regional water resource availability is another physical locality factor that influences firms' water strategies. It directly influences the amount of water a facility can acquire for production. As discussed in Chapter 5, there is a general water shortage in this region. Firms' water accessibility is constrained by regional water availability, which leads to firms' conservation practice on site, so as not to exceed the water withdrawal quota issued by local governments[145]. Water availability also differs within the study region[146]; it is indicated by all the interviewed firms in Beijing that the water quota they get from the local water authority has not much margin, whereas in Hebei, it has been indicated (by Firm-22, 24, 25, 26, 27 in particular) that there is bargaining space with the local authority over the water quota, and "they [the government] wants us to use more water, so that we can pay more bills" (pers. comm. in Firm-24, 7 November 2017)[147]. For the physical water availability in Beijing and Hebei, also refer to Chapter 4 on 'Physical water risk'. In 2016 for example, the total regional water supply is 3.51 billion cubic meters, while the total water consumption is 3.88 billion cubic meters (the deficit is

[144] For evidence, also refer to Chapter 4: 4.5 Industrial water consumption on both 'Water supply' and 'Water pricing'.
[145] Though it was argued in Chapter 4 that the 'water quota system' does not stimulate conservation innovations, firm still need to pay attention not to exceed the water quota issued by local water authority, and when issuing water quota to individual firms, local authority needs to consider the regional water availability (refer to the interview quotation on Page 55). This indicates that the regional regulation and regulator acted as a moderating role between regional water availability and firm's water use.
[146] For water availability in the study region, also refer to Chapter 4: 4.2 Water in North China on 'Physical water risk'.
[147] This has also been verified by interviews with local water supply agency that provide Firm-24's water (Interview date: 7/11/2017).

made up by inter-region water transfer) in Beijing[148]. While in Hebei in the same year, total supply and consumption are 20.83 and 18.257 billion cubic meters, respectively[149]. This regional physical availability has resulted in perception difference in firms across localities mentioned before. To counter the impact from regional water availability, in some cases, businesses outsource resource intensive production[150] or even relocate to other regions to break the constraint on water resources[151] (Table 5.1). However, as concluded in Chapter 4, pressure from regional water shortage is rather assimilated by local water authority through issuing water quota and relocate water intensive productions. There is no significant difference between Beijing and Hebei industries on adaptations to physical water availability, except for water quota leniency and policy guided industrial relocation.

Still physical water availability shapes a firm's behaviour by shaping local people's (who are also firm staff) awareness of water conservation. Firm-24 in Hebei is in a newly developed industrial area which initially had no access to fresh water:

> It felt like we were living in an isolated place, there was no water there. We used trucks to ship water here for our everyday life and production in the factory. No one dare to waste a single drop of water because we know how hard it is to get this water. Till now we still have the habit of saving water.
>
> – Field worker, Firm-24, Hebei.

Therefore, regional water availability not only poses direct physical constraint on firm behaviour, leading to strategies including technological innovation in conservation, relocation and outsourcing, but also shapes the values and attitudes of employees, which indirectly influence organizational behaviour. Firms in Beijing also reported high awareness of water conservation by their staff:

> We all know that Beijing is short of water resources, no one will waste water on purpose, especially with the increased water price every year. At home I will also reuse water in dish washing and laundry.
>
> – EHS manager, Firm-01, Beijing.

Currently in the study region, the state relies heavily on engineering measures to tackle the challenge of physical water constraints – both the gigantic SNWT and seawater desalination.

[148] Data source: Beijing Water Resources Bulletin 2016.
[149] Data source: Hebei Water Resources Bulletin 2016.
[150] Refer to the example of Firm-08 in Chapter 5: 5.3 Avoidance on 'Outsourcing'.
[151] Refer to the example of Firm-23 in Chapter 5: 5.3 Avoidance on 'Relocation' and Box 5.4.

According to an internal document[152] from one of the economic development zones in Hebei, the local government is aware that the water shortage is intensified by regional economic growth and identified it as a core factor constraining socio-economic development in its locality. Therefore, the Municipal Construction Administration Bureau has investigated the regional water balance (water supply and discharge) and proposed several measures to solve the problems. These are all engineering projects, including new diversion project, seawater desalination, sewage treatment and water reuse, surface water storage, exploration of shallow groundwater, and wastewater collection project. In addition, the local government also stated that it would apply for a larger water quota from superior government agencies, including Urban and Rural Planning Bureau, Construction Administration Bureau, Municipal Administration Bureau and so on. It seems that the local government's focus is largely on supply management, while demand management is overlooked, even though scientists and government consultants have long been proposing the concept of demand management[153] and it has appeared in various political discourses. Actions have been mild. And this (demand management) has not impact on firm-level water management according to this case study.

And as for the supply management, would a one-sided reliance on water diversion hurt water uses' incentives for conservation? According to evidence in this study, localities that use SNWTP water are all experiencing increased water prices and the amount of water each manufacturing facility can withdraw has not changed unless it is enlarging production, otherwise it is business as usual with a slight increase in water price. However, as discussed in Chapter 4, water pricing does not act to regulate industrial water consumption at the enterprise-level. Therefore, enterprise-level users' conservation incentives have not been significantly impacted by the diversion. As discussed before, the regional water pressure is assimilated by regional regulators, in the sense that if there is scarcity, the state will strengthen regulation or relocate industry. This further indicated that scale (whether on regional or firm level) should be considered when assessing scarcity[154].

Recycled water

Now in the study region and in China in general, the use of recycled water is promoted by the state as an alternative unconventional water source to increase regional water availability and is

[152] Research report on water supply balance from Municipal Construction Administration Bureau. Internal document.
[153] February 14-15, 2009, National Water Resources Working Conference was held in Guilin, Guangxi. Qian Zhengying, former vice chairman of the Chinese People's Political Consultative Conference and academician of the Chinese Academy of Engineering, was invited to attend the meeting and made an important speech on "Transition from water supply management to water demand management".
[154] As illustrated both in Chapter 4 and this chapter that though there is water scarcity in the study region on regional level, such pressure is assimilated by local government by relocating water intensive enterprise to other localities and issuing water quota to the remaining firms according to local water carrying capacity. Whereas, at firm-level, pressure from water scarcity is not significant.

supported by water resource managers, industrial sectors and researchers in China (W. Chen et al., 2015). Recycled water also requires infrastructure construction. Recycled water, which is the non-potable, greywater, or 'middle water' in Chinese, is the practice of using treated wastewater. The recycled water can be used in landscaping, irrigation, industrial processes, flushing toilets, replenishing groundwater and the like (Yi et al., 2011). There are applications of recycled water reuse in the study region, both from a centralized facility with water reused for domestic or industrial purposes[155], and from decentralized, on-site plants in industrial firms[156].

As a sustainable choice of water source, there are still some implementation gaps. One lies in infrastructure, especially for industrial users (D. Chang & Ma, 2012). Take Beijing for example: there is a lack of centralized reuse treatment plants. By the end of 2018, there were only five municipal-run centralized reuse treatment plants and the city produced just 20 per cent of its water from recycling (Neighbour, 2018). The industrial sector uses 20 per cent of the reclaimed water in Beijing (Neighbour, 2018). However, as indicated in Chapter 5, the adoption of this technology by industrial firms is path-dependent on original technological conditions and dependent on adaptation capabilities (which small firms lack). And compared with other technological innovations in water use, infrastructure required by reclaimed water reuse is complicated as a separate pipeline network needs to be built to distribute the reclaimed water for reuse, let alone the high cost for the treatment equipment and facilities. Therefore, to further promote recycled water reuse, centralized treatment facilities need to be developed.

As mentioned in Chapter 5, Firm-02 in Beijing is one of the few firms in my sample that adopted the reclaimed water reuse system. Firm-02 is a listed state-holding enterprise in the automobile sector. The facility I visited in Beijing is one of its many factories manufacturing cars and new energy vehicles. Put into operation in early 2012, it is a relatively new establishment compared with its parent firm, which has more than 30 years of history in car manufacturing. As a new subsidiary, Firm-02 inherited the well-established environmental management system from the headquarters. Water conservation is delegated to production departments as it is also a part of production cost reduction. Wastewater treatment, which is ever stricter with increasing regulations in Beijing, is outsourced to a third-party environmental service company appointed by the headquarter. As this is a newly built plant, its manufacturing technique and waste treatment technologies are advanced and able to meet government resource conservation and pollution control regulations without further adaptation, even though environmental regulations have been tightened over recent years. And the advanced reclaimed water system was adopted by Firm-02

[155] According to interviews with municipal waste treatment plants in Beijing and Hebei (Interview date: 8/7/2017 in Beijing, 7/11/2017 in Hebei).
[156] Refer to reclaimed water reuse in Firm-02 and 28, in Chapter 5 on technological innovation on Page 86-87.

when it first started building the plant. According to the staff in charge of maintaining the reclaimed water system, the whole system cost them 3 million yuan (USD 428.57 thousand), and the membrane (the major consumable item in this system) costs 8 000 yuan (USD 1142.86) each; they have to constantly change membranes to guarantee water quality. These costs are not affordable in small and medium facilities.

Therefore, though reclaimed water technique is encouraged by the state, adaptation cost prevented other firms from adopting the same technology. However, since Firm-02 is a new establishment, there is less adaptation cost. Therefore, water-related technological adaptation is a highly path dependent process, especially for techniques like reclaimed water reuse that require large scale infrastructure construction[157]. For all that, firms in my interview expressed willingness to use reclaimed water if it could be provided by the municipal water network[158] since reclaimed water is cheaper and can meet the quality requirement for most manufacturing processes. Therefore, I argue that reclaimed water reuse should be developed on regional level by the state. As a matter of fact, with increased demand for urban and industrial water use in the study area, sewage discharge is also increasing, municipal governments are investing in new sewage treatment projects to expand wastewater treatment capability (L. Lu, 2014). Many cities in the study region are also building reclaimed water plant to reuse the reclaimed water. Still new infrastructures must be built, indicating the path dependence on infrastructure.

Another problem with reclaimed water reuse lies in trust on quality. Public knowledge of reclaimed water reuse is limited, and the quality of recycled water is distrusted though it is not for drinking purpose (W. Chen et al., 2015; Z. Zhu, Wang, & Li, 2019). That explains why commercial and residential decentralized water reuse systems are failing in Beijing (Neighbour, 2018). When Beijing initially promoted reclaimed water reuse in 2003, the government mandated that all residential and commercial buildings larger than 30,000 square meters be equipped with an onsite water reuse system[159]. However, most of them remained idle now (Neighbour, 2018). For industrial users, the quality issue is less complicated than for domestic users. For one thing, general water used in production does not have such high-quality standards as domestic water (pers. comm. with Beijing Water Authority, 21 August 2017)[160]. For another, as water is used in

[157] For example, Firm-04, 07, 14, 24, 25, 26, 27 and 29 stated that they would rather do it in new facility than through reconstructing existing facility

[158] Also refer to Box 7.2, where it is indicated that firms in Beijing are willing to use reclaimed water if it is provided by municipal network.

[159] Notice of The People's Government of Beijing Municipality of issuing the planned important practical things directly related to people's lives in 2003 (北京市人民政府办公厅关于印发北京市 2003 年在直接关系群众生活方面拟办重要实事的通知), Gazette of the People's Government of Beijing Municipality 2003 (05).

[160] Also refer to 'The reuse of urban recycling water-Water quality standard for industrial uses GB/T 19923-2005' and 'The reuse of urban recycling water-Water quality standard for urban miscellaneous water consumption (GB/T 18920-2002)' in 'The reuse of urban recycling water' standard series (5 volumes).

various production processes subject to different quality standards, for certain uses there are also high quality requirement for water; for example, in Firm-03, 09 and 12 (food, wine and drug industry), water in the final product is subject to drinking water standard. However, except for those process, industrial water in processes such as cooling, slurry, or boiler does not have high quality requirements. In addition, with the advance in waste treatment techniques, the quality of reclaimed water has also been increased to meet the requirement for industrial use[161]. Still there is a distrust on quality that prevents firms from adopting this technology (W. Chen et al., 2015).

Even without the distrust on quality, the cost of reclaimed water is high[162], which prevents small firms from adopting the technique and pushes residential and commercial buildings in Beijing to abandon the built facilities. Therefore, I argue that perception towards reclaimed water should be changed and centralized reclaimed water reuse facilities be operated for both domestic and industrial uses. In addition, with the effect of scale economies, centralized water recycling could further reduce the cost of water use. Therefore, if recycling is supported by regional water infrastructure, adaptation cost by firm would be reduced. In sum, evidence in this sub-section shows that the regional condition of recycled water influences firm's technological innovation in water conservation.

Alternative water sources

With regional water availability affecting firm's water management, it has also been observed that alternative water sources have been used in the study region to make up for regional water scarcity, resulting in the adoption of alternative water sources strategies in some of the sample firms (Table 5.1). This subsection will discuss the locality factors shaping this particular strategy with the example of two particular alternative water sources, seawater desalination and stormwater harvest.

Seawater desalination

Whether firms can adopt this strategy is dependent on their locality (accessibility to seawater). In my sample, there is one firm in coastal area Hebei that adopted this technology, which will be elaborated in the following paragraphs. In terms of seawater desalination, according to a practitioner in the water industry in China, at present, seawater desalination has a capacity of over 1 million tons per day (pers. comm. 21 August 2017). Desalination is mainly adopted in coastal cities in the north for industrial consumption. There are a lot of large-scale industrial desalination projects, concentrated in water intensive industries such as electricity, iron and steel manufacturing in Tianjin, Hebei and Shandong. Among these projects, there are mainly two

[161] Refer to the interview quotation from Firm-02 on Page 86, indicating that the reclaimed water they produced is better than tap water in certain quality indicators.
[162] In both the initial infrastructure investment and the operation cost, exemplified in the case of Firm-02 introduced before.

technological approaches, namely membrane desalination and thermal desalination. For now, more applications adopt the former approach as the latter consumes more electricity. However, in some industries if there is recycled heat, the cost for the thermal approach could be significantly reduced. One such case in the study area that adopted thermal desalination will be introduced later in this section. With current technology in China, the average cost for seawater desalination comes down to 6 yuan per cubic meter. One possible approach to reduce the cost is to reduce energy consumption, which could possibly reduce the cost to 3/4 yuan per cubic meter. Some firms built their own power plant to reduce such cost. Compared with SNWT, where cost is fixed for now, there is still room to cut the cost of desalination.

For water managers of Beijing, reservoirs like the Miyun Reservoir are the primary water source, while SNWT water is considered as the second water source. And for now, southern water is the major urban water source. Desalination is planned as the third water source for Beijing.

> Further application for desalination is policy guided. Especially in water scarcity regions, supplementary water networks need to be built. It is likely to replace the SNWT in the future.
>
> – Chief engineer, Desalination plant in Hebei.

Many coastal cities in the study region are thinking of initiating seawater desalination to make up for the lack of fresh water (pers. comm. with government official Hebei, 6 November 2017). With the advance in desalination technique and reduced cost, desalination is planned to be developed as an alternative water source.

Desalination was also developed in individual firms for direct industrial consumption. Such projects are now in line with national industrial policy, encouraged in the 'Catalogue of Industrial Structure Adjustment Guidance'. Firm-23 in Hebei is engaged in iron and steel manufacturing. Built by the sea, Firm-23 has a thermal desalination facility that produces 50,000 tons of industrial water a day. Of all the 80,000 tons of daily water consumption in Firm-23, more than 60 per cent comes from seawater desalination. Now Firm-23 is planning to expand its desalination capacity and use desalinated water only, to cut water cost. As of now, the price of purchased water exceeds the cost of desalination.

The low cost in Firm-23 originated from its circular economy. Water produced by desalination enters the iron and steel smelting system and generates steam in the steel smelting equipment. The steam drives the steam turbine generator. The steam that has completed this work then enters the seawater desalination device as a heat source, and this part of the heat source passes through the heat exchange with the seawater. Evaporated seawater produces qualified desalinated water. Such recycling between liquid water and steam maximizes the use of energy. In addition, the

concentrated brine, the by-product in desalination is also utilized, as it is transported to a nearby chemical plant to be used as production material.

Stormwater harvest

Stormwater harvesting is also promoted by the government; it too requires more infrastructure (Qin, 2015). In addition to providing an alternative water source, it could also reduce sewage treatment pressure, as most current stormwater pipe networks are connected to sewage networks. But stormwater flows are not as regular as sewage flows. During abrupt precipitation periods, large amounts of stormwater rush into sewage networks, which lead the water into sewage treatment plants. When plant cannot deal with such large inflows, the water is flushed into the natural environment without treatment, introducing untreated wastewater into the environment[163]. Baoding, one of the first two pilot cities in China developing a stormwater harvest system, was visited during my field work. The interview with local officials in the Environmental Protection Bureau indicated that stormwater was not fully harvested due to the lack of infrastructure[164].

Certainly, the adaptation of existing networks is difficult and complicated. However, now for newly built factories or residential areas, it is required by the government to separate sewage networks from stormwater pipelines. While for old infrastructure, adaptation has been retarded.

> Now we are doing rain and sewage network separation to respond to policy. Our plant was built early, sewage and stormwater were not separated from each other, and they all go into the river. Now the state is initiating River Chief System and the Ministry of Environmental Protection is issuing various new regulations. We have to collect both production and domestic sewage, although the impact of domestic sewage is not significant. Before, there are quite a lot of places where the domestic sewage is directly discharged. Some areas don't even have stormwater pipelines. Stormwater just runs everywhere. And there is no room for new pipelines. So, for new construction project, we build rain pipelines according to current regulations. But for adaptation projects, sometimes it's just not feasible for the separation.
>
> – Manager, Firm-14, Beijing

Therefore, stormwater harvest in order to increase available water is also dependent on water infrastructure, and the observed regional difference (rural-urban, old-new, rich-poor) in water infrastructure also applies here. Locality in terms of physical water scarcity created the demand for alternative water sources, no matter water desalination or stormwater harvest, while it also impacts on the applicability of this strategy by firm, on whether there are supporting infrastructure.

[163] For more evidence, also refer to Box 7.1.
[164] Interview date: 16/11/2017.

In summary, regional water infrastructure and availability directly influence water use in industrial enterprises in determining the water quota (regional water carrying capacity for industrial production) and providing supporting water infrastructure (water supply, wastewater treatment, stormwater harvest, reclaimed water reuse). The way in which water is used thus determines whether certain strategies can or cannot be adopted in environmental reforms. Locality factors also indirectly impact on firms' water management by shaping corporate value and culture in water use. Through this field research, regional difference in infrastructure is also observed, not only between the two study areas of Beijing and Hebei in physical water availability, but more significantly between rural and urban, old and new, rich and poor regions in water infrastructures. In addition, the two major locality factors, water availability and infrastructure are also intercorrelated with each other, as adaptations to water availability no matter on firm or regional scale is dependent on water infrastructure.

7.3 Institutions

In this section, I identify the institutional locality factors that affect firm water management behaviour, which lead firm to adopt different strategies. Table 7.2 is an overview of such impacts; the remainder of this section details those impacts with examples from sample firms.

Table 7.2 Institution and firm strategy

Institution	Strategy	Example
Policy agenda	Technological and institutional innovation in water conservation and pollution control	In Chapter 5
Regulation enforcement	Differences between pollution control and resource conservation innovations	In Chapter 5
Institutional deficiency	Rule breaking with enforcement deficit	Firm-03, 15

Policy agenda

In Chapter 4, government water policies pertaining to corporate water management were illustrated. Water governance in China is in principle regulated by various laws, regulations, targets, standards, quotas/norms[165]. A distinction between water resource conservation and water pollution control in current water policy agenda in China has been identified (Chapter 4), which shaped firm perceptions (Table 4.2) and further resulted in firms responding differently to different policies (Chapter 5). While Chapter 4 and 5 illustrated how firms perceive and respond to water policies, this chapter about localities focuses on the distinction between policy and enforcement. Water conservation related policies are often not mandatory, with regional or national policies on water conservation often ambiguous, without specific targets for the quantity of water a region or an enterprise is supposed to conserve or for the increase in water use

[165] For details, refer to Chapter 4: 4.2 Water in North China on 'Regulatory water risk'.

efficiency (Box 4.1). Pollution control policies, on the other hand, are mandatory and in principle enforced by central and local authorities, which I will elaborate in the next subsection.

Whether for resource conservation or pollution control, policies decided at central government level are usually broad and vague. Implementation depends largely on interpretation by local governments (Box 4.1). Taking the Water Pollution Control Action Plan (State Council [2015]17 Reference Number: 000014349/2015-00042) for example, the plan issued by the State Council presents the overall goal, lists the major pollutant indicators and sets a broad action timeline with around 15,000 words for the whole nation (details refer to Box 4.1). With the central government's document alone, nothing specific can be done by local authorities, so there is task decomposition (任务分解) by local governments at different levels. At the lowest level, in some cases county level Environmental Protection Bureau, the policy is finally implemented. The interpretation of central government policy by the local governments is subject to local needs and priorities, and such fragmented governance structure may render central policy ineffective when environmental targets are not fitted squarely into the fragmented government organizations (Yifei Li, 2019). This would further lead to differences in policy enforcement across administrative regions.

In terms of the policy agenda, in addition to the resource-pollution distinction and policy ambiguity, disparity across the study region also exists. Regions are subject to distinct environmental regulations or standards, for example:

> The wastewater treatment standards in Baoding are advanced in the country. Now all drainage reaches Level 1 A, which is the most demanding in the country. Baoding's sewage treatment water is first-class in the country, and there is no such requirement in other places. Because the discharged sewage is heading to Baiyangdian. With the highest requirements for sewage treatment and the new national strategy of Xiong'an New Area, a lot of companies cannot survive in Baoding.
>
> – Official, EPB, Hebei.

In this case, industries in Baoding, Hebei are subject to strict environmental regulations due to the protection of Baiyangdian Lake in the Xiong'an New Area development[166]. This is just one example of differences in sewage treatment standards due to locality. It has been widely reported that now Beijing has the strictest environmental standards in the country, followed by Hebei (J. Feng, 2017; D. Li, 2014; Yingjiu Zhou & Zhang, 2018). Here in this research, with limited study

[166] Xiong'an New Area development plan is a national strategy in China aiming at alleviating the pressure for the capital Beijing by transferring population and capital from Beijing to Xiong'an in Hebei. To guarantee water supply for the about-to-increased population and production, Baiyangdian, a major water supply source in the Xiong'an area has to be protected.

cases, I am not trying to establish a comparison between the two study areas of Beijing and Hebei or find out which region has stricter environmental regulations. Here different regions may be subject to different factors shaping environmental policy. But what I am trying to prove here is that policy differs across locality, which will lead to differences in firms' responses[167].

One school of literature in China's environmental governance argues that the motivation for central environmental initiatives is to maintain stability as environmental degradation is causing the public to question CCP's legitimacy, resulting in ad hoc measures to mitigate social pressure. For example, the overemphasis on air pollution control, which is more likely to trigger widespread public unrest (A. L. Wang, 2013). The environmental campaigns in China are mostly focused on pollution control arena. Such campaign-style of governance (Kostka & Zhang, 2018; N. N. Liu, Lo, Zhan, & Wang, 2015; Y. Shen & Ahlers, 2019; Q. Shi, Shi, & Guo, 2020; van Rooij, Zhu, Na, & Wang, 2017) might partially explain the distinction between resource conservation and pollution control.

Fragmented governance with diverse responsibilities among different government agencies further widened this resource-pollution distinction. Firms in the study region reported more pressure from the local EPB in regulating their waste treatment than from local Water Authority in resource conservation (also refer to Table 4.2). As an official from local Water Authority in Beijing remarked,

> (On industrial water use) Water Pollution Control Action Plan is implemented by EPB, we oversee water supply, quality and quantity. Water consumption is our job, EPB won't care. Water Authority will limit the amount of water used by water users, but to be honest it is little. In addition to Water Authority and EPB, Commission of Economy and Information Technology also regulate industrial water consumption. In the assessment of Water Pollution Control Action Plan, industry is assigned to the Commission.
>
> – Official, WA, Beijing.

However, theoretically, beyond end-of-the-pipe treatment, resources conservation contributes to pollution prevention (Pearce & Warford, 1993). And the distinction in policy agenda lead to firm perception (Table 4.2) and adaptation strategy (illustrated in Chapter 5) difference in resource conservation and pollution control, resulting in more attention and adaptation to pollution control rather than resource conservation in the studies firms. Segregation of these two approaches ought to be prevented.

[167] In the field interview, firms generally reported pressure in management if local environmental regulations are tight. Also refer to Table 4.2.

Regulation enforcement

In China, the implementation of environmental regulations has long been condemned for huge gaps (H. S. Chan, Wong, Cheung, & Lo, 1995; Eaton & Kostka, 2014; Kostka & Mol, 2013; L. C. Li, 2010; R. Ran, 2013; C. Wong & Karplus, 2017). Before, this could be attributed to China's prioritization of economic development over environmental protection at both central and local levels (Jianguo Liu & Diamond, 2005). It was not until the 1980s and 1990s that central government began to address environmental protection and sustainable development issues. However, local implementation has always been sluggish as economic growth is still major criterion for China's cadre evaluation, and the frequent cadre turnover further took accountability away from local officials hampering the implementation of environmental regulations at local levels (Y. Deng, Wu, & Xu, 2019; Eaton & Kostka, 2014; R. Ran, 2013). As early as 2005, environmental criteria were first included in cadre evaluation in Decision of the State Council on Implementing Scientific Outlook on Development and Strengthening Environmental Protection (关于落实科学发展观加强环境保护的决定) issued by central government; however, in practice, whether environmental concerns play a significant part in local cadre evaluation is still under debate (Heberer & Senz, 2011). Though revision of China's Environmental Protection Law in 2015 signed environmental performance of cadre into law, the evaluation system is still in practice flawed. For one thing, environmental indicators carry small weight in the evaluation system; for another, indicator data is reported by lower level officials affiliated to the cadre that is being evaluated; such power relation casts doubt on the authenticity of evaluation data. In addition, the fragmented governance dose not only lie in the central-local politics and various vertical agencies (Lieberthal & Oksenberg, 1988); the complexity of institutional arrangement under the fragmented governance structure created inter-department or inter-jurisdiction tension (Nickum & Lee, 2006; R. Y. Wang et al., 2017) and further impairs the efficiency of policy implementation. Distinction of the implementation between resource conservation and pollution control policy is identified in this research. I will describe the phenomenon and theoretical reasons beneath it in this section; and provide empirical evidence in the next section.

With various enforcement campaigns including environmental monitoring, central environmental protection inspection, environmental protection discussion and close monitoring of polluting industries[168], enterprises are strictly regulated. Recently, aiming at water environment protection, in March 2018, the Ministry of Ecology and Environment and the Ministry of Water Resources released Programme of Action for the Environmental Protection of Nationwide Centralized Drinking Water Sources (全国集中式饮用水水源地环境保护专项行动). Soon after in May, the Ministry of Ecology and Environment started the first round of inspection nationwide

[168] For details, refer to Chapter 4: 4.2 Water in North China on 'Regulatory water risk'.

targeting at 1,586 drinking water sources in 212 prefecture-level cities and 1,069 counties. In May 2018, the Ministry of Ecology and Environment together with the Ministry of Housing and Urban-Rural Development launched a special Action for the Treatment of Black and Odorous Waters (黑臭水体整治专项行动). Resolutions for water pollution control are seen in various actions.

By contrast, in resource conservation, actions have been mild, though government has been calling for water conservation for years (C. Xia & Pahl-Wostl, 2012). One of the reasons might be the metering of water. Water quality monitoring can be done by setting monitoring points in major areas and get the overall water quality picture. For water consumption metering, every end should be monitored to calculate the consumption, adding to the difficulty of conservation governance. This metering problem is more common in rural areas, where there is no proper infrastructure for metering. Water consumption data is reported according to estimation. And this is more common in agricultural and domestic use (which consume more water in China) than industrial use. Furthermore, if China is ever going to marketize its water right and promote water trading, this issue ought to be addressed. Otherwise, when users could steal water easily, why bother trying to buy it? Theoretically, the failure of resource conservation could contribute to pollution (Pearce & Warford, 1993). In principle, conservation can be economically beneficial. There are inherent incentives of resource conservation for consumers, which helps explain the mild resource conservation policy. In addition, without mandatory regulations, conservation measures will only be adopted if it can be demonstrated that they generate net economic benefits (Turner, 2000).

With the differences in regulation enforcement in China in general and in the study regions, industrial entities reported more pressure on pollution control than on conservation (Table 4.2) and take measures to comply with related regulations (refer to Chapter 5). Firms in the study region reported compliance to water regulations to different degree. Compliance to pollution control regulations is in general good. For small enterprises, emissions violation fines compel their compliance. For large enterprises, often state-owned or foreign invested, they are more concerned about their public image and some such firms even go beyond compliance and have higher standard of wastewater treatment to reduce regulatory risk. In resource conservation, water is often conserved with the technological innovation in main production process as a side effect. There are seldom water conservation adaptations to comply with conservation policies (refer to Chapter 5 and 6).

Institutional deficiency

Defiance of water regulations, especially of pollution control regulations, is not uncommon in the study region[169]. This can be attributed to, on the one hand, improperly designed policy due to the non-participatory policy making and central-local politics; on the other hand, enforcement gaps derived from institutional deficit, governance-enterprise collusion/local protectionism.

China used to be accused of lacking strict environmental regulations. Evidence from my field study showed that with ecological modernization in China, current standards are simply too high for some small enterprises to comply with, and due to restricted enforcement power, small firms are encouraged to ignore the rule and wait for the government to spot them and die. Otherwise, they will just keep profiting without change[170].

> For a small enterprise, the revenue of the whole year won't even cover the environmental protection cost. So, now that environmental inspections are tight, many small businesses have closed their doors. They are forced to close; they won't make money.
>
> – Practitioner, water service sector, Beijing.

This exposes the defect of non-participatory policy making. The fragmented central-local relation also adds to the making of impractical environmental policies (Box 7.3).

Box 7.3 Interview on water policy

(At present in policy making) policymakers in central government rely heavily on those so-called experts. But they can be incompetent, they cannot even figure out where real pollution source lies in. Therefore, the formulated policies lack pertinence and feasibility. They propose bold and ambitious pollution reduction goal, but it cannot be realized at all. Why not? Because they are heading in the wrong direction. Even the Ministry of Environmental Protection has neglected the domestic water pollution source. They don't believe its COD could reach 500. But that is simply not true. We selected representative residential areas and got the monitor data to refute that. But the MEP doesn't believe it. Bureaucracy, what can you say? They outrank you and won't listen to you. Local governments don't have a say.

– Official, EPB, Hebei.

This case (Box 7.3) also shows that, though large corporate actors have been targeted in the ecological modernization process, the citizenry is a major polluter these days in China. As one of the practical findings, this might inform environmental governance in China that due attention meeds to be paid on domestic polluters.

As for enforcement, due to the lack of labour in environmental or water authorities, the enforcement of regulations and monitoring of firms are inadequate, resulting in the 'grasp the large, let go of the small' (Hsieh & Song, 2015) strategies.

[169] Also refer to Chapter 5 on 'Factory closure' and 'Rule breaking'.
[170] Also refer to the case of Firm-05 in Chapter 5: 5.3 Avoidance on 'Factory closure'.

> We are mainly monitoring the large emitters. We seldom go to firms that do not produce large amount of waste, not enough labour. Additionally, for some small firms that contribute pollution, they are not registered with the Industrial and Commercial Bureau, we don't even know of their existence.
>
> – Official, EPB, Hebei.

In 2013, I was told by an official in the former Ministry of Environmental Protection that the local environmental protection agencies that oversee enforcing various environmental regulations were seriously shorthanded at all levels. So, during field work in 2017, I interviewed officials in local Environmental Protection Bureaus in Beijing and Hebei:

> There are over 300 staff in my bureau, only half of them are regular employees that enjoy government welfare…There are eight environmental monitoring teams in charge of spotting and punishing enterprises operating outside the regulations. In each team, there are normally 2-3 regular employees with at least a bachelor's degree in environmental protection-related majors. While there are around 20 non-regular employees in each team. They [the non-regular employees] are usually the second generation of a local family that received a fortune as compensation from demolition because of urban development. They haven't received much higher education and their families are rich. They are just doing this job because their families don't want to see them loafing around and some of them enjoy the authority when they go out inspecting local enterprises.
>
> – Official, EPB, Beijing.

Regulatory agencies still lack the capacity to monitor and regulate industry effectively. The result is a 'grasp the large, let go of the small' strategy, leaving small firms unregulated in environmental supervision[171].

Moreover, the local political environment may foster collusion between government and enterprises, and government may tolerate misbehaviour by local enterprises[172]. This may come in as a form of local protectionism, with governments turning a blind eye to misbehaving firms. Here not only small firms, but also large firms are involved (the case of Firm-15); or personal favours (the case of Firm-03). Other cases in my empirical study also showed that firms have bargaining power on water pricing or emission violation fine with the local government. This may come as a form of local protectionism as in the case of Firm-15, or as personal favour when firm managers have personal network with local officials. This showed that in current authoritarian governance,

[171] This leads to opportunist enterprises engaging in rule breaking strategy, for evidence, also refer to Chapter 5: 5.4 Rule breaking on 'Opportunist'.
[172] For evidence, also refer to Chapter 5: 5.4 Rule breaking on 'Collusion'.

power is in the state and enterprise elites. Collusion between government and enterprise is embedded in the Chinese social and political context.

Another institutional deficit is metering[173]. Some, mostly remote, regions lack metering devices, leaving water conservation unregulated because users are not paying enough for water and government do not know exactly how much water has been used. This condition also revealed lack of motivation in resource conservation. In sum, institutional deficiencies encourage rule breaking strategies.

7.4 Conclusion

In response to the second part of research question 3 (How does locality factors exert influence on water management strategies?), this chapter explored locality factors that impact on corporate water management. Locality factors not only directly influence firm strategies but also have an indirect impact on them through shaping firm characteristics.

Major findings include the impact of physical infrastructure in a firm's locality on its water use behaviour. In the study region, at a regional level, water infrastructure directly impacts on firm water adaptation in providing supporting networks or facilities (in water supply, wastewater treatment, stormwater harvest and reclaimed water reuse). In addition to local water infrastructure, regional water resource availability is another physical locality factor that influences firms' water strategies and shape their environmental culture and value. Resorting to alternative water source is a potential way to counter regional water scarcity, but still dependent on infrastructure[174] and locality[175]. These infrastructure factors lead to firm strategies in technological innovations including building and adapting water withdrawal and wastewater treatment infrastructures, recycle and reuse, reclaimed water reuse, resorting to alternative water sources and water conservation specific technological and institutional changes.

From the institutional aspect, this study evaluated current regulations and enforcement of water governance, identifying major gaps in policy (resource-pollution distinction, policy ambiguity, disparity across the study region) as well as implementation (resource-pollution distinction, inadequate enforcement and monitoring, government-enterprise collusion, and basic water metering problem), which consequently impact on firm response to water policies and the corresponding adaptation strategies. While infrastructure factors mainly lead to technological innovation strategies in firms, institutional locality factors lead firms to technological and institutional innovation in water conservation and pollution control – though with certain differences between these two realms – and may result in rule breaking with enforcement deficit.

[173] Also refer to Table 4.5 comments from Firm 03; and Table 4.5 comments from Firm-03, 05, 08.
[174] For example, in stormwater harvest, the infrastructure for stormwater collection.
[175] For example, in seawater desalination, the geographical accessibility to seawater.

The empirical study of water management identified a distinction between resource conservation and pollution control, in policy agenda, government enforcement and corporate compliance. Now environmental governance is efficient in pollution control, though still fragmented and bureaucratic to some degree, but inefficient in resource conservation. In addition to the resource-pollution distinction, which with locality factors co-shape firm's water management, regional disparities in environmental performance across the study region are also observed. Firms in Beijing face greater regulatory scrutiny and do better in policy compliance. Cities in Hebei are also under high regulatory pressure with their proximity to Beijing. And for coastal cities in Hebei technological innovation is initiated, using alternative water resources and conserving water from conventional sources.

The previous socio-economic development mode in China resulted in inter-region and urban-rural disparity. While environmental regulations and enforcement in the study region are stricter than in other regions in China, there are also disparities within the study region: the environmental protection of Beijing is prioritized. Under the policy of General Manufacturing Relocation, resource and pollution intensive industries are relocated from Beijing to Tianjin and Hebei. According to the Beijing Municipal Commission of Economy and Information Technology, from 2013 to 2016, the government relocated or closed 1341 polluting firms (You Li, 2017). Tianjin and Hebei are made de facto pollution havens in this inter-region disparity.

On the relocation issue[176] in particular, one distinctive phenomenon might challenge the common assumption of the impact of industrial relocation on the environment. The policy-guided involuntary relocation in the study region and relocation of general manufacturing industry from Beijing to Hebei left Hebei increasingly resource and pollution intensive, as extra pressure is exerted on regional water consumption and new pollution sources are introduced. At a firm level, relocation breaks the lock-in of technology and creates a new path, which leads to innovation in water use. The environmental performance of individual relocated firms actually increased, contrary to the assumption in the Pollution Haven Hypothesis. Relocation of manufacturing plants in the study region, though coerced by the state most of the time, provides opportunities for new path creation, and environmental regulation is playing a positive role in guiding the behaviour of relocated firms. This suggests that scale (whether on regional or firm level) should be considered when evaluating the environmental impact of industrial relocation.

On a large scale, the study region has distinctive water governance compared to other regions in China. The region is subject to physical water shortage and strict environmental regulations and enforcement. Within the study region, intra-region disparity is exemplified by urban-rural, old-new, rich-poor discrepancies. In each locality urban-rural disparity still prevails with urban areas

[176] For evidence on relocation, refer to Chapter 5 on 'Relocation'.

enjoy better infrastructure condition, but, subject to severe environmental regulations (pers. comm. with EPB official, 16 November 2017). And for newly developed areas there are both sophisticated infrastructure and institutions compared to old industrial clusters due to the convergence effect and less path-dependency.

While Chapter 5 focuses more on what the firms are doing and Chapter 6 on firms' characteristics, this chapter is more on what the state is doing and how does that impact firm behaviours. Therefore, another empirical contribution of this chapter is that it offers a view of the interaction between the state (in regional water infrastructure development, water quota allocation and industrial relocation; water regulation and enforcement) and enterprise (response to state regulations) in water governance and depicts the dynamics of policy implementation and compliance. In addition, previous research, including some of the latest on water governance in China, largely focusses on agricultural water use (R. Y. Wang et al., 2018), with less work on industrial water use. Moreover, findings on relocation in this region challenge the previous common assumption that relocation to pollution haven will decrease corporate environmental performance.

This chapter contributed to the ecological modernization theory in the following ways. Firstly, it found that modernization in China is uneven in terms of the distinction between resource conservation and pollution control and the spatially unevenness. This applies at the level of policy and at the level of behaviour, since behaviour is found to be driven by policy. Secondly, it specified different types of regulations, in this case resource conservation and pollution control in the often-generalized application of ecological modernization. Thirdly, it explored both regulatory and physical drivers for corporate environmental management, especially the overlooked physical perspective in most ecological modernization studies. Fourthly, results in this chapter explicitly implied that locality and scale[177] matter in environmental governance and that differentiated governance[178] should be adopted.

[177] In terms of whether on enterprise or regional level.
[178] Governance that recognize the regional distinctions and firm heterogeneity to take targeted measures.

Chapter 8 Conclusion

8.1 Introduction

This thesis sought to understand firms' adaptation to environmental constraints through the lens of ecological modernization using the case of industrial water management in Beijing and Hebei. It took a behavioural approach to investigate water management strategies in North China industrial organizations, specifically based on empirical research in firms. It investigated how industrial firms, one of the major market actors in ecological modernization, responded to environmental regulation as well as physical constraints on water availability, particularly by analyzing firms' strategies as influenced by characteristics and locality. It contributed to understanding the ecological modernization process and demonstrated that ecological modernization is a useful tool for understanding water management.

This research characterizes firm adaptation to environmental constraints, which is different from individual or government adaptation. To understand this phenomenon, it is necessary to delve into approaches to firms' decision making, which have been covered widely in geographical, sociological, economics and management literatures. Based on those literatures, this study adopts a view of the firm that is resource-based and traces the implications of that view for an empirical design to enrich geographical understandings of corporate behaviour and the literature on adaptation of environmental stresses. This thesis builds on recent insights in ecological modernization, organizational behaviour, and economic geography on industrial upgrading, innovation, relocation, policy compliance, path dependence, governance, infrastructure, institution. In characterizing firms' responses to ecological modernization in China, the thesis focuses on firm behaviour in water management and documents some of the ways different kinds of firms are attempting to deal with intensified physical and regulatory water risks. Water governance literatures mainly focus on state initiatives, characterizing government management, while in this research I investigated water management from the perspective of firm, the one that is being regulated, and entangle the interplay of a variety of actors involved in this dynamic. In addition, previous studies on regions and firm performance are mostly concentrated on innovation within firms or about profitability, or other measures of economic development. There is little about resource use. Drawing on literature of regional impacts on firm performance, this study established links between resource use and firms within regions, contributing to both firm performance and geographical literature.

This final chapter summarizes this thesis. The chapter provides specific and reasoned answers to the research questions. The theoretical and practical contributions of this research are presented. Finally, some brief further research agendas are proposed.

8.2 Thesis summary

In this thesis, I examined industrial water management in North China. I categorized firm-level water management strategies regarding resource and regulation constraints and explored how firm characteristics and locality factors affect corporate water management. The primary aim is to determine: Is ecological modernization a useful tool for understanding water management in China? To address this aim, three secondary questions are asked.

> What is physical and regulatory water availability in northern China?
>
> What do industrial firms do to manage water?
>
> How do firm characteristics and locality factors exert influence on water management strategies?

In order to understand the issue in question, the literature on ecological modernization, organizational behaviour, evolutionary economic geography was systematically reviewed, together with appropriate empirical studies on water management, to lay a theoretical foundation for my inquiry (Chapter 2). The analytical framework developed in this thesis uses the resource-based view to explain firm level adaptations to changes in water availability, by regarding a firm's ability to adapt to the change as one of its internal resources that increase the firm's competitive advantage. While management theory is the main tool used to analyze firms' strategies in water management, evolutionary economic geography concepts are also applied to explore firm heterogeneity and regional differences. I constructed an analytical framework that emphasises firm characteristics and locality factors in the account of firm behaviour. Within this framework, on the micro-scale, within an individual firm, I probed the micro-routines of the organization, while on the macro-scale, I investigated how the institutions of territories played a part in formulating firm characteristics and influencing firm behaviour; and how sectors and networks are evolving in the locality, including the coevolution of firms, technologies and territorial institutions. This analytical framework acknowledges the complexity of the manner in which firm characteristics and locality shape firm strategies.

Empirical research was conducted with a case study in Beijing and Hebei (Chapter 3). The methods used are primarily qualitative: semi-structured interviews and direct observation, supported by secondary data collection. The empirical evidence mainly derived from my field work during 2017-2018. In sum, 30 manufacturing firms from 18 sectors were studied. A total of 53 people, mainly from those manufacturing firms was interviewed. Government officials, practitioners from the environmental service sector and scholars were also interviewed. The data gathered in the interviews were complemented with background information about the specific firm and the sector it belongs to.

Four key findings in response to the research questions are presented.

Firstly, it is found that North China industries are faced with both physical and regulatory water stress (Chapter 4). Regional physical water scarcity has been alleviated by the SNWT to some extent. The impact of SNWT is mainly exerted at a regional level, in terms of regional water availability/water carrying capacity/water security: SNWTP water is introduced to enlarge the regional water supply. However, industrial users are not substantially influenced by the water transfer. With regional restrictions on the development of new factories and industrial relocation, governments have guaranteed the water supply for existing facilities, making them less constrained by the current physical water resources. From a regulation perspective, governments in this region rely on pricing and location policy to manage or shift demand. However, the current price fails to regulate industrial consumption. The second regulatory tool is industrial relocation in the study region. This prioritizes Beijing's needs, aiming to transform its economy from resource-driven to efficiency-driven; and from a large city economy to a capital city economy[179]. The third regulatory tool is environment regulation, which forces firms in both Beijing and Hebei to face the need for environmental upgrading. While examining water stress in the region, a distinction between resource conservation and pollution control policy was identified. Water conservation related policies are often not mandatory; regional or national policies on water conservation are often ambiguous, without specific targets for the quantity of water a region or an enterprise is supposed to conserve or for the increase in water use efficiency. Such water conservation-related policies are soft regulations. Pollution control policies, on the other hand, are hard regulations – mandatory and in principle enforced by central and local authorities.

Secondly, the thesis investigated firms' adaptation to resource constraints and environmental regulations under the current ecological modernization process in China, which is characterized by large-scale industrial transformation through industrial upgrading, technological advancement or developing new industries. This investigation (Chapter 5) was in response to research question 2 'What do industrial firms do to manage water?' Firm-level adaptations that feature either upgrading or downgrading are identified. Strategies include innovation, avoidance through relocation, outsourcing or factory closure, and rule breaking. Innovations, both technological and institutional, help with policy compliance, and some firms go beyond compliance towards proactive environmental behaviour through innovation. However, this process is constrained by firm capability and orientation, and depends on routine practices. Relocation features involuntary relocation from Beijing to Hebei imposed by the state; such relocation introduced higher demand for water consumption and new pollution sources to Hebei. At the firm level, relocation in the

[179] Ease Non-Capital Function of Beijing and Promote Coordinated Development of Beijing-Tianjin-Hebei (疏解非首都功能 推进京津冀协同发展), The People's Government of Beijing Municipality. http://www.beijing.gov.cn/ywdt/zwzt/sjfsdgn/ (Last accessed: 30 March 2020).

form of creative destruction broke the technological lock-in, as new investment stimulated innovation and improved water use performance. Outsourcing is another strategy to reduce water risk for enterprises in global production networks. For some firms, especially small size/scale firms, the lack of adaptation capability leads to factory closure. Resistance through rule breaking is also observed, facilitated by institutional deficit and government-enterprise collusion. Moreover, the policy-level distinction between resource conservation and pollution control, identified in Chapter 4, leads to differences in firm behaviour observed in this chapter. Pollution control strategies in sample firms are driven by relevant polices, while improved water conservation performance often come as a side effect of technological innovation.

Thirdly, in Chapter 6, the thesis investigated the strategies taken in different types of firms, to respond to the third research question. The principal characteristics analyzed were ownership, size/scale, financial status, market position and sectoral characteristics, all of which have an impact on the incentives and capability of firms to adapt. The major internal firm characteristics driving factors identified in this chapter are ownership and scale. While ownership has more to do with the incentive for CEM, scale adds to the capability of CEM. During the exploration of internal factors that affect firm response, it was found that it is imperative to consider firm characteristics when designing environmental regulations and take the heterogeneity of characteristics into consideration to avoid the one-size-fit-all type of policy. Moreover, results in this chapter also showed that SOEs in this research tend to possess the characteristics (often large-scale, profitable, listed, reputation sensitive with some in environmental sensitive sectors) that drive proactive environmental strategies; this finding challenges previous characterizations of Chinese SOE as a resistance force in environmental governance.

Fourthly, Chapter 7 completed the response to research question 3 by examining the locality factors that affect corporate water management. It was found that in the study region, at a regional level, water infrastructure directly impacts on firms' water adaptation by providing supporting networks or facilities (in water supply, wastewater treatment, stormwater harvest and reclaimed water reuse). Currently in the study region, at a regional level, to facilitate firm's water use, it is important to improve water performance by further infrastructure development; for example, separating domestic water pipelines from industrial water pipelines, separating stormwater from sewage in the drainage system and building municipal reclaimed water systems. In addition to local water infrastructure, regional water resource availability is another physical locality factor that influences firms' water strategies and shapes their environmental culture and value. Resorting to alternative water source is a potential way to counter regional water scarcity, but still dependent on infrastructure and locality. Institutionally, localities also differ in terms of their regulations and enforcement of water governance, leading to identifiable differences in the effectiveness in industrial water management and major gaps in policy (e.g. resource-pollution distinction, policy

ambiguity, disparity across the study region) as well as implementation (e.g. resource-pollution distinction, inadequate enforcement and monitoring, government-enterprise collusion, and basic water metering problem), which consequently impact on firm response to water policies and the corresponding adaptation strategies. The empirical study of water management institutions also confirmed the distinction between resource conservation and pollution control in policy agenda, government enforcement and corporate compliance. On a regional scale, the locality of the study region is distinctive compared to other regions in China with its physical water shortage, strict environmental regulations and enforcement. Within the study region, inter-region disparity also exists exemplified by urban-rural, old-new, rich-poor discrepancies.

8.3 Contribution to knowledge

After answering the three research questions in the previous section, this section discusses the primary research question: Is ecological modernization a useful tool for understanding water management in China? This thesis explored industrial water management at a firm-level through the lens of ecological modernization and found that ecological modernization reflects both current environmental as well as institution changes and firm adaptations.

In contrast to the theoretical development of ecological modernization, with relatively little research at the firm scale, this study approached the ecological modernization in China from the point of view of firms to understand the relationship between ecological modernization and business practices and reveal a way forward towards ecological modernization. It offered contextualized information to reflect on ecological modernization theory and its application in China. It investigated firms' responses to ecological modernization in China with specific attention to technological advancement/environmental innovation in manufacturing enterprises, the environmental service sector and R&D institutions – all in the context of environmental policy and compliance (regulating the firm). The thesis found that policy must align environmental management approaches to the manner in which firms respond, and that different kinds of regulations matter, as exemplified in the distinction between resource conservation (soft regulation) and pollution control (hard regulation). Furthermore, starting from firm perspective, the thesis reflected on environmental governance in China through the lens of ecological modernization theory.

Following the approach developed by Mol (2006), I examined ecological modernization in China from the perspectives of political modernization, economic actors and market dynamics, civil society and international integration. I found that political modernization, while reforming environmental institutions and strengthening local enforcement, is also creating divergent interests between central and local government through decentralization. In many localities, environmental interests are not internalized. In exploring enterprise behaviour, this thesis

examined how different types of firms articulate environmental interests. On state-enterprise interaction, the thesis found that the current model of environmental governance needs to be changed in this region to promote innovation and environment-friendly behaviour. In one direction, environmental governance should depend less on top-down policy instruments (e.g. command and control), which require an already-insufficient supervision force; bottom-up instruments, including economic incentives and voluntary agreements, could encourage the uptake of environmental norms and values by individuals and firms. In another direction, improved public awareness of water conservation and pollution (repeatedly mentioned by interviewees) and increased use of public reports on firm behaviour could reduce the supervision burden. Empirical study at the facility level did not observe significant impact from civil society actors; however, international integration is playing a huge part in driving corporate water management.

Since previous ecological modernization applications in China are mostly empirical without substantial theoretical development, this thesis critically contributed to existing ecological modernization theory: existing theory is too general since it fails to differentiate water from other environmental elements, pollution control from resource conservation, separate localities and different industries. And in contrast to the overwhelming focus of ecological modernization on political institutions, this research emphasized responses from enterprises. In addition, former studies of ecological modernization focus on the conceptualization of ecological modernization or on its discourses. By contrast, this thesis focuses on the detail – of environmental policies being implemented and state-corporate interactions. Moreover, this study revealed the unevenness in China's ecological modernization, in the sense of the distinction between resource conservation and pollution control and the spatial unevenness (across region, between urban and rural, old and new, rich and poor locals) which applies at the level of policy as well as at the level of behaviour, since behaviour is found to be driven by policy.

In applying and developing ecological modernization theory, this thesis employed concepts from organizational behaviour and evolutionary economic geography. While previous research on organizational behaviour and evolutionary economic geography pays less attention to firm-level environmental management, this case study filled those gaps in current organizational behaviour and evolutionary economic geography literatures.

First, consider the application of organizational behaviour to the ecological modernization framework. With organizational behaviour theory being the major guide for analyzing firm behaviour, from a resource-based view, analysis in this thesis explained how firm capability (resource) mediates the relationship between firm characteristics and firm environmental management behaviour and explored how different types of firm internalize external

environmental pressures and generate various proactive, reactive or resistive environmental practices. The resource dependent theory of firms explained firms' dependency on external stakeholders including state, market, international, industrial community stakeholders etc., which also shape firms' adaptation capability and orientation. The attention-based view further explained firm adaptation orientation from the perspective of managers' perception. In a word, from an organizational behaviour perspective, the thesis found that firm characteristics determined the capability and orientation of corporate environmental management. This is consistent with ecological modernization theories of state, market and international integration in shaping firm's capability and orientation in ecological modernization. While organizational behaviour theories focus on individual organizations in terms of their internal resources and capability and dependence on external resources (including external organizations/stakeholders), ecological modernization theory offers a more comprehensive insight into the interaction with other stakeholders (including various state, market or international stakeholders) in promoting environmental innovation. Therefore, this study achieved a combination of organizational behaviour and ecological modernization theories in analyzing firm-level adaptation to environmental constraints.

Firm heterogeneity and institutional context are often neglected in the traditional analyzes of Chinese manufacturing based on evolutionary economic geography. This thesis, by taking firm characteristics and locality factors into consideration, generated a more comprehensive understanding of firm behaviour. This thesis also contributes to the application of evolutionary concepts in enterprise-level environmental management in a non-Anglo-American context. It finds that water management in Chinese industrial firms is highly path dependent. Regular industrial users pay scant attention to water, with the water quota system as the primary institution managing water supply. Industrial consumption is routine unless firms are enlarging production and therefore need to apply for extra quota. Adaptations to regulatory risk are also dependent on previous technological and institutional conditions. In the end, environmental performance is often improved as a by-product of technological innovations in production, while relocation, on the other hand, breaks the lock-in of technology and creates a new path, which leads to innovations in water use. Therefore, relocation of manufacturing plants in the study region, though coerced by the state most of the time, provides opportunities for new path creation. Further, the empirical findings on relocation challenge the common belief that environmental performance decreases during relocation to pollution havens, suggesting that scale (firm vs. region) should be considered when evaluating the impact of relocation.

Building on Zhu et al.'s heuristic analytical framework to investigate the effect of environmental regulation on firms' strategies, this study proposed an extended framework, not only suitable for investigating the impact of environmental regulation (one of the locality factors) on firm

behaviour, but also for analyzing firm environmental behaviour in general. The case study is just in one region, of course, and does not imply any unified conclusion on environmental governance in China: indeed, my analytical framework indicates that, in addition to firms' own characteristics, their locations also lead them onto divergent paths. In summary, this research contributes to a holistic view of the complexity of firm strategy in environmental management, taking firm characteristics and locality factors into account. Firms' water use adaptation is subject to constraints that arise from infrastructure and institutions inside and outside firms. The result is a picture of firm behaviour in water management which is co-shaped by the firm's own natures and attributes as well as the institutions of territories: knowledge, technologies and infrastructure co-evolve in firms and territories.

8.4 Research implication

In the previous section, with the overarching conclusion of this thesis on the applicability and development of ecological modernization, contributions to other conceptual areas including organizational behaviour and path dependence are also made. Moreover, through this specific case, there are some interesting and novel observations, which will be summarized in this section.

Firstly, this study explored water management from firms' perspective, which fills a gap in the literature on firm adaptation and CEM, in which water is scarcely studied. It is found that corporate water adaptation was a highly path dependent process – depending on physical infrastructure and historical institution. In addition, with the case of water management, I also identified a distinction between resource conservation and pollution control. Environmental performance includes both resource consumption and pollution production (Gauthier, 2005; Q. Zhu & Sarkis, 2004). Among firms in the North China region, which can be extended to the whole country I suspect, more attention has been paid to pollution control than to resource conservation. On the policy level alone, resource conservation policies are often marked as 'recommended', while pollution control policies are mandatory and in principle enforced by central and local authorities. This is in line with Williamson and Lynch-Wood's (2012) argument that different forms of regulation can be used in different ways in ecological modernization and generate different outcomes. The distinction between resource conservation (soft regulation) and pollution control (hard regulation) in contemporary Chinese environmental management also constitutes a further research agenda. And while this study mainly serves to identify this distinction, the antecedents and implications of this phenomenon need to be further researched.

Secondly, this study contributes to the environmental governance literature mainly in the following two respects. 1) The results about firm characteristics driving behaviour indicate that ownership matters in current corporate environmental management in China. This study explored SOE's role in environmental governance in particular. Results showed that Chinese SOEs are

reactive and some are proactive in response to environmental regulations; both technological and institutional innovations were initiated in SOEs to reduce resource consumption and produce less pollution. Along with the exploration of firm behaviour in water management, both internal and external factors that motivate CEM were identified. Evidence showed that SOEs in the study region had internalized environmental externalities. Other than ownership, there are other firm characteristic factors that influence CEM, including size/scale, financial status, market position, and sectoral character. SOEs own most of the characteristics that tend to drive CEM; therefore, now SOEs are taking the lead in CEM in the study region. 2) In terms of the interplay of a variety of actors in environmental governance, this study mainly examined the role of enterprise and the state along with their interactions. Results showed that in the state-led ecological modernization process, other actors need to be institutionalized into the system and for enterprises particularly, economic incentives need to be given to enforce environmental implementation; a shift away from the command and control approaches is still imperative.

Moreover, this study explored a specific area in environmental management, with water as the environmental element under investigation. Thus, the thesis contributes to the literature about China's construction of water market and to the scarce studies on industrial water pricing. The so-called water market in China (no matter whether water trades or the SNWT) now functions to allocate water between regions/government units at fixed prices. It is equivalent to a compensated reallocation scheme, but by no means a buy-and-sell market. It is, in essence, a transfer within state jurisdictions, without large-scale infrastructure construction. This is still a long way from a truly liberal water market; for now, water governance in China is by no means neoliberal. However, the PPP mode examined though the case of regional water management (PPP water supply/wastewater treatment plants) is a real market mechanism and deserves further research.

This thesis also contributed to the SNWT literature in the sense that previous researches tend to argue that with the SNWT and increased regional water availability, the incentive for water conservation among water users would decrease. However, from this case, water availability for individual enterprise has not changed much, as changes have been assimilated on the regional level. This also challenges the scarcity discourse as there are no scarcity at the facility level, indicating that scale should be considered in assessing scarcity. And when there is not much physical scarcity to drive conservation, regulations play the major role, which diverts the regional pressure back again onto individual water users. Understanding such mechanisms of scarcity transfer would help inform water governance. And to truly promote the transition from supply management to demand management, resort should be turned from water diversion projects to the adjustment of industrial layout to reduce demand. In doing so, public and businesses value and behaviour ought to be reshaped towards sustainable water usage.

Finally, this research leads to an explicit conclusion about the overall changes in the spatial patterns of water availability in China as a result of the SNWTP. Specifically, instead of a North vs. South divide based primarily on physical availability constraints, there are now more complex spatial disparities associated with primarily regulatory availability and a range of both environmental and political conditions in each locality. My findings on firm strategies also show how firms are responding to this changing geography of water availability.

8.5 Further research agenda

This section considers some of the limitations and possible extensions of this research.

This thesis explored firms' responses to environmental constraints in Beijing and Hebei in North China, one of the coastal industrialized areas in China. Other regions in China, with different geographical, economic and political contexts, may experience different dynamics. Research in different localities may help generalize the findings in this research. The analytical framework is not confined to this region or the firm strategies and drivers identified in this thesis. Therefore, applying this framework in other geographical or regulatory settings constitutes another future research agenda. In addition, due to limited accessibility to firms, this study only covers 18 industrial sectors in Beijing and Hebei; this is important because sectoral characteristics influence CEM. Including more industry sectors may enhance this research. Moreover, relying on qualitative methods, this research problem could be complemented by quantitative data that could help to verify or generalize the findings on a larger scale. Furthermore, qualitative or quantitative research focusing on one sector may also help to characterize firm adaptation in detail.

Taken together, this thesis also suggested several other avenues for future research. Firstly, beyond firms' responses to ecological modernization and state-corporate relationships, there are various other actors in the landscape of environmental governance. This thesis mainly investigated China's environmental governance from state-corporate perspectives; other actors, including ENGOs, media, citizenry, and interactions among different actors need attention. For example, in regulating firms, media attention exerts an impact on corporate environmental performance (Deephouse, 2000; Z. Zhou, Zhang, Wen, Zeng, & Chen, 2018). What is more, from the perspective of the firm, stakeholders including government (local environmental state, local government), market (customers, shareholders, industry associations), and civil society (community via legal actions, media organizations, and community via other means) also exert an impact on corporate environmental management practices (Yee et al., 2013). Either from environmental governance or CEM theory, the stakeholders are similar, and their behaviour deserves due attention to better understand ecological modernization and firm responses.

Secondly, this thesis considered industrial water use, which is the major source of water pollution. However, the other types of water consumption, agricultural and domestic water use, are also

worth exploring. Agricultural water consumption is still the largest water consuming sector in China, and agricultural non-point source pollution from fertilizer or pesticide use also contributes greatly to water pollution. I also found in this research that domestic/household water pollution is a major source of water pollution nowadays[180]. However, attention on domestic water pollution either from the policymakers or researchers is lacking (pers. comm. with EPB official, 16 November 2017)[181]. Therefore, research on individual/household behaviour on domestic water use also deserves scholarly attention to fill this gap in our understanding of water consumption and pollution in water governance. Furthermore, studies of the water utility sector (public utility)/water industry in particular is another promising research area in water governance.

Finally, this study applied ecological modernization theory in China and examined firms' responses to environmental and regulatory constraints. In the next phase, I plan to engage in not only larger scale research in China, but also international comparison to draw some more generalized conclusions on firms' responses to environmental constraints.

[180] Refer to Box 7.3, "Even the Ministry of Environmental Protection has neglected the domestic water pollution source. They don't believe its COD could reach 500. But that is simply not true. We selected representative residential areas and got the monitor data to refute that. But the MEP doesn't believe it." Local experience showed increased domestic water pollution level (demonstrated in high COD concentration), without central MEP attention. In addition, other research also showed that since 2005, domestic and agricultural wastewater began to become the main source of water pollution in China (Yingfeng Li, Zhang, & Liu, 2006).

[181] Other research also showed that compared with non-point source pollution from agriculture and domestic sources, it is easier for local governments to effectively control point source pollution from industry (Kahn, Li, & Zhao, 2015).

References

Abbott, M., & Cohen, B. (2009). Productivity and efficiency in the water industry. *Utilities Policy, 17*(3), 233-244.

Allcott, H., & Mullainathan, S. (2010). Behavior and energy policy. *Science, 327*(5970), 1204-1205.

Andersen, M. S., & Massa, I. (2000). Ecological modernization—origins, dilemmas and future directions. *Journal of Environmental Policy & Planning, 2*(4), 337-345.

Anonymous. (2014). A canal too far; water consumption. *The Economist, 412*(8906), 44-45.

Aragón-Correa, J. A., & Sharma, S. (2003). A contingent resource-based view of proactive corporate environmental strategy. *Academy of Management Review, 28*(1), 71-88.

Arthur, W. B. (1989). Competing technologies, increasing returns, and lock-in by historical events. *The Economic Journal, 99*(394), 116-131.

Aviso, K. B., Tan, R. R., Culaba, A. B., & Cruz Jr, J. B. (2011). Fuzzy input-output model for optimizing eco-industrial supply chains under water footprint constraints. *Journal of Cleaner Production, 19*(2-3), 187-196.

Bai, X., McPhearson, T., Cleugh, H., Nagendra, H., Tong, X., Zhu, T., & Zhu, Y.-G. (2017). Linking urbanization and the environment: Conceptual and empirical advances. *Annual Review of Environment and Resources, 42*(1), 215-240.

Banchongphanith, L., & Kaneko, S. (2009). *Urbanization and water use situation in Beijing, China - an evidence from water production and supply sector*. Boca Raton: Crc Press-Taylor & Francis Group.

Barnett, J., Rogers, S., Webber, M., Finlayson, B., & Wang, M. (2015). Transfer project cannot meet China's water needs. *Nature, 527*(7578), 295-297.

Barney, J. (1986). Strategic factor markets: Expectations, luck, and business strategy. *Management Science, 32*(10), 1231-1241.

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management, 17*(1), 99-120.

Barney, J., Ketchen, D. J., & Wright, M. (2011). The future of resource-based theory: Revitalization or decline? *Journal of Management, 37*(5), 1299-1315.

Barney, J., Wright, M., & Ketchen, D. J. (2001). The resource-based view of the firm: Ten years after 1991. *Journal of Management, 27*(6), 625-641.

Barringer, B. R., & Harrison, J. S. (2000). Walking a tightrope: Creating value through interorganizational relationships. *Journal of Management, 26*(3), 367-403.

Baylis, R., Connell, L., & Flynn, A. (1998a). Company size, environmental regulation and ecological modernization: Further analysis at the level of the firm. *Business Strategy and the Environment, 7*(5), 285-296.

Baylis, R., Connell, L., & Flynn, A. (1998b). Sector variation and ecological modernization: Towards an analysis at the level of the firm. *Business Strategy and the Environment, 7*(3), 150-161.

Berger, G., Flynn, A., Hines, F., & Johns, R. (2001). Ecological modernization as a basis for environmental policy: Current environmental discourse and policy and the implications on environmental supply chain management. *Innovation: The European Journal of Social Science Research, 14*(1), 55-72.

Berkhout, F., Hertin, J., & Gann, D. M. (2006). Learning to adapt: Organisational adaptation to climate change impacts. *Climatic Change, 78*(1), 135-156.

Berrittella, M., Hoekstra, A. Y., Rehdanz, K., Roson, R., & Tol, R. S. (2007). The economic impact of restricted water supply: A computable general equilibrium analysis. *Water Research, 41*(8), 1799-1813.

Berrone, P., & Gomez-Mejia, L. R. (2009). Environmental performance and executive compensation: An integrated agency-institutional perspective. *Academy of Management Journal, 52*(1), 103-126.

Binz, C., Truffer, B., & Coenen, L. (2015). Path creation as a process of resource alignment and anchoring: Industry formation for on-site water recycling in Beijing. *Economic Geography, 92*(2), 172-200.

Boons, F. (1997). *Organisatieverandering en ecologische modernisering: Het voorbeeld van groene produktontwikkeling*. Paper presented at the the Dutch NSV conference.

Boschma, R., & Capone, G. (2016). Relatedness and diversification in the European Union (EU-27) and European neighbourhood policy countries. *Environment and Planning C: Government and Policy, 34*(4), 617-637.

Boschma, R., & Frenken, K. (2006). Why is economic geography not an evolutionary science? Towards an evolutionary economic geography. *Journal of Economic Geography, 6*(3), 273-302.

Boschma, R., & Martin, R. (2010). The aims and scope of evolutionary economic geography. In *Handbook of evolutionary economic geography* (pp. 3-39). UK: Edward Elgar Publishing Limited.

Bourlakis, M., Maglaras, G., Aktas, E., Gallear, D., & Fotopoulos, C. (2014). Firm size and sustainable performance in food supply chains: Insights from Greek SMEs. *International Journal of Production Economics, 152*, 112-130.

Boxer, B. (2001). Contradictions and challenges in China's water policy development. *Water International, 26*(3), 335-341.

Breschi, S., & Lissoni, F. (2001). Knowledge spillovers and local innovation systems: A critical survey. *Industrial and Corporate Change, 10*(4), 975-1005.

Buchanan, D. A. (2019). *Organizational behaviour*. Essex, England: Pearson UK.

Bulkeley, H. (2001). No regrets? Economy and environment in Australia's domestic climate change policy process. *Global Environmental Change, 11*(2), 155-169.

Buttel, F. H. (2000). Ecological modernization as social theory. *Geoforum, 31*(1), 57-65.

Cai, B., Bo, X., Zhang, L., Boyce, J. K., Zhang, Y., & Lei, Y. (2016). Gearing carbon trading towards environmental co-benefits in China: Measurement model and policy implications. *Global Environmental Change, 39*, 275-284.

Cao, K., Ge, Z., Xue, M., & Song, Y. (2009). Analysis of urban rain island effect in Shanghai and its changing trend (in Chinese). *Water Resources and Power, 27*(5), 31-33, 54.

Caprotti, F., Springer, C., & Harmer, N. (2015). 'Eco' for whom? Envisioning eco-urbanism in the Sino-Singapore Tianjin eco-city, China. *International Journal of Urban and Regional Research, 39*(3), 495-517.

Carolan, M. S. (2004). Ecological modernization theory: What about consumption? *Society and Natural Resources, 17*(3), 247-260.

Chan, H. S., Wong, K.-k., Cheung, K., & Lo, J. M.-k. (1995). The implementation gap in environmental management in China: The case of Guangzhou, Zhengzhou, and Nanjing. *Public Administration Review, 55*(04), 333-340.

Chan, R. Y. (2010). Corporate environmentalism pursuit by foreign firms competing in China. *Journal of World Business, 45*(1), 80-92.

Chang, C.-H. (2011). The influence of corporate environmental ethics on competitive advantage: The mediation role of green innovation. *Journal of Business Ethics, 104*(3), 361-370.

Chang, D., & Ma, Z. (2012). Wastewater reclamation and reuse in Beijing: Influence factors and policy implications. *Desalination, 297*, 72-78.

Chao, P., Yin, H., & Ma, C. (2009). International integration: A hope for a greener China? *International Marketing Review, 26*(3), 348-367.

Chen, Q. (2011). A brief analysis of the problems existing in the ecological environment of Baiyangdian waters and countermeasures (in Chinese). *Science & Technology Information*(08), 382.

Chen, W., Bai, Y., Zhang, W., Lyu, S., & Jiao, W. (2015). Perceptions of different stakeholders on reclaimed water reuse: The case of Beijing, China. *Sustainability, 7*(7), 9696-9710.

Chen, Y.-S. (2008). The positive effect of green intellectual capital on competitive advantages of firms. *Journal of Business Ethics, 77*(3), 271-286.

Chen, Z., & Le, T. (2018). Rule of law on the comprehensive governance of 'dispersed, disrupted and polluted' enterprises (全面推进“散乱污”企业综合治理的法治观察). *Greenleaf*(9), 36-42.

Cheng, H., Hu, Y., & Zhao, J. (2009). Meeting China's water shortage crisis: Current practices and challenges. *Environmental Science and Technology, 43*(2), 240–244.

Child, J., & Tsai, T. (2005). The dynamic between firms' environmental strategies and institutional constraints in emerging economies: Evidence from China and Taiwan. *Journal of Management Studies, 42*(1), 95-125.

Christmann, P., & Taylor, G. (2001). Globalization and the environment: Determinants of firm self-regulation in China. *Journal of International Business Studies, 32*(3), 439-458.

Christoff, P. (1996). Ecological modernisation, ecological modernities. *Environmental Politics, 5*(3), 476-500.

Chu, X., Deng, X., Jin, G., Wang, Z., & Li, Z. (2017). Ecological security assessment based on ecological footprint approach in Beijing-Tianjin-Hebei region, China. *Physics and Chemistry of the Earth, Parts A/B/C, 101*, 43-51.

Copeland, B. R., & Taylor, M. S. (2004). Trade, growth, and the environment. *Journal of Economic literature, 42*(1), 7-71.

Costanzo, M., Archer, D., Aronson, E., & Pettigrew, T. (1986). Energy conservation behavior: The difficult path from information to action. *American Psychologist, 41*(5), 521-528.

Crow-Miller, B. (2015). Discourses of deflection: The politics of framing China's south-north water transfer project. *Water Alternatives, 8*(2), 173-192.

Crow-Miller, B., Webber, M., & Molle, F. (2017). The (re) turn to infrastructure for water management? *Water Alternatives, 10*(2), 195-207.

Cui, X., Wu, X., He, X., Li, Z., Shi, C., & Wu, F. (2018). Regional suitability of virtual water strategy: Evaluating with an integrated water-ecosystem-economy index. *Journal of Cleaner Production, 199*, 659-667.

Cushing, K. K., Wise, P. L., & Hawes-Davis, J. (1999). Evaluating the implementation of cleaner production audit demonstration projects. *Environmental Impact Assessment Review, 19*(5-6), 569-586.

da Silva Monteiro, S. M., & Aibar-Guzmán, B. (2010). Determinants of environmental disclosure in the annual reports of large companies operating in Portugal. *Corporate Social Responsibility and Environmental Management, 17*(4), 185-204.

Daily, B. F., & Huang, S.-c. (2001). Achieving sustainability through attention to human resource factors in environmental management. *International Journal of Operations & Production Management, 21*(12), 1539-1552.

Danneels, E. (2002). The dynamics of product innovation and firm competences. *Strategic Management Journal, 23*(12), 1095-1121.

Darnall, N., & Edwards Jr, D. (2006). Predicting the cost of environmental management system adoption: The role of capabilities, resources and ownership structure. *Strategic Management Journal, 27*(4), 301-320.

Darnall, N., Henriques, I., & Sadorsky, P. (2010). Adopting proactive environmental strategy: The influence of stakeholders and firm size. *Journal of Management Studies, 47*(6), 1072-1094.

Dasgupta, S., Laplante, B., Mamingi, N., & Wang, H. (2001). Inspections, pollution prices, and environmental performance: Evidence from China. *Ecological Economics, 36*(3), 487-498.

Dasgupta, S., Wheeler, D., & Huq, M. (1997). *Bending the rules: Discretionary pollution control in China*. New York: The World Bank.

De Groot, H. L., Verhoef, E. T., & Nijkamp, P. (2001). Energy saving by firms: Decision-making, barriers and policies. *Energy Economics, 23*(6), 717-740.

De Jong, M., Chen, Y., Joss, S., Lu, H., Zhao, M., Yang, Q., & Zhang, C. (2018). Explaining city branding practices in China's three mega-city regions: The role of ecological modernization. *Journal of Cleaner Production, 179*, 527-543.

DeCanio, S. J. (1993). Barriers within firms to energy-efficient investments. *Energy Policy, 21*(9), 906-914.

DeCanio, S. J. (1998). The efficiency paradox: Bureaucratic and organizational barriers to profitable energy-saving investments. *Energy Policy, 26*(5), 441-454.

Deephouse, D. L. (2000). Media reputation as a strategic resource: An integration of mass communication and resource-based theories. *Journal of Management, 26*(6), 1091-1112.

Deng, G. (2010). The hidden rules governing China's unregistered NGOs: Management and consequences. *China Review, 10*(01), 183-206.

Deng, Y., Wu, Y., & Xu, H. (2019). Political turnover and firm pollution discharges: An empirical study. *China Economic Review, 58*, 101363.

Dent, C. M. (2015). China's renewable energy development: Policy, industry and business perspectives. *Asia Pacific Business Review, 21*(1), 26-43.

Devall, B., & Sessions, G. (1985). *Deep ecology*. Salt Lake City, Utah: Gibbs. M. Smith.

Di Gregorio, M., Gallemore, C. T., Brockhaus, M., Fatorelli, L., & Muharrom, E. (2017). How institutions and beliefs affect environmental discourse: Evidence from an eight-country survey on REDD+. *Global Environmental Change, 45*, 133-150.

Ding, X., Qu, Y., & Shahzad, M. (2019). The impact of environmental administrative penalties on the disclosure of environmental information. *Sustainability, 11*(20), 5820.

Dong, R. (2018, September 12). Debut of the central ecological environmental inspection office, normalization of inspection system (“中央生态环保督察办公室”亮相 专家：督察常态化制度形成). Retrieved from http://www.eeo.com.cn/2018/0912/336914.shtml

Downing, P. B., & Kimball, J. N. (1983). Enforcing pollution control laws in the United States. *Policy Studies Journal, 11*(1), 55-65.

Du, G., Wu, Y., Yang, Z., Wu, D., & Liu, J. (2005). Analysis of water quality on urban rivers and lakes in Beijing (in Chinese). *Journal of Lake Sciences, 17*(4), 373-377.

Duan, L. (2018). Hebei province focused on cleaning up 'dispersed, disrupted and polluted' enterprises (河北省集中对“散乱污”企业进行清理整治). *Hebeinews*. Retrieved from http://hebei.hebnews.cn/2018-03/30/content_6830159.htm

Eaton, S., & Kostka, G. (2014). Authoritarian environmentalism undermined? Local leaders’ time horizons and environmental policy implementation in China. *The China Quarterly, 218*, 359-380.

Egri, C. P., & Herman, S. (2000). Leadership in the North American environmental sector: Values, leadership styles, and contexts of environmental leaders and their organizations. *Academy of Management Journal, 43*(4), 571-604.

Eisenhardt, K. M. (1989). Building theories from case-study research. *Academy of Management Review, 14*(4), 532-550.

Estache, A., & Rossi, M. A. (2002). How different is the efficiency of public and private water companies in Asia? *The World Bank Economic Review, 16*(1), 139-148.

Faber, A., & Frenken, K. (2009). Models in evolutionary economics and environmental policy: Towards an evolutionary environmental economics. *Technological Forecasting and Social Change, 76*(4), 462-470.

Fang, G., Xu, L., Wu, W., & Tan, W. (2002). An investigation of the management of water resources fee collection in China (in Chinese). *Journal of Economics of Water Resources, 20*(05), 33-37.

FAO. (2011). AQUASTAT - FAO's global information system on water and agriculture. Retrieved from http://www.fao.org/nr/water/aquastat/main/index.stm

Feeley, T. J., Skone, T. J., Stiegel, G. J., McNemar, A., Nemeth, M., Schimmoller, B., . . . Manfredo, L. (2008). Water: A critical resource in the thermoelectric power industry. *Energy, 33*(1), 1-11.

Feng, J. (2017, August 10). Stricter environmetnal policies pushing industrial upgrading (环保政策越来越严格，企业需尽快“升级”). *The Beijing News*. Retrieved from http://epaper.bjnews.com.cn/html/2017-08/10/content_691357.htm?div=-1

Feng, K., & Wang, S. (2019). Application of PPP model in water pollution environmental governance. *Caribbean Journal of Science, 52*(1), 190-192.

Ferreira, L. C. d. M. (2015). When a thousand words are (not) enough: An empirical study of the relationship between firm performance and attention to shareholders. *Brazilian Administration Review, 12*(2), 129-149.

Foltz, J. D. (2003). The economics of water-conserving technology adoption in Tunisia: An empirical estimation of farmer technology choice. *Economic Development and Cultural Change, 51*(2), 359-373.

Francesch-Huidobro, M., Lo, C. W.-H., & Tang, S.-Y. (2012). The local environmental regulatory regime in China: Changes in pro-environment orientation, institutional capacity, and external political support in Guangzhou. *Environment and Planning A, 44*(10), 2493-2511.

Frijns, J., Phuong, P. T., & Mol, A. P. (2000). Ecological modernisation theory and industrialising economies: The case of viet nam. *Environmental Politics, 9*(1), 257-292.

Fu, J., & Geng, Y. (2019). Public participation, regulatory compliance and green development in China based on provincial panel data. *Journal of Cleaner Production, 230*, 1344-1353.

Gao, S. S., Heravi, S., & Xiao, J. Z. (2005). Determinants of corporate social and environmental reporting in Hong Kong: A research note. *Accounting Forum, 29*(2), 233-242.

Gao, W. (2016, December 01). Hebei pollution control, say no to online monitoring data fraud (河北利剑斩污对在线监测数据造假说“不”). Retrieved from http://hebei.hebnews.cn/2016-12/01/content_6112162.htm

Gao, Y., Wang, H., Han, L., Wang, Y., & Wang, Z. (2010). Consciousness of water resources crisis and the innovation of the water resources management system in Beijing (in Chinese). *Resources Science, 32*(2), 274-281.

Gauthier, C. (2005). Measuring corporate social and environmental performance: The extended life-cycle assessment. *Journal of Business Ethics, 59*(1-2), 199-206.

Geall, S., & Ely, A. (2018). Narratives and pathways towards an ecological civilization in contemporary China. *The China Quarterly, 236*, 1175-1196.

General Office of Hebei Provincial Government. (2016). *A circular of establishing and improving the water price adjustment and compensation mechanism (河北省人民政府印发关于建立健全水价调整补偿机制意见的通知)*. (冀政发[2016]51 号). Retrieved from http://info.hebei.gov.cn/hbszfxxgk/329975/329982/6694963/index.html

Geng, L. (2003). Approach to the analysis methods of tolerance of industrial water fee (in Chinese). *South-to-North Water Transfers and Water Science & Technology, 1*(4), 28-29.

George, B., Malano, H. M., & Davidson, B. (2007). *Integrated water allocation-economic modelling at a catchment scale.* Paper presented at the Modsim 2007: International Congress on Modelling and Simulation, Christchurch, New Zealand.

Gilley, B. (2012). Authoritarian environmentalism and China's response to climate change. *Environmental Politics, 21*(2), 287-307.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative theory*. Chicago, IL: Aldine.

Godfrey, P. C., & Hill, C. W. (1995). The problem of unobservables in strategic management research. *Strategic Management Journal, 16*(7), 519-533.

González, P., Sarkis, J., & Adenso-Díaz, B. (2008). Environmental management system certification and its influence on corporate practices: Evidence from the automotive

industry. *International Journal of Operations & Production Management, 28*(11), 1021-1041.
Gouldson, A., & Murphy, J. (1996). Ecological modernization and the European Union. *Geoforum, 27*(1), 11-21.
Gourbesville, P., & Batica, J. (2014). *Flood risk assessment strategies*. doi: 10.13140/RG.2.1.2083.6323.
Grimpe, C., & Kaiser, U. (2010). Balancing internal and external knowledge acquisition: The gains and pains from R&D outsourcing. *Journal of Management Studies, 47*(8), 1483-1509.
Grossman, G. M., & Krueger, A. B. (1991). *Environmental impacts of a North American free trade agreement* (0898-2937). Retrieved from https://www.nber.org/papers/w3914
Gulati, R., & Sytch, M. (2007). Dependence asymmetry and joint dependence in interorganizational relationships: Effects of embeddedness on a manufacturer's performance in procurement relationships. *Administrative Science Quarterly, 52*(1), 32-69.
Gunningham, N. A., Thornton, D., & Kagan, R. A. (2005). Motivating management: Corporate compliance in environmental protection. *Law & Policy, 27*(2), 289-316.
Guo, F., & Shi, Q. (2017). Official turnover, collusion deterrent and temporary improvement of air quality (in Chinese). *Economic Research Journal, 52*(07), 155-168.
Guttman, D., Young, O., Jing, Y., Bramble, B., Bu, M., Chen, C., . . . Logan, K. (2018). Environmental governance in China: Interactions between the state and “nonstate actors”. *Journal of Environmental Management, 220*, 126-135.
Habich-Sobiegalla, S. (2018). How do central control mechanisms impact local water governance in China? The case of Yunnan province. *The China Quarterly, 234*, 444-462.
Hajer, M. A. (1995). *The politics of environmental discourse: Ecological modernization and the policy process*. Oxford: Clarendon Press.
Han, M., Guo, S., Chen, H., Ji, X., & Li, J. (2014). Local-scale systems input-output analysis of embodied water for the Beijing economy in 2007. *Frontiers of Earth Science, 8*(3), 414-426.
Hanasaki, N., Fujimori, S., Yamamoto, T., Yoshikawa, S., Masaki, Y., Hijioka, Y., . . . Kanae, S. (2013). A global water scarcity assessment under shared socio-economic pathways - part 1: Water use. *Hydrology and Earth System Sciences, 17*(7), 2375-2391.
Hansen, M. H., Li, H., & Svarverud, R. (2018). Ecological civilization: Interpreting the Chinese past, projecting the global future. *Global Environmental Change, 53*, 195-203.
Hart, S. L. (1995). A natural-resource-based view of the firm. *Academy of Management Review, 20*(4), 986-1014.
Hassan, R. M. (2003). Economy-wide benefits from water-intensive industries in South Africa: Quasi-input-output analysis of the contribution of irrigation agriculture and cultivated plantations in the Crocodile river catchment. *Development Southern Africa, 20*(2), 171-195.
Hassink, R. (2007). The strength of weak lock-ins: The renewal of the Westmünsterland textile industry. *Environment and Planning A, 39*(5), 1147-1165.
He, C., Pan, F., & Chen, T. (2016). Research progress of industrial geography in China. *Journal of Geographical Sciences, 26*(8), 1057-1066.
He, C., Zhang, T., & Rui, W. (2012). Air quality in urban China. *Eurasian Geography and Economics, 53*(6), 750-771.
He, S., Bayrak, M. M., & Lin, H. (2017). A comparative analysis of multi-scalar regional inequality in China. *Geoforum, 78*, 1-11.
He, X., Miao, S., Shen, S., Li, J., Zhang, B., Zhang, Z., & Chen, X. (2015). Influence of sky view factor on outdoor thermal environment and physiological equivalent temperature. *International Journal of Biometeorology, 59*(3), 285-297.

Hebei Province Environmental Protection Hall. (2017). *2016 Hebei province environment statement (2016 年河北省环境状况公报)*. Hebei: Hebei Environmental Monitoring Center Retrieved from http://hbepb.hebei.gov.cn/root8/auto454/201706/W020170607342065621951.pdf

Heberer, T., & Senz, A. (2011). Streamlining local behaviour through communication, incentives and control: A case study of local environmental policies in China. *Journal of Current Chinese Affairs, 40*(3), 77-112.

Henriques, I., & Sadorsky, P. (1996). The determinants of an environmentally responsive firm: An empirical approach. *Journal of Environmental Economics and Management, 30*(3), 381-395.

Hillary, R. (2004). Environmental management systems and the smaller enterprise. *Journal of Cleaner Production, 12*(6), 561-569.

Hillman, A. J., Withers, M. C., & Collins, B. J. (2009). Resource dependence theory: A review. *Journal of Management, 35*(6), 1404-1427.

Hills, P., & Welford, R. (2002). Ecological modernisation as a weak form of sustainable development in Hong Kong. *International Journal of Sustainable Development & World Ecology, 9*(4), 315-331.

Ho, P. (2001). Greening without conflict? Environmentalism, NGOs and civil society in China. *Development and Change, 32*(5), 893-921.

Holz, C. A. (2013). Chinese statistics: Classification systems and data sources. *Eurasian Geography and Economics, 54*(5-6), 532-571.

Hong, D.-L., Chien, S.-S., & Liao, Y.-K. (2019). Green developmentalism and trade-offs between natural preservation and environmental exploitation in China. *Environment and Planning E: Nature and Space*, Retrieved from https://doi.org/10.1177/2514848619880896.

Hong, T., Yu, N., & Mao, Z. (2019). Does environment centralization prevent local governments from racing to the bottom? -evidence from China. *Journal of Cleaner Production, 231*, 649-659.

Hsieh, C.-T., & Song, Z. M. (2015). *Grasp the large, let go of the small: The transformation of the state sector in China* (NBER Working Paper No. 21006). Retrieved from https://www.nber.org/papers/w21006

Hu, A.-G. (2016). The Five-Year Plan: A new tool for energy saving and emissions reduction in China. *Advances in Climate Change Research, 7*(4), 222-228.

Hu, D., Wang, Y., & Yang, X. (2018). Trading your diversification strategy for a green one: How do firms in emerging economies get on the green train? *Organization & Environment, 32*(4), 391-415.

Hu, G. P., Ou, X. M., Zhang, Q., & Karplus, V. J. (2013). Analysis on energy-water nexus by Sankey diagram: The case of Beijing. *Desalination and Water Treatment, 51*(19-21), 4183-4193.

Huang, Q., He, C., Shi, P., Zhao, Y., & Yang, Y. (2009). Modeling water resources carrying capacity change under stress of drought and socioeconomic developmen t in Beijing (in Chinese). *Journal of Natural Resources, 24*(5), 859-870.

Huber, J. (1982). *The lost innocence of ecology: New technologies and superindustrial development*. Frankfurt am Main: Fischer.

Huber, J. (1991). Ecological modernization. Away from scarcity, soberness and bureaucracy. In *Technologie en milieubeheer* (pp. 12-41). Den Haag: SDU.

Huber, J. (2000). Towards industrial ecology: Sustainable development as a concept of ecological modernization. *Journal of Environmental Policy & Planning, 2*(4), 269-285.

Huber, J. (2008). Pioneer countries and the global diffusion of environmental innovations: Theses from the viewpoint of ecological modernisation theory. *Global Environmental Change, 18*(3), 360-367.

Jänicke, M., Mönch, H., Ranneberg, T., & Simonis, U. E. (1989). Economic structure and environmental impacts: East-west comparisons. *Environmentalist, 9*(3), 171-183.
Jayathirtha, R. (2001). Combating environmental repercussions through 'TQEM' and 'ISO 14000'. *Business Strategy and the Environment, 10*(4), 245-250.
Ji, Z., & Ma, X. (2006). Analysis and protective countermeasures of condition of water pollution in Hebei province (in Chinese). *Environmental Protection*(5), 22-25.
Jia, H., Guo, R., Xin, K., & Wang, J. (2005). Research on wastewater reuse planning in Beijing central region. *Water Science and Technology, 51*(10), 195-202.
Jia, S., & Zhang, S. (2003). Response of industrial water use to water price rising in Beijing (in Chinese). *Journal of Hydraulic Engineering*(4), 110-115.
Jiang, M., Webber, M., Barnett, J., Rogers, S., Rutherfurd, I., Wang, M., & Finlayson, B. (2019). Beyond contradiction: The state and the market in contemporary Chinese water governance. *Geoforum, 108*, 246-254.
Jiang, Y. (2009). China's water scarcity. *Journal of Environmental Management, 90*(11), 3185-3196.
Jin, Z., Shang, Y., & Xu, J. (2018). The impact of government subsidies on private R&D and firm performance: Does ownership matter in China's manufacturing industry? *Sustainability, 10*(7), 2205.
Johnson, T. M., Liu, F., & Newfarmer, R. (1997). *Clear water, blue skies: China's environment in the new century*. New York: The World Bank.
Kahn, M. E., Li, P., & Zhao, D. (2015). Water pollution progress at borders: The role of changes in China's political promotion incentives. *American Economic Journal: Economic Policy, 7*(4), 223-242.
Karamouz, M., Mojahedi, S. A., & Ahmadi, A. (2010). Interbasin water transfer: Economic water quality-based model. *Journal of Irrigation and Drainage Engineering, 136*(2), 90-98.
Kay, S., Zhao, B., & Sui, D. (2015). Can social media clear the air? A case study of the air pollution problem in Chinese cities. *The Professional Geographer, 67*(3), 351-363.
Kemper, E. A., Stringfield, S., & Teddlie, C. (2003). Mixed methods sampling strategies in social science research. In *Handbook of mixed methods in social and behavioral research* (pp. 273-296). Thousand Oaks, CA: SAGE Publications, Inc.
Kim, B., Kim, E., & Foss, N. J. (2016). Balancing absorptive capacity and inbound open innovation for sustained innovative performance: An attention-based view. *European Management Journal, 34*(1), 80-90.
Koch, H., & Vögele, S. (2009). Dynamic modelling of water demand, water availability and adaptation strategies for power plants to global change. *Ecological Economics, 68*(7), 2031-2039.
Kogut, B., & Zander, U. (1992). Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization Science, 3*(3), 383-397.
Kohli, A., Frenken, K., & Spottorno, C. (2010). Disambiguation of water use statistics. *The AQUASTAT Programme of FAO, Rome, Italy*.
Kostka, G., & Mol, A. P. (2013). Implementation and participation in China's local environmental politics: Challenges and innovations. *Journal of Environmental Policy & Planning, 15*(1), 3-16.
Kostka, G., & Nahm, J. (2017). Central–local relations: Recentralization and environmental governance in China. *The China Quarterly, 231*, 567-582.
Kostka, G., & Zhang, C. (2018). Tightening the grip: Environmental governance under Xi Jinping. *Environmental Politics, 27*(5), 769-781.
Kuo, L., Yeh, C. C., & Yu, H. C. (2012). Disclosure of corporate social responsibility and environmental management: Evidence from China. *Corporate Social Responsibility and Environmental Management, 19*(5), 273-287.

Lai, K. H., Wong, C. W., & Cheng, T. (2012). Ecological modernisation of Chinese export manufacturing via green logistics management and its regional implications. *Technological Forecasting and Social Change, 79*(4), 766-770.

Langhelle, O. (2000). Why ecological modernization and sustainable development should not be conflated. *Journal of Environmental Policy & Planning, 2*(4), 303-322.

Lee, S. Y., & Rhee, S. K. (2007). The change in corporate environmental strategies: A longitudinal empirical study. *Management Decision, 45*(2), 196-216.

Leroy, P., & Van Tatenhove, J. (2000). Political modernization theory and environmental politics. In *Environment and global modernity* (pp. 187-208). London: SAGE Publications Limited.

Li, D. (2014, June 19). Beijing has established the strictest local environmental protection standards in the country followed by Tianjin and Hebei (北京形成全国最严地方环保标准 天津河北拟“紧随其后”). *China National Radio*. Retrieved from http://news.cnr.cn/native/city/201406/t20140619_515689140.shtml

Li, L. C. (2010). Central-local relations in the People's Republic of China: Trends, processes and impacts for policy implementation. *Public Administration and Development, 30*(3), 177-190.

Li, R., Zhou, Y., Bi, J., Liu, M., & Li, S. (2020). Does the central environmental inspection actually work? *Journal of Environmental Management, 253*, doi:10.1016/j.jenvman.2019.109602.

Li, T., & Shen, M. (2015). Research into regulating strategies of water pricing for industrial water conservation (in Chinese). *Journal of Hohai University (Philosophy and Social Sciences), 17*(4), 82-92.

Li, V., & Lang, G. (2010). China's “green GDP” experiment and the struggle for ecological modernisation. *Journal of Contemporary Asia, 40*(1), 44-62.

Li, Y. (2017, June 23). Beijing, Tianjin, Hebei regions integrated and complementary. *China Daily*. Retrieved from http://www.chinadaily.com.cn/cndy/2017-06/23/content_29857613.htm

Li, Y. (2019). Bureaucracies count: Environmental governance through goal-setting and mandate-making in contemporary China. *Environmental Sociology, 5*(1), 12-22.

Li, Y., Chen, W., & Chang, G. (2008). China's environmental polices evolution and circular economy development: Their implications to realize ecological modernization (in Chinese). *China Population Resources and Environment, 18*(5), 12-18.

Li, Y., & Ye, F. (2011). Institutional pressures, environmental innovation practices and firm performance—an institutional theory and ecological modernization theory perspective (in Chinese). *Studies in Science of Science, 29*(12), 1884-1894.

Li, Y., Zhang, L., & Liu, Z. (2006). The map of China's water pollution is startling - 2.2 billion tons of domestic sewage a year (中国水污染地图触目惊心——每年仅生活污水即达 22 亿吨). *Science and Technology of West China*(030), 8.

Li, Z. (2007, August 28). Problems existing in water price in Beijing and countermeasures for reform (北京市水价存在的问题和改革对策). Retrieved from http://www.china-esc.org.cn/c/2007-08-28/603381.shtml

Liang, J., & Langbein, L. (2015). Performance management, high-powered incentives, and environmental policies in China. *International Public Management Journal, 18*(3), 346-385.

Liang, X. (2016, October 08). Two years since the first phase of the middle route of the south-to-north water diversion project was completed, residential water quality improved markedly (南水北调中线一期完工近两年：居民用水质量明显提升). *People's Daily*. Retrieved from http://www.rmzxb.com.cn/c/2016-10-09/1071043.shtml

Liao, Z. (2018a). Institutional pressure, knowledge acquisition and a firm's environmental innovation. *Business Strategy and the Environment, 27*(7), 849-857.

Liao, Z. (2018b). Market orientation and firms' environmental innovation: The moderating role of environmental attitude. *Business Strategy and the Environment, 27*(1), 117-127.
Lieberthal, K., & Oksenberg, M. (1988). *Policy making in China: Leaders, structures, and processes*. Princeton, NJ: Princeton University Press.
List, J. A., & Gallet, C. A. (1999). The environmental Kuznets curve: Does one size fit all? *Ecological Economics, 31*(3), 409-423.
Liu, A., & Mukheibir, P. (2018). Digital metering feedback and changes in water consumption – a review. *Resources, Conservation and Recycling, 134*, 136-148.
Liu, H., Li, Z., Zhang, Y., Zhang, W., & Lin, B. (2006). Nitrate contamination of deep groundwater in rural plain areas of Beijing (in Chinese). *Acta Pedologica Sinica, 43*(3), 405-413.
Liu, J. (2014). The temporal-spatial variation characteristics of precipitation in Beijing-Tianjin-Hebei during 1961-2012 (in Chinese). *Climate Change Research Letters*(3), 146-153.
Liu, J. (2019). Modeling analysis of the fierce influence of environmental governance on small science and technology of enterprises. *Caribbean Journal of Science, 52*(1), 521-525.
Liu, J., & Diamond, J. (2005). China's environment in a globalizing world. *Nature, 435*(7046), 1179.
Liu, J., & Diamond, J. (2008). Revolutionizing China's environmental protection. *Science, 319*(5859), 37-38.
Liu, J., & Yang, W. (2012). Water sustainability for China and beyond. *Science, 337*(6095), 649-650.
Liu, L., Zeng, S., Dong, X., & Chen, J. (2013). Design and assessment of urban drainage and water reuse systems for the reconstruction of formerly industrial areas: A case in Beijing. *Water Science and Technology, 67*(1), 55-62.
Liu, L., Zeng, S., Xin, D., & Chen, J. (2011). *Assessment of urban drainage and water reuse system schemes with weight uncertainty analysis.* Paper presented at the 2011 International Conference on Electric Technology and Civil Engineering, ICETCE 2011, Lushan, China.
Liu, L., Zhang, B., & Bi, J. (2012). Reforming China's multi-level environmental governance: Lessons from the 11th Five-Year Plan. *Environmental Science & Policy, 21*, 106-111.
Liu, M., Wei, J., Wang, G., & Wang, F. (2017). Water resources stress assessment and risk early warning–a case of Hebei province China. *Ecological Indicators, 73*, 358-368.
Liu, N., Tang, S.-Y., Zhan, X., & Lo, C. W.-H. (2018). Political commitment, policy ambiguity, and corporate environmental practices. *Policy Studies Journal, 46*(1), 190-214.
Liu, N. N., Lo, C. W.-H., Zhan, X., & Wang, W. (2015). Campaign-style enforcement and regulatory compliance. *Public Administration Review, 75*(1), 85-95.
Liu, Q., & Sang, L. (2007). Problems and countermeasures on water quota management mechanism in China (in Chinese). *Journal of Yangtze River Scientific Research Institute*(01), 20-23.
Liu, S., Yang, D., Liu, N., & Liu, X. (2019). The effects of air pollution on firms' internal control quality: Evidence from China. *Sustainability, 11*(18), 5068.
Liu, W., & Lu, D. (2002). Rethinking the development of economic geography in mainland China. *Environment and Planning A, 34*(12), 2107-2126.
Liu, X., & Anbumozhi, V. (2009). Determinant factors of corporate environmental information disclosure: An empirical study of Chinese listed companies. *Journal of Cleaner Production, 17*(6), 593-600.
Liu, X., Du, H., Zhang, Z., Crittenden, J. C., Lahr, M. L., Moreno-Cruz, J., . . . Zuo, J. (2019). Can virtual water trade save water resources? *Water Research, 163*, 114848.
Liu, X., Hewings, J. D. G., Chen, X., & Wang, S. (2016). A factor decomposing model of water use efficiency at sector level and its application in Beijing. *Journal of Systems Science & Complexity, 29*(2), 405-427.
Liu, X., Liu, B., Shishime, T., Yu, Q., Bi, J., & Fujitsuka, T. (2010). An empirical study on the driving mechanism of proactive corporate environmental management in China. *Journal of Environmental Management, 91*(8), 1707-1717.

Liu, X. L., Hewings, J. D. G., Chen, X. K., & Wang, S. Y. (2016). A factor decomposing model of water use efficiency at sector level and its application in Beijing. *Journal of Systems Science & Complexity, 29*(2), 405-427.

Liu, Y., Liu, J., Zhao, X., & Zhang, Y. (2016). Assessment of vulnerability of water resources in Beijing-Tianjin-Hebei region. *Bulletin of Soil and Water Conservation, 36*(3), 211-218.

Liu, Y., Mol, A. P., & Chen, J. (2005). The environmental industry in transitional China: Barriers and opportunities between state and market. *International Journal of Environment and Sustainable Development, 4*(3), 269-289.

Lo, C. W.-H., Fryxell, G. E., & Tang, S.-Y. (2010). Stakeholder pressures from perceived environmental impacts and the effect on corporate environmental management programmes in China. *Environmental Politics, 19*(6), 888-909.

Lo, C. W.-H., & Leung, S. W. (2000). Environmental agency and public opinion in Guangzhou: The limits of a popular approach to environmental governance. *The China Quarterly, 163*, 677-704.

Lo, C. W.-H., Liu, N., Li, P. H. Y., & Wang, W. (2016). Controlling industrial pollution in urban China: Towards a more effective institutional milieu in the Guangzhou environmental protection bureau? *China Information, 30*(2), 232-258.

Lo, C. W.-H., & Tang, S.-Y. (2006). Institutional reform, economic changes, and local environmental management in China: The case of Guangdong province. *Environmental Politics, 15*(02), 190-210.

Lockett, A., & Thompson, S. (2001). The resource-based view and economics. *Journal of Management, 27*(6), 723-754.

Lu, L. (2014). Current situation analysis and countermeasures of reclaimed water reuse in China (中国中水回用的现状分析和对策建议). *Energy and Energy Conservation*(11), 96-97,142.

Lu, Q. (2019). Who is in charge of the river? The river chief water resource system in China. *The Public Sphere: Journal of Public Policy, 7*(1), 131-144.

Lu, Y., & Abeysekera, I. (2014). Stakeholders' power, corporate characteristics, and social and environmental disclosure: Evidence from China. *Journal of Cleaner Production, 64*, 426-436.

Luo, J., Shen, Y., Qi, Y., Zhang, Y., & Xiao, D. (2018). Evaluating water conservation effects due to cropping system optimization on the Beijing-Tianjin-Hebei plain, China. *Agricultural Systems, 159*, 32-41.

Ma, M., & Hassink, R. (2014). Path dependence and tourism area development: The case of Guilin, China. *Tourism Geographies, 16*(4), 580-597.

Ma, S., & Wang, R. (1984). Social–economic–natural complex ecosystem. *Acta Ecologica Sinica, 4*(1), 1-9.

Ma, X., & Ortolano, L. (2000). *Environmental regulation in China: Institutions, enforcement, and compliance*. New York: Rowman & Littlefield Publishers.

Martens, S. (2006). Public participation with Chinese characteristics: Citizen consumers in China's environmental management. *Environmental Politics, 15*(02), 211-230.

Martin, R. (2010). Roepke lecture in economic geography—rethinking regional path dependence: Beyond lock-in to evolution. *Economic Geography, 86*(1), 1-27.

Martin, R., & Sunley, P. (2006). Path dependence and regional economic evolution. *Journal of Economic Geography, 6*(4), 395-437.

Maskell, P., & Malmberg, A. (2007). Myopia, knowledge development and cluster evolution. *Journal of Economic Geography, 7*(5), 603-618.

Meng, X., Zeng, S., Shi, J. J., Qi, G., & Zhang, Z. (2014). The relationship between corporate environmental performance and environmental disclosure: An empirical study in China. *Journal of Environmental Management, 145*, 357-367.

Menguc, B., Auh, S., & Ozanne, L. (2010). The interactive effect of internal and external factors on a proactive environmental strategy and its influence on a firm's performance. *Journal of Business Ethics, 94*(2), 279-298.

Midttun, A., & Kamfjord, S. (1999). Energy and environmental governance under ecological modernization: A comparative analysis of Nordic countries. *Public Administration, 77*(4), 873-895.

Miller, D. (2003). An asymmetry-based view of advantage: Towards an attainable sustainability. *Strategic Management Journal, 24*(10), 961-976.

Miner, J. B. (2003). The rated importance, scientific validity, and practical usefulness of organizational behavior theories: A quantitative review. *Academy of Management Learning & Education, 2*(3), 250-268.

Ministry of Environmental Protection. (2012). *Measures for environmental supervision (环境监察办法)*. (Order No.21 of the Ministry of Environmental Protection). Retrieved from http://www.lawinfochina.com/display.aspx?lib=law&id=11744&CGid=

Moiwo, J. P., Yang, Y., Li, H., Han, S., & Yang, Y. (2010). Impact of water resource exploitation on the hydrology and water storage in Baiyangdian lake. *Hydrological Processes, 24*(21), 3026-3039.

Mol, A. P. (1995). *The refinement of production. Ecological modernisation theory and the chemical industry*. Utrecht: Jan van Arkel/International Books.

Mol, A. P. (1997). Ecological modernization: Industrial transformations and environmental reform. In *The international handbook of environmental sociology* (pp. 138-149). UK: Edward Elgar Publishing Limited.

Mol, A. P. (1999). Ecological modernization and the environmental transition of Europe: Between national variations and common denominators. *Journal of Environmental Policy & Planning, 1*(2), 167-181.

Mol, A. P., & Sonnenfeld, D. A. (2000). Ecological modernization around the world: An introduction. *Environmental Politics, 9*, 3-16.

Mol, A. P. (2002). Ecological modernization and the global economy. *Global Environmental Politics, 2*(2), 92-115.

Mol, A. P. (2003). *Globalization and environmental reform: The ecological modernization of the global economy*. Cambridge, MA: MIT Press.

Mol, A. P. (2006). Environment and modernity in transitional China: Frontiers of ecological modernization. *Development and Change, 37*(1), 29-56.

Mol, A. P., & Carter, N. T. (2006). China's environmental governance in transition. *Environmental Politics, 15*(02), 149-170.

Moore, S. (2014). Modernisation, authoritarianism, and the environment: The politics of China's south–north water transfer project. *Environmental Politics, 23*(6), 947-964.

Moore, S., Shaofeng, J., & Nickum, J. E. (2017). The three red lines and China's water resources policy in the twenty-first century. In *Routledge handbook of environmental policy in China* (pp. 95-106). London: Routledge.

NDRC. (2018). *Gradually adjust the price of non-residential water to the compensation cost and reasonable profit level (逐步将非居民用水价格调整至补偿成本并合理盈利水平)*. ([2018]943). National Development and Reform Commission Retrieved from http://www.gov.cn/xinwen/2018-07/02/content_5302737.htm

Neighbour, D. (2018, November 19). Recycled water could solve Beijing's water woes, but implementation falls short. *China Environment Forum*. Retrieved from https://www.newsecuritybeat.org/2018/11/recycled-water-solve-beijings-water-woes-implementation-falls-short-2/

Neil Adger, W., Arnell, N. W., & Tompkins, E. L. (2005). Successful adaptation to climate change across scales. *Global Environmental Change, 15*(2), 77-86.

Nickum, J., & Lee, Y.-S. (2006). Same longitude, different latitudes: Institutional change in urban water in China, north and south. *Environmental Politics, 15*(2), 231-247.
Nicot, J.-P., & Scanlon, B. R. (2012). Water use for shale-gas production in Texas, US. *Environmental Science & Technology, 46*(6), 3580-3586.
Niu, X., Wang, X., Gao, J., & Wang, X. (2020). Has third-party monitoring improved environmental data quality? An analysis of air pollution data in China. *Journal of Environmental Management, 253*, doi:10.1016/j.jenvman.2019.109698.
Ocasio, W. (1997). Towards an attention-based view of the firm. *Strategic Management Journal, 18*, 187-206.
Oliver, C. (1990). Determinants of interorganizational relationships: Integration and future directions. *Academy of Management Review, 15*(2), 241-265.
Olmstead, S. M., & Stavins, R. N. (2009). Comparing price and nonprice approaches to urban water conservation. *Water Resources Research, 45*(4), doi:10.1029/2008WR007227.
Orsato, R. J. (2006). Competitive environmental strategies: When does it pay to be green? *California Management Review, 48*(2), 127-143.
Pahl-Wostl, C. (2019). The role of governance modes and meta-governance in the transformation towards sustainable water governance. *Environmental Science & Policy, 91*, 6-16.
Pan, J., & Yao, Y. (2017). Delinitation of metropolitan shadow area in Beijing-Tianjin-Hebei metropolitan region (in Chinese). *Journal of Human Settlements in West China, 32*(6), 100-106.
Park, J., Sarkis, J., & Wu, Z. (2010). Creating integrated business and environmental value within the context of China's circular economy and ecological modernization. *Journal of Cleaner Production, 18*(15), 1494-1501.
Pascoe, S., Brincat, S., & Croucher, A. (2019). The discourses of climate change science: Scientific reporting, climate negotiations and the case of Papua New Guinea. *Global Environmental Change, 54*, 78-87.
Patchell, J., & Hayter, R. (2013). Environmental and evolutionary economic geography: Time for EEG2? *Geografiska Annaler: Series B, Human Geography, 95*(2), 111-130.
Patel, P., & Pavitt, K. (1997). The technological competencies of the world's largest firms: Complex and path-dependent, but not much variety. *Research Policy, 26*(2), 141-156.
Pearce, D. W., & Warford, J. J. (1993). *World without end: Economics, environment, and sustainable development*. Oxford,UK: Oxford University Press.
Peng, F., Yu, F., Ma, G., & Yang, W. (2018). Analysis of social-economic benefits and environmental pollution control costs of 'dispersed, disrupted and polluted' enterprises in the '2+26' region (in Chinese) *Research of Environmental Sciences, 31*(12), 1993-1999.
Peoples Network. (2017, Feburary 11). Beijing municipal commission of economy and information technology: In 2016, 4,477 "messy and dirty" enterprises were rectified (北京市经信委:2016 年整治"散乱污"企业 4477 家). Retrieved from http://bj.people.com.cn/n2/2017/0211/c82840-29701804.html
Pfeffer, J., & Salancik, G. R. (2003). *The external control of organizations: A resource dependence perspective*. Stanford, CA: Stanford University Press.
Pfister, S., Koehler, A., & Hellweg, S. (2009). Assessing the environmental impacts of freshwater consumption in LCA. *Environmental Science & Technology, 43*(11), 4098-4104.
Pfister, S., Saner, D., & Koehler, A. (2011). The environmental relevance of freshwater consumption in global power production. *International Journal of Life Cycle Assessment, 16*(6), 580-591.
Phuong, P. T. (2002). *Ecological modernisation of industrial estates in viet nam.* (PhD Dissertation). Wageningen University, Wageningen.
Piao, S., Ciais, P., Huang, Y., Shen, Z., Peng, S., Li, J., . . . Ding, Y. (2010). The impacts of climate change on water resources and agriculture in China. *Nature, 467*(7311), 43-51.

Pohlner, H. (2016). Institutional change and the political economy of water megaprojects: China's south-north water transfer. *Global Environmental Change-Human and Policy Dimensions, 38*, 205-216.

Porter, M. E. (2008). *Competitive strategy: Techniques for analyzing industries and competitors*. New York: Simon and Schuster.

Pugliese, A., Minichilli, A., & Zattoni, A. (2014). Integrating agency and resource dependence theory: Firm profitability, industry regulation, and board task performance. *Journal of Business Research, 67*(6), 1189-1200.

Qin, L. (2015). Current situation and prospect of comprehensive utilization of urban rainwater in China (中国城市雨水综合利用现状及展望). *Global City Geography*(6), 153.

Ran, L. (2005). Discussion on the determination of water quota (in Chinese). *China Water Resources*(11), 19-20.

Ran, R. (2013). Perverse incentive structure and policy implementation gap in China's local environmental politics. *Journal of Environmental Policy & Planning, 15*(1), 17-39.

Ren, W., & Mu, S. (2005). Integration of Beijing, Tianjin and Hebei and leaping-over strategy selection of Hebei's economy (in Chinese). *Journal of Shijiazhuang University of Economics, 28*(2), 202-205.

Renzetti, S. (1993). Examining the differences in self-and publicly supplied firms' water demands. *Land Economics, 69*(2), 181-188.

Ridoutt, B. G., & Pfister, S. (2010). A revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. *Global Environmental Change, 20*(1), 113-120.

Rinkevicius, L. (2000). Public risk perceptions in a 'double-risk' society: The case of the ignalina nuclear power plant in lithuania. *The European Journal of Social Science Research, 13*(3), 279-289.

Rogers, P., De Silva, R., & Bhatia, R. (2002). Water is an economic good: How to use prices to promote equity, efficiency, and sustainability. *Water Policy, 4*(1), 1-17.

Rogers, S., Jiang, M., Shi, C., & Zhang, W. (2018, May 11). Re-evaluating China's water crisis. *China Dialogue*. Retrieved from https://www.chinadialogue.net/article/show/single/en/10628-Re-evaluating-China-s-water-crisis

Rosegrant, M. W., Cai, X. M., Ringlerl, C., & Cline, S. (2005). *Market adaptations to increased water prices in China: The impact on water demand and food production.* Paper presented at the 2nd International Yellow River Forum on Keeping Healthy Life of the River, Zhengzhou, China.

Rowe, A. L., & Guthrie, J. (2010). The Chinese government's formal institutional influence on corporate environmental management. *Public Management Review, 12*(4), 511-529.

Rugman, A. M., & Verbeke, A. (1998). Corporate strategies and environmental regulations: An organizing framework. *Strategic Management Journal, 19*(4), 363-375.

Russo, M. V., & Fouts, P. A. (1997). A resource-based perspective on corporate environmental performance and profitability. *Academy of Management Journal, 40*(3), 534-559.

Ruttan, V. W. (1997). Induced innovation, evolutionary theory and path dependence: Sources of technical change. *The Economic Journal, 107*(444), 1520-1529.

Sapienza, H. J., De Clercq, D., & Sandberg, W. R. (2005). Antecedents of international and domestic learning effort. *Journal of Business Venturing, 20*(4), 437-457.

Schilling, M. A. (1998). Technological lockout: An integrative model of the economic and strategic factors driving technology success and failure. *Academy of Management Review, 23*(2), 267-284.

Schmitz, H. (1995). Collective efficiency: Growth path for small-scale industry. *The Journal of Development Studies, 31*(4), 529-566.

Schroeder, R. G., Bates, K. A., & Junttila, M. A. (2002). A resource-based view of manufacturing strategy and the relationship to manufacturing performance. *Strategic Management Journal, 23*(2), 105-117.

Schumpeter, J. A. (1947). The creative response in economic history. *The Journal of Economic History, 7*(2), 149-159.

Schwartz, J. (2004). Environmental NGOs in China: Roles and limits. *Pacific Affairs, 77*(1), 28-49.

Shahab, Y., Ntim, C. G., Chengang, Y., Ullah, F., & Fosu, S. (2018). Environmental policy, environmental performance, and financial distress in China: Do top management team characteristics matter? *Business Strategy and the Environment, 27*(8), 1635-1652.

Sharma, S. (2000). Managerial interpretations and organizational context as predictors of corporate choice of environmental strategy. *Academy of Management Journal, 43*(4), 681-697.

Sharma, S., & Vredenburg, H. (1998). Proactive corporate environmental strategy and the development of competitively valuable organizational capabilities. *Strategic Management Journal, 19*(8), 729-753.

Shen, D. (2014). Post-1980 water policy in China. *International Journal of Water Resources Development, 30*(4), 714-727.

Shen, D., & Speed, R. (2009). Water resources allocation in the People's Republic of China. *Water Resources Development, 25*(2), 209-225.

Shen, Y., & Ahlers, A. L. (2019). Blue sky fabrication in China: Science-policy integration in air pollution regulation campaigns for mega-events. *Environmental Science & Policy, 94*, 135-142.

Sheng, N., & Tang, U. W. (2016). The first official city ranking by air quality in China-a review and analysis. *Cities, 51*, 139-149.

Shi, C., Guo, F., & Shi, Q. (2019). Ranking effect in air pollution governance: Evidence from Chinese cities. *Journal of Environmental Management, 251*, doi:10.1016/j.jenvman.2019.109600.

Shi, C., Shi, Q., & Guo, F. (2019). Environmental slogans and action: The rhetoric of local government work reports in China. *Journal of Cleaner Production, 238*, doi:10.1016/j.jclepro.2019.117886.

Shi, H., & Zhang, L. (2006). China's environmental governance of rapid industrialisation. *Environmental Politics, 15*(02), 271-292.

Shi, Q., Chen, S., Shi, C., Wang, Z., & Deng, X. (2014). The impact of industrial transformation on water use efficiency in northwest region of China. *Sustainability, 7*(1), 56-74.

Shi, Q., Shi, C., & Guo, F. (2020). Political blue sky: Evidence from the local annual "Two Sessions" in China. *Resource and Energy Economics*, doi:10.1016/j.reseneeco.2020.101165.

Simonis, U. E. (1989). Ecological modernization of industrial society—three strategic elements. In *Economy and ecology: Towards sustainable development* (pp. 119-137). Dordrecht: Springer.

Smith, E. (2001). The emergence of ecological modernisation. Integrating the environment and the economy? *Journal of Environmental Policy & Planning, 3*(4), 325-328.

Sonnenfeld, D. A. (2000). Contradiction of ecological modernisation: Pulp and paper manufacturing in south-east africa. *Environmental Politics, 9*(1), 235-256.

Spaargaren, G. (2000a). Ecological modernization theory and domestic consumption. *Journal of Environmental Policy & Planning, 2*(4), 323-335.

Spaargaren, G. (2000b). Ecological modernization theory and the changing discourse on environment and modernity. In *Environment and global modernity* (pp. 41-71). London: SAGE Publications Limited.

Spaargaren, G., & Mol, A. P. (1992). Sociology, environment, and modernity: Ecological modernization as a theory of social change. *Society & Natural Resources, 5*(4), 323-344.

Spaargaren, G., & Mol, A. P. (2008). Greening global consumption: Redefining politics and authority. *Global Environmental Change, 18*(3), 350-359.

Spaargaren, G., & Van Vliet, B. (2000). Lifestyles, consumption and the environment: The ecological modernization of domestic consumption. *Environmental Politics, 9*(1), 50-76.

Spires, A. J. (2011). Contingent symbiosis and civil society in an authoritarian state: Understanding the survival of China's grassroots NGOs. *American Journal of Sociology, 117*(1), 1-45.

State Council. (2012). *Opinions from the state council on implementing the strictest water management system (国务院关于实行最严格水资源管理制度的意见)*. (2012[3]). Retrieved from http://www.gov.cn/zwgk/2012-02/16/content_2067664.htm

State Council. (2015). *A circular of the state council on the issuance of an action plan for the prevention and control of water pollution (国务院关于印发水污染防治行动计划的通知)*. (2015[17]). Retrieved from http://www.gov.cn/zhengce/content/2015-04/16/content_9613.htm

Stea, D., Linder, S., & Foss, N. J. (2015). Understanding organizational advantage: How the theory of mind adds to the attention-based view of the firm. In *Cognition and strategy* (pp. 277-298). UK: Emerald Group Publishing Limited.

Stern, N. (2007). *The economics of climate change: The Stern review*. Cambridge: Cambridge University Press.

Sternfeld, E. (2017). Introduction. In *Routledge handbook of environmental policy in China* (pp. 95-106). London: Routledge.

Strambach, S. (2010). Path dependence and path plasticity: The co-evolution of institutions and innovation - the German customized business software industry. In *Handbook of evolutionary economic geography* (pp. 406-431). UK: Edward Elgar Publishing Limited.

Sydow, J., Schreyögg, G., & Koch, J. (2009). Organizational path dependence: Opening the black box. *Academy of Management Review, 34*(4), 689-709.

Takama, N., Kuriyama, T., Shiroko, K., & Umeda, T. (1980). Optimal water allocation in a petroleum refinery. *Computers & Chemical Engineering, 4*(4), 251-258.

Thrane, S., Blaabjerg, S., & Møller, R. H. (2010). Innovative path dependence: Making sense of product and service innovation in path dependent innovation processes. *Research Policy, 39*(7), 932-944.

Tian, J., & Dai, H. (2010). *A novel water resources management method based on system dynamics model.* Paper presented at the 2010 International Conference on E-Health Networking, Digital Ecosystems and Technologies, EDT 2010, Hubei, China.

Tian, Z., Tian, Y., Chen, Y., & Shao, S. (2020). The economic consequences of environmental regulation in China: From a perspective of the environmental protection admonishing talk policy. *Business Strategy and the Environment, 29*(4), 1723-1733.

Tong, Y. (2011). Re-discussion on population carry-capacity of water resources in Beijing (in Chinese). *Social Science of Beijing*(5), 22-28.

Tong, Z. (2001). Wastewater reuse, the effective way behind urban water shortage (in Chinese). *Water & Wastewater Engineering, 27*(11), 1-6.

Tracy, E. F., Shvarts, E., Simonov, E., & Babenko, M. (2017). China's new Eurasian ambitions: The environmental risks of the silk road economic belt. *Eurasian Geography and Economics, 58*(1), 56-88.

Truffer, B., Binz, C., Gebauer, H., & Störmer, E. (2013). Market success of on-site treatment: A systemic innovation problem. In *Source separation and decentralization for wastewater management* (pp. 209-223). London, UK: IWA Publishing.

Tuggle, C. S., Sirmon, D. G., Reutzel, C. R., & Bierman, L. (2010). Commanding board of director attention: Investigating how organizational performance and CEO duality affect board members' attention to monitoring. *Strategic Management Journal, 31*(9), 946-968.

Turner, R. K. (2000). *Markets and environmental quality* (CSERGE Working Paper PA 2000-01). Retrieved from https://www.researchgate.net/publication/268260428_MARKETS_AND_ENVIRONMENTAL_QUALITY

van Rooij, B., & Lo, C. W.-H. (2010). Fragile convergence: Understanding variation in the enforcement of China's industrial pollution law. *Law & Policy, 32*(1), 14-37.

van Rooij, B., Zhu, Q., Na, L., & Wang, Q. (2017). Centralizing trends and pollution law enforcement in China. *The China Quarterly, 231*, 583-606.

Walter, I. (1982). Environmentally induced industrial relocation to developing countries. *Environment and Trade, 2*, 235-256.

Wang, A. L. (2013). The search for sustainable legitimacy: Environmental law and bureaucracy in China. *Harvard Environmental Law Review, 37*, 365.

Wang, H.-R., & Wang, Y. (1998). Three industries and water consumption of Beijing. *Journal of Environmental Sciences, 10*(2), 181-188.

Wang, H., & Bernell, D. (2013). Environmental disclosure in China: An examination of the green securities policy. *The Journal of Environment & Development, 22*(4), 339-369.

Wang, H., Bi, J., Wheeler, D., Wang, J., Cao, D., Lu, G., & Wang, Y. (2004). Environmental performance rating and disclosure: China's GreenWatch program. *Journal of Environmental Management, 71*(2), 123-133.

Wang, H., & Jin, Y. (2007). Industrial ownership and environmental performance: Evidence from China. *Environmental and Resource Economics, 36*(3), 255-273.

Wang, J. (2008). Research on the correlation among environmental information disclosure, industry differences and supervisory system (in Chinese). *Accounting Research, 6*, 54-62.

Wang, J., Shang, Y., Wang, H., Zhao, Y., & Yin, Y. (2015). Beijing's water resources: Challenges and solutions. *Journal of the American Water Resources Association, 51*(3), 614-623.

Wang, J., Zhong, L., & Iceland, C. (2017). China's water stress is on the rise. Retrieved from http://www.wri.org/blog/2017/01/chinas-water-stress-rise

Wang, M., Webber, M., Finlayson, B., & Barnett, J. (2008). Rural industries and water pollution in China. *Journal of Environmental Management, 86*(4), 648-659.

Wang, M., Zhang, X., & Yan, X. (2013). Modeling the climatic effects of urbanization in the Beijing–Tianjin–Hebei metropolitan area. *Theoretical and Applied Climatology, 113*(3-4), 377-385.

Wang, R. (1989). Probing the nothingness-human ecological relationship analysis. In *Human systems ecology*. Beijing: China Science and Technology Press.

Wang, R. Y., Liu, T., & Dang, H. (2018). Bridging critical institutionalism and fragmented authoritarianism in China: An analysis of centralized water policies and their local implementation in semi-arid irrigation districts. *Regulation & Governance, 12*(4), 451-465.

Wang, R. Y., Ng, C. N., Lenzer Jr, J. H., Dang, H., Liu, T., & Yao, S. (2017). Unpacking water conflicts: A reinterpretation of coordination problems in China's water-governance system. *International Journal of Water Resources Development, 33*(4), 553-569.

Wang, S. (2016, November 01). The first phase of the middle route of the south-to-north water diversion project has completed its annual diversion of 1.1 billion cubic meters of water into Beijing (南水北调中线一期工程年度调水结束 北京分水量 11 亿立方米). *The Beijing News*. Retrieved from http://www.bjnews.com.cn/news/2016/11/01/421824.html

Wang, S., Ma, H., & Zhao, Y. (2014). Exploring the relationship between urbanization and the eco-environment—a case study of Beijing–Tianjin–Hebei region. *Ecological Indicators, 45*, 171-183.

Wang, X., Fan, S., & Cheng, Y. (2011). Research on the scale of construction water reuse. *Applied Mechanics and Materials, 58-60*, 738-742.

Wang, X., & Zhang, J. (2008). Analysis of industrial water price bearing capacity in Hebei province (in Chinese). *City and Town Water Supply*(01), 111-114.
Wang, Z., Huang, K., Yang, S., & Yu, Y. (2013). An input-output approach to evaluate the water footprint and virtual water trade of Beijing, China. *Journal of Cleaner Production, 42*, 172-179.
Warner, R. (2010). Ecological modernisation theory: Towards a critical ecopolitics of change? *Environmental Politics, 19*(4), 538-556.
Warren, K. A., Ortolano, L., & Rozelle, S. (1999). Pollution prevention incentives and responses in Chinese firms. *Environmental Impact Assessment Review, 19*(5-6), 521-540.
Water law of the People's Republic of China (2016 amendment) [effective], Order No. 48 of the President of the People's Republic of China (2016).
Water pollution prevention and control law of the People's Republic of China (2017 revision) [effective], Order No. 70 of the President of the People's Republic of China (2017).
Webber, M., Barnett, J., Finlayson, B., & Wang, M. (2008). Pricing China's irrigation water. *Global Environmental Change-Human and Policy Dimensions, 18*(4), 617-625.
Wei, M. (2017, September 18). More than 2.6 billion cubic meters of "southern water" have flooded the capital, benefiting more than 11 million people (逾 26 亿方“南水”润京城 受益人口超 1100 万). *Xinhuanet*. Retrieved from http://www.xinhuanet.com/politics/2017-09/18/c_1121682774.htm
Wei, M., & Li, L. (2014, December 27). Water from China's south-north water diversion project officially enters Beijing to ease "water crisis" (中国南水北调之水正式进京缓解“水危机”). *Xinhuanet*. Retrieved from http://www.chinanews.com/gn/2014/12-27/6917209.shtml
Wei, Y., Langford, J., Willett, I. R., Barlow, S., & Lyle, C. (2011). Is irrigated agriculture in the Murray Darling Basin well prepared to deal with reductions in water availability? *Global Environmental Change, 21*(3), 906-916.
Wei, Y., Wang, Z., Wang, H., Yao, T., & Li, Y. (2018). Promoting inclusive water governance and forecasting the structure of water consumption based on compositional data: A case study of Beijing. *Science of the Total Environment, 634*, 407-416.
Weidner, H. (2002). Capacity building for ecological modernization: Lessons from cross-national research. *American Behavioral Scientist, 45*(9), 1340-1368.
Wernerfelt, B. (1984). A resource-based view of the firm. *Strategic Management Journal, 5*(2), 171-180.
Westman, L. K., & Castán Broto, V. (2019). Techno-economic rationalities as a political practice in urban environmental politics in China. *Environment and Planning C: Politics and Space, 37*(2), 277-297.
Williamson, D., & Lynch-Wood, G. (2012). Ecological modernisation and the regulation of firms. *Environmental Politics, 21*(6), 941-959.
Winpenny, J. (2005). *Managing water as an economic resource*. London: Routledge.
Wong, C., & Karplus, V. J. (2017). China's war on air pollution: Can existing governance structures support new ambitions? *The China Quarterly, 231*, 662-684.
Wong, E. (2017, June 13). Nearly 14,000 companies in China violate pollution rules. *The New York Times*. Retrieved from https://www.nytimes.com/2017/06/13/world/asia/china-companies-air-pollution-paris-agreement.html
World Bank. (2002). *Agenda for water sector strategy for north China : Summary report*. Retrieved from Washington, DC.© World Bank: https://openknowledge-worldbank-org.ezp.lib.unimelb.edu.au/handle/10986/15418 License: CC BY 3.0 IGO.
Wu, H., Guo, H., Zhang, B., & Bu, M. (2017). Westward movement of new polluting firms in China: Pollution reduction mandates and location choice. *Journal of Comparative Economics, 45*(1), 119-138.

Wu, X., Gao, M., Guo, S., & Maqbool, R. (2019). Environmental and economic effects of sulfur dioxide emissions trading pilot scheme in China: A quasi-experiment. *Energy & Environment, 30*(7), 1255-1274.

Xi, Y. (2015, December 12). The incoming water of the first phase of the middle route of the south-to-north water diversion project accounts for 70% of Beijing's urban water in one year (南水北调中线一期通水 1 年 来水占北京城市用水 70%). *Beijing Youth Daily*. Retrieved from http://www.chinanews.com/gn/2015/12-12/7667835.shtml

Xia, C., & Pahl-Wostl, C. (2012). The process of innovation during transition to a water saving society in China. *Water Policy, 14*(3), 447-469.

Xia, J., Deng, Q., & Sun, Y. (2010). Integrated water and CGE model of the impacts of water policy on the Beijing's economy and output. *Chinese Journal of Population Resources and Environment, 8*(2), 61-67.

Xie, H., Qiang, M., & Shen, M. (2018). Structural rectification of industrial water rate in China: A perspective of water resource fee (in Chinese). *Journal of Zhejiang University (Humanities and Social Sciences Online Edition)*(4), 54-73.

Xie, L. (2017, December 08). Million tons of desalinated seawater from Caofeidian will enter Beijing, desalination seawater utilization is in the research stage (曹妃甸百万吨淡化海水将进京 淡化海水利用正处研究阶段). *Beijing Youth Daily*. Retrieved from http://bj.people.com.cn/n2/2017/1208/c82840-31008809.html

Xing, Y. (2018, May 14). Environmental protection discussions with local governments, how powerful is it? ("环保约谈"地方政府 威力有多大？). *Beijing Youth Daily*. Retrieved from http://epaper.ynet.com/html/2018-05/14/content_287664.htm?div=0

Xinhua. (2017, April 01). China to create Xiongan new area in Hebei. *Xinhuanet*. Retrieved from http://www.xinhuanet.com//english/2017-04/01/c_136177270.htm

Xinhuanet. (2018, August 06). No more scattered pollution enterprises in Beijing (北京散乱污企业将动态清零). Retrieved from http://www.xinhuanet.com/energy/2018-08/06/c_1123226875.htm

Xu, R., Wu, Y., Wang, G., Zhang, X., Wu, W., & Xu, Z. (2019). Evaluation of industrial water use efficiency considering pollutant discharge in China. *PloS ONE, 14*(8), e0221363.

Xu, X., Zeng, S., & Tam, C. M. (2012). Stock market's reaction to disclosure of environmental violations: Evidence from China. *Journal of Business Ethics, 107*(2), 227-237.

Yang, Y., Liu, Y., Li, Y., & Li, J. (2018). Measure of urban-rural transformation in Beijing-Tianjin-Hebei region in the new millennium: Population-land-industry perspective. *Land Use Policy, 79*, 595-608.

Ye, T. (2011). Study on the Beijing-Tianjin-Hebei industry upgrading and integration during the 12th Five-Year (in Chinese). *Research On Development, 1*, 23-25.

Yee, W.-H., Lo, C. W.-H., & Tang, S.-Y. (2013). Assessing ecological modernization in China: Stakeholder demands and corporate environmental management practices in Guangdong province. *The China Quarterly, 213*, 101-129.

Yeh, E. T. (2009). Greening western China: A critical view. *Geoforum, 40*(5), 884-894.

Yeung, G. (2009). Hybrid property, path dependence, market segmentation and financial exclusion: The case of the banking industry in China. *Transactions of the Institute of British Geographers, 34*(2), 177-194.

Yi, L., Jiao, W., Chen, X., & Chen, W. (2011). An overview of reclaimed water reuse in China. *Journal of Environmental Sciences, 23*(10), 1585-1593.

Yu, F., Chen, J., Sun, F., Zeng, S., & Wang, C. (2011). Trend of technology innovation in China's coal-fired electricity industry under resource and environmental constraints. *Energy Policy, 39*(3), 1586-1599.

Yu, J., Lo, C. W.-H., & Li, P. H. Y. (2017). Organizational visibility, stakeholder environmental pressure and corporate environmental responsiveness in China. *Business Strategy and the Environment, 26*(3), 371-384.

Yu, M. (2020). Modernization of environmental governance from 3D-path respective. In *Report of strategic studies in China (2018)* (pp. 113-131). Singapore: Springer.

Yu, Z., & Huang, P. (2020). Local governments' incentives and governing practices in low-carbon transition: A comparative study of solar water heater governance in four Chinese cities. *Cities, 96*, doi:10.1016/j.cities.2019.102477.

Yuan, Z., Bi, J., & Moriguichi, Y. (2006). The circular economy: A new development strategy in China. *Journal of Industrial Ecology, 10*(1-2), 4-8.

Zeng, S., Tam, C., Tam, V. W., & Deng, Z. (2005). Towards implementation of ISO 14001 environmental management systems in selected industries in China. *Journal of Cleaner Production, 13*(7), 645-656.

Zeng, S., Xu, X., Dong, Z., & Tam, V. W. (2010). Towards corporate environmental information disclosure: An empirical study in China. *Journal of Cleaner Production, 18*(12), 1142-1148.

Zeng, S., Xu, X., Yin, H., & Tam, C. M. (2012). Factors that drive Chinese listed companies in voluntary disclosure of environmental information. *Journal of Business Ethics, 109*(3), 309-321.

Zhai, Y., Wang, J., Zheng, J., & Huan, H. (2011). Evolution and driving forces of water consumed structure in Beijing during the past 30 years. *Journal of Natural Resources, 26*(4), 635-643.

Zhang, B., Bi, J., Yuan, Z., Ge, J., Liu, B., & Bu, M. (2008). Why do firms engage in environmental management? An empirical study in China. *Journal of Cleaner Production, 16*(10), 1036-1045.

Zhang, B., Chen, Z. M., Zeng, L., Qiao, H., & Chen, B. (2016). Demand-driven water withdrawals by Chinese industry: A multi-regional input-output analysis. *Frontiers of Earth Science, 10*(1), 13-28.

Zhang, D., Fan, F., & Park, S. D. (2019). Network analysis of actors and policy keywords for sustainable environmental governance: Focusing on Chinese environmental policy. *Sustainability, 11*(15), 4068.

Zhang, G., Zhang, P., Zhang, Z. G., & Li, J. (2019). Impact of environmental regulations on industrial structure upgrading: An empirical study on Beijing-Tianjin-Hebei region in China. *Journal of Cleaner Production, 238*, doi:10.1016/j.jclepro.2019.117848.

Zhang, J. (2018). Beijing: Taking multiple measures to wipe out "scattered pollution" enterprises (北京：多措并举推动“散乱污”企业“动态清零”). *China Environment Supervision*(10), 13.

Zhang, K., & Wen, Z. (2008). Review and challenges of policies of environmental protection and sustainable development in China. *Journal of Environmental Management, 88*(4), 1249-1261.

Zhang, L. (2018, April 02). Xiong'an new area: One locale, two histories, a thousand years apart. *China Dialogue*. Retrieved from https://www.chinadialogue.net/culture/10508-xiong-an-new-area-one-locale-two-histories-a-thousand-years-apart/en

Zhang, L. (2002). Ecologizing industrialization in Chinese small towns. In *Greening industrialization in asian transitional economies*. Oxford: Lexington Book.

Zhang, L., He, G., Mol, A. P., & Zhu, X. (2013). Power politics in the revision of China's environmental protection law. *Environmental Politics, 22*(6), 1029-1035.

Zhang, L., Li, S., Loáiciga, H. A., Zhuang, Y., & Du, Y. (2015). Opportunities and challenges of interbasin water transfers: A literature review with bibliometric analysis. *Scientometrics, 105*(1), 279-294.

Zhang, L., Mol, A. P., & Sonnenfeld, D. A. (2007). The interpretation of ecological modernisation in China. *Environmental Politics, 16*(4), 659-668.

Zhang, P., Zhu, S., & Zhu, Y. (2012). Spillover effect of environmental investment (in Chinese). *Journal of Beijing Normal University (Social Sciences), 3*, 126-133.

Zhang, S. (2018). *Research on coordinated development between economy and environment of Hebei province under the background of undertaking industry transfer (承接产业转移背景下河北省经济与环境协调发展研究).* (Master Dissertation). Tianjin University of Commerce, Tianjin. Retrieved from http://cdmd.cnki.com.cn/Article/CDMD-10069-1018186056.htm Available from CNKI CMFD2018

Zhang, W. (2014). The future of private and state-owned enterprises in China. In *The oxford companion to the economics of China* (pp. 285).

Zhang, W., & Zhang, L. (2006). Research and practice on comprehensive reform of water price (水价综合改革研究与实践). *Hebei Water Resources*(6), 32.

Zhang, Z., Liu, J., Cai, B., Shan, Y., Zheng, H., Li, X., . . . Guan, D. (2020). City-level water withdrawal in China: Accounting methodology and applications. *Journal of Industrial Ecology*, 1-14. doi:10.1111/jiec.12999.

Zhao, X., Li, H., Wu, L., & Qi, Y. (2014). Implementation of energy-saving policies in China: How local governments assisted industrial enterprises in achieving energy-saving targets. *Energy Policy, 66*, 170-184.

Zhao, X., & Ortolano, L. (2010). Implementing China's national energy conservation policies at state-owned electric power generation plants. *Energy Policy, 38*(10), 6293-6306.

Zhao, X., & Sun, B. (2016). The influence of Chinese environmental regulation on corporation innovation and competitiveness. *Journal of Cleaner Production, 112*, 1528-1536.

Zhao, Y., Feng, T., & Shi, H. (2018). External involvement and green product innovation: The moderating role of environmental uncertainty. *Business Strategy and the Environment, 27*(8), 1167-1180.

Zhi, J., Qiao, Q., Li, Y., Meng, L., & Zhao, R. (2019). The definition and framework of classified control management for dispersed, violative and polluted enterprises (in Chinese). *Environmental Protection*(20), 46-50.

Zhong, L., & Mol, A. P. (2010). Water price reforms in China: Policy-making and implementation. *Water Resources Management, 24*(2), 377-396.

Zhou, D., Zhang, Z., & Shi, M. (2015). Where is the future for a growing metropolis in north China under water resource constraints? *Sustainability Science, 10*(1), 113-122.

Zhou, S., & Wang, X. (2017). A neoclassical economic analysis of the institutional impacts on firm's location choice: A case study of the relocation of an API firm from Beijing to Hebei (in Chinese). *Economic Geography, 37*(02), 1-6.

Zhou, Y. (2015). State power and environmental initiatives in China: Analyzing China's green building program through an ecological modernization perspective. *Geoforum, 61*, 1-12.

Zhou, Y., & Zhang, M. (2018, September 06). Hebei has issued three local standards for the discharge of water pollutants stricter than national standards (河北发布 3 个严于国标的水污染物排放地方标准). *China Environment News*. Retrieved from http://epaper.cenews.com.cn/html/2018-09/06/content_76009.htm

Zhou, Z., Zhang, T., Wen, K., Zeng, H., & Chen, X. (2018). Carbon risk, cost of debt financing and the moderation effect of media attention: Evidence from Chinese companies operating in high-carbon industries. *Business Strategy and the Environment, 27*(8), 1131-1144.

Zhu, Q., Geng, Y., & Lai, K. H. (2010). Circular economy practices among Chinese manufacturers varying in environmental-oriented supply chain cooperation and the performance implications. *Journal of Environmental Management, 91*(6), 1324-1331.

Zhu, Q., Geng, Y., Sarkis, J., & Lai, K. H. (2011). Evaluating green supply chain management among Chinese manufacturers from the ecological modernization perspective. *Transportation Research Part E: Logistics and Transportation Review, 47*(6), 808-821.

Zhu, Q., Geng, Y., Sarkis, J., & Lai, K. H. (2015). Barriers to promoting eco-industrial parks development in China: Perspectives from senior officials at national industrial parks. *Journal of Industrial Ecology, 19*(3), 457-467.

Zhu, Q., & Sarkis, J. (2004). Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises. *Journal of Operations Management, 22*(3), 265-289.

Zhu, Q., & Sarkis, J. (2006). An inter-sectoral comparison of green supply chain management in China: Drivers and practices. *Journal of Cleaner Production, 14*(5), 472-486.

Zhu, Q., Sarkis, J., & Lai, K. H. (2012). Green supply chain management innovation diffusion and its relationship to organizational improvement: An ecological modernization perspective. *Journal of Engineering and Technology Management, 29*(1), 168-185.

Zhu, Q., Sarkis, J., Lai, K. H., & Geng, Y. (2008). The role of organizational size in the adoption of green supply chain management practices in China. *Corporate Social Responsibility and Environmental Management, 15*(6), 322-337.

Zhu, S., & He, C. (2016). Global and local governance, industrial and geographical dynamics: A tale of two clusters. *Environment and Planning C-Government and Policy, 34*(8), 1453-1473.

Zhu, S., & He, C. (2017). Upgrading in China's apparel industry: International trade, local clusters and institutional contexts. *Post-Communist Economies, 30*(2), 193-215.

Zhu, S., & He, C. (2018). Moving beyond Anglo-American economic geography: The significance of non-Anglo-American model. *International Journal of Urban Sciences, 23*(2), 191-197.

Zhu, S., He, C., & Liu, Y. (2014). Going green or going away: Environmental regulation, economic geography and firms' strategies in China's pollution-intensive industries. *Geoforum, 55*, 53-65.

Zhu, S., He, C., & Luo, Q. (2019). Good neighbors, bad neighbors: Local knowledge spillovers, regional institutions and firm performance in China. *Small Business Economics, 52*, 617-632.

Zhu, S., Jin, W., & He, C. (2019). On evolutionary economic geography: A literature review using bibliometric analysis. *European Planning Studies, 27*(4), 639-660.

Zhu, Z., Wang, H., & Li, A. (2019). On the factors influencing public knowledge and acceptance of reclaimed water from a survey of three cities in northern China. *Journal of Water Reuse and Desalination, 9*(2), 193-202.

Zou, Y., & Zhao, W. (2018). Making a new area in Xiong'an: Incentives and challenges of China's “Millennium Plan”. *Geoforum, 88*, 45-48.

Appendices

Appendix A List of General Manufacturing Industry in China

Code	Name (EN)	Name (CN)
C	Manufacturing	制造业
13	Processing of food from agric. products	农副食品加工业
14	Manufacture of foods	食品制造业
15	Manufacture of alcohol, beverages, and refined tea	酒、饮料和精制茶制造业
16	Manufacture of tobacco	烟草制品业
17	Manufacture of textiles	纺织业
18	Manufacture of textiles, clothing; apparel industry	纺织服装、服饰业
19	Manufacture of leather, fur, feather and related products; footwear industry	皮革、毛皮、羽毛及其制品和制鞋业
20	Processing of timber, manufacture of wood, bamboo, rattan, palm, and straw products	木材加工和木、竹、藤、棕、草制品业
21	Manufacture of furniture	家具制造业
22	Manufacture of paper and paper prod.	造纸和纸制品业
23	Printing and recorded media	印刷和记录媒介复制业
24	Manufacture of articles for culture, education, art, sports, and entertainment	文教、工美、体育和娱乐用品制造业
25	Processing of petroleum, coking, processing of nuclear fuel	石油、煤炭及其他燃料加工业
26	Manufacture of chemical raw materials and chemical products	化学原料和化学制品制造业
27	Manufacture of medicines	医药制造业
28	Manufacture of chemical fibers	化学纤维制造业
29	Manufacture of rubber and plastics	橡胶和塑料制品业
30	Manuf. of non-metallic mineral products	非金属矿物制品业
31	Smelting and processing of ferrous metals	黑色金属冶炼和压延加工业
32	Smelting and processing of non-ferrous metals	有色金属冶炼和压延加工业
33	Manufacture of metal products	金属制品业
34	Manufacture of general purpose machinery	通用设备制造业
35	Manufacture of special purpose machinery	专用设备制造业
36	Manufacture of automobiles	汽车制造业
37	Manufacture of railway, ships, aerospace and other transportation equipment	铁路、船舶、航空航天和其他运输设备制造业
38	Manufacture of electrical machinery and equipment	电气机械和器材制造业
39	Manufacture of computers, communication and other electronic equipment	计算机、通信和其他电子设备制造业
40	Manufacture of measuring instruments	仪器仪表制造业
41	Other manufacturing	其他制造业
42	Comprehensive use of waste resources	废弃资源综合利用业
43	Repair of metal products, machinery and equipment	金属制品、机械和设备修理业

Note: Industrial classification for national economic activities GB/T 4754—2017 (Excerpts). Category C general manufacturing. This category includes code 13 to 43 industries. It refers to new products after physical or chemical changes, whether they are made by power machinery or by hand, whether they are sold in wholesale or retail, they are all considered to be manufactured. Translation of sector name referred to (Holz, 2013).

Appendix B Classification of Large, Medium, Small and Miniature Enterprises

Sector	Manufacturing	
Indicator	Employee (X)	Revenue (Y)
Unit	number	10^4 yuan
Large	X≥1000	Y≥40000
Medium	300≤X＜1000	2000≤Y＜40000
Small	20≤X＜300	300≤Y＜2000
Miniature	X＜20	Y＜300

Notes: Large, medium and small enterprises must meet the lower limit of all the listed indicators; miniature enterprises need only meet one of the listed indicators. In this research, miniature enterprises are classified into small enterprises.

Source: Notice of the National Bureau of Statistics on Issuing the Measures for Classification of Large, Medium, Small and Miniature Enterprises for the Purpose of Statistics 2017 (Excerpts). http://www.stats.gov.cn/tjsj/tjbz/201801/t20180103_1569357.html

Appendix C Interview Question

With firm personnel

Background information: Age, Gender, Education, Position, Basic information about the firm.

Opening questions

What do you do in your company/agency?

How long have you been in this position?

Questions about firm's water use

How much water do you consume and what do you do with it?

What factors influence your water usage?

How is your firm’s water supplied?

How much do you value your relationship with your water supply organization?

Are there any water recycling or pollution treatment measures in your firm?

Is there wastewater generated? If so where do they go? How is the waste emission charged?

Who is there to regulate the wastewater emission?

Questions about the perception of water constraint

Is there any change in the amount of available water in recent years?

Is there any change in the water quality in recent years?

Is there any change in the water price in recent years?

Do you think the SNWTP has an impact on your water availability?

If yes, what do you think of the availability change then?

Is there any change in the policy and regulation on your water use?

Questions about adaptation behaviour

Have you taken any measure to change water use in your firm? And what are the measures?

What factors drive you to take the action?

Are there any alternative measures proposed during the decision-making?

Questions about performance evaluation

How is the result of the change in water use?

Closing questions

Thank you for allowing me to interview you. Is there any question you consider important in water management that we have not discussed?

Could you please recommend someone else I could talk to?

With government official/other informants

Background information: Age, Gender, Education, Position

Opening questions

What do you do in your agency/department?

How long have you been in this position?

Questions about SNWTP

Where does the southern water go after it entered this locality?

How is the southern water utilized in this locality?

Is the water coming daily or during certain period?

What factors are the quantity subject to?

Water price has changed several times ever since the SNWTP, how much dose the project contribute to the change?

Which SNWTP related department has a say in the water pricing?

Has the transferred water changed the water quality?

What are the related policies regarding the water transfer?

Questions about policy and water governance

What is the specific water pollution control action plan in your administration?

Is there any water conservation related policy enforced in your district?

What is your major concern when you enforce water conservation or water pollution control regulations?

What measures have you taken to enforce these policies?

How does environmental performance influence official promotion evaluation?

Questions about firm behaviour

When do industrial firms start to use the southern water (or water that is mixed up with southern water)? How much southern water is utilized by industrial firms?

Is there any restriction on firms' water withdrawal?

Is there any change in industrial firms' water use in recent years?

What factors do you think changed their water use behaviour?

Closing questions

Thank you for allowing me to interview you. Is there any question you consider important in water governance that we have not discussed?

Could you please recommend someone else I could talk to?

Appendix D Profile of Major Interviewees

No	Interview date	Gender	Position	Location	Entity type	Establishment date
1	21/04/2017	F	Researcher	Beijing	Research Institute	-
2	23/06/2017	M	Senior Official	Beijing	GOV	-
3	29/06/2017	M	Researcher	Beijing	Research Institute	-
4	08/07/2017	M	Researcher	Beijing	Research institute	-
5	28/07/2017	F	Staff	Beijing	IF(SOE)	1981-01-19
6	01/08/2017	F	EHS Manager	Beijing	IF	2009-03-23
7	03/08/2017	F	Environmental Inspection Officer	Beijing	EPB	-
8	06/08/2017	F	EHS Manager	Beijing	IF(SOE)	2010-08-24
9	06/08/2017	M	Water Treatment Manager	Beijing	ES	2002-11-25
10	06/08/2017	M	Water Treatment Staff	Beijing	ES	2002-11-25
11	09/08/2017	M	General Manager	Beijing	IF	2012-08-10
12	10/08/2017	F	EPB Law Enforcement	Beijing	EPB	-
13	12/08/2017	M	EHS Staff (Facility Engineering)	Beijing	IF	2002-10-16
14	14/08/2017	M	General Manager	Beijing	IF	2007-02-08
15	21/08/2017	F	Director of the Water Conservation Office	Beijing	WA	-
16	21/08/2017	M	Manger	Beijing	IF	2007-09-18
17	21/08/2017	F	Chemical Engineer	Beijing	IF(SOE)	2001-09-19
18	23/08/2017	M	Logistics Department Manager	Beijing	IF	2004-11-03
19	23/08/2017	M	Facility Department Manager	Beijing	IF(SOE)	1997-07-23
20	23/08/2017	M	Logistics Department Manager (Water Electricity)	Beijing	IF	1999-11-17
21	24/08/2017	F	Accountant	Beijing	IF	2000-08-18
22	25/08/2017	M	Engineering Department Manager	Beijing	IF(SOE)	1993-12-08
23	28/08/2017	M	Manger	Beijing	ES	2002-11-27
24	31/08/2017	M	Manger	Beijing	IF(SOE)	1986-10-09
25	31/08/2017	M	Manger	Beijing	IF(SOE)	1993-01-06
26	09/09/2017 14/11/2017	M	Engineering Section Chief	Hebei	SNWTO	-
27	17/09/2017 15/10/2017	M	Manufacturing Staff	Hebei	IF	2001-06-12
28	18/09/2017	M	Senior Engineer (New Energy)	Beijing	IF(SOE)	2003-05-13
29	21/09/2017	M	General Manager	Hebei	IF	1992-02-24
30	21/09/2017	M	Supplier	Hebei	IF	1992-02-24
31	11/10/2017	M	General Manager	Tianjin	IF	2014-03-31
32	11/10/2017	M	Senior Official	Hebei	GOV	-
33	15/10/2017	M	Engineering Design Staff	Hebei	IF(SOE)	2007-07-10

34	02/11/2017	M	Senior Official	Hebei	WA	-
35	03/11/2017	M	Senior Official	Hebei	GOV	-
36	03/11/2017	M	CTO	Hebei	IF	2010-03-12
37	03/11/2017	M	Chemical Operation Department Manager	Hebei	IF(SOE)	2004-12-07
38	06/11/2017	F	Staff	Hebei	IF	2003-05-28
39	06/11/2017	M	Energy Environment Department Manager-Water	Hebei	IF(SOE)	2005-10-09
40	06/11/2017	M	Division Head	Hebei	GOV	-
41	07/11/2017	M	Technology Centre Director	Hebei	IF(SOE)	2005-01-11
42	07/11/2017	F	Deputy General Ma nager	Hebei	IF(SOE)	2004-12-09
43	07/11/2017	M	Plant Manager	Hebei	IF(SOE)	Affiliated with GOV
44	07/11/2017	M	Plant Manager	Hebei	IF(SOE)	Affiliated with GOV
45	16/11/2017	M	Department of Public Utilities Management-Deputy Manager	Hebei	IF(SOE)	2005-02-03
46	16/11/2017	F	Department of Public Utilities Management-Director	Hebei	IF(SOE)	2005-02-04
47	16/11/2017	M	Deputy Director	Hebei	EPB	-
48	21/06/2018	M	Researcher	Beijing	University	-
49	10/07/2018	M	Plant Manager	Hebei	IF	1938-05-04
50	10/07/2018	M	EHS Staff	Hebei	IF	1938-05-04

Notes: GOV stands for local government, IF stands for industrial firm, EPB stands for Environmental Protection Bureau, WA stands for Water Authority, ES stands for environmental service company, SNWTO stands for SNWT Office, CTO stands for Chief Technology Officer.

Appendix E Laws and Regulations Pertaining to Corporate Water Management

No	Title of Law/Regulation	Time of Adoption or Implementation	Scope and Property
1	Environmental Protection Law of the People's Republic of China	1979 (Amended 1989, 2014)	National Law
2	Discharge/Emission Standards of Water Pollutants for Different Industries	1983 (Amended 1992, 1993, 1995, 2001, 200, 2005, 2008, 2010, 2011, 2012, 2013)	National Standard
3	Water Pollution Prevention and Control Law of the People's Republic of China	1984 (Amended 1996, 2008, 2017)	National Law
4	Standards for Drinking Water Quality	1985 (Amended 2006)	National Standard
5	Environmental Quality Standards for Surface Water	1988 (Amended 2002)	National Standard
6	Water Law of the People's Republic of China	1988 (Amended 2002, 2009, 2016)	National Law
7	The General Principles of Water Balance Test in Enterprises	1990 (Amended 2008)	National Standard
8	Measures of Beijing Municipality on Administration of Urban Public Water Supply	1992 (Amended 1997, 2002)	Local Government Rules
9	Standard for Groundwater Quality	1993 (Amended 2017)	National Standard
10	Integrated Wastewater Discharge Standard	1996	National Standard
11	Circular on the Collection of Wastewater Treatment Fees and the Establishment of Urban Pollution Discharge and Centralized Treatment	1999	Administrative Regulation
12	Classification and Definition of Industrial Water	1999	Departmental Rules (MOC)
13	Water Balance Test Method for Industrial Enterprises	1999	Departmental Rules (MOC)
14	Assessment Index and Calculation Method of Industrial Water Use	1999	Departmental Rules (MOC)
15	Law of the People's Republic of China on Environmental Impact Assessment	2002 (Amended 2018)	National Law
16	Water Intake Norm for Industrial Product	2002 (Amended 2006, 2011, 2012, 2014, 2015, 2016, 2017, 2018, 2019)	National Standard (Quota)
17	Measures of Beijing Municipality on Water Conservation	2005	Local Government Rules
18	The Reuse of Urban Recycling Water-Water Quality Standard for Industrial Uses	2005	National Standard
19	Regulation on the Administration of the License for Water Drawing and the Levy of Water Resource Fees	2006 (Amended 2017)	Administrative Regulation
20	Evaluating Guide for Water Saving Enterprises	2006 (Amended 2018)	National Standard (Guide)
21	Measures of Beijing Municipality for Administration of Water Supply by Self-Constructed Facilities	2007	Local Government Rules
22	General Provisions on Equipping and Managing of the Measuring Instrument of Water in Organization of Water Using	2009	National Standard

23	Measures of Beijing Municipality for Administration of Drainage and Water Recycling	2009	Local Government Rules
24	Norm of Water Intake of Hebei Province: Industrial Water	2009 (Amended 2016)	Provincial Local Standard
25	Opinions of the State Council on Applying the Strictest Water Resources Control System	2012	Interpretation of Administrative Regulation
26	Directive for Technique of Water Metering	2012	National Standard
27	Catalogue of the Industrial Water Saving Process, Technology and Equipment Encouraged by the State	2014 (Amended 2016, 2019)	Departmental Rules (MIIT, MWR)
28	Notice of the State Council on Issuing the Action Plan for Prevention and Control of Water Pollution	2015	Regulatory Documents of the State Council
29	Plan for Controlling the Implementation of the Pollution Discharge Permit System	2016	Regulatory Documents of the State Council
30	Thirteenth Five-Year Plan for Energy-Saving and Environmental Protection	2016	Regulatory Documents of the State Council
31	Measures for the Administration of Water Efficiency Labels	2017	Departmental Rules (NDRC, MWR, AQSIQ)
32	Administrative Measures on Key Pollutant-Discharging Enterprises	2017	Departmental Rules (MEP)
33	Decision of the Standing Committee of the People's Congress of Beijing Municipality on the Applicable Environmental Protection Tax Rates for Taxable Air Pollutants and Water Pollutants in Beijing Municipality	2017	Provincial Local Regulations