Collaborative governance for technological innovation

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Collaborative governance for technological innovation:

A comparative case-study of wind energy in Xinjiang, Shanghai and Guangdong

Abstract

This paper examines relationships between collaborative governance and technological innovation. Collaborative governance is a key strategy for this form of innovation but remains under-researched. This paper explores how and to what extent collaborative governance can contribute to technological innovation, using a case study of wind energy in China. Drawing on a comparative analysis of three provinces, Xinjiang, Shanghai and Guangdong, the paper presents three major findings. Firstly, the three provinces reflect local variations in their models of government-industry-university collaboration. Xinjiang illustrates a *hierarchical* model, Shanghai's model is highly *institutionalised*, while Guangdong has adopted a *market* model. Secondly, the mechanisms for collaborative governance are conceptualised into three integral elements: resources (such as funds, personnel and technological knowledge), structures (such as collaborative institutions and learning networks) and processes (such as resource pooling and learning). Thirdly, the Chinese model of collaborative governance for technological innovation shares some important characteristics with western models but also exhibits some differences. The relatively limited role of public service organisations, a domestic market dominated

by state-owned enterprise, the relatively inactive role of industrial associations and an emergence of policy networks distinguishes the Chinese models.

INTRODUCTION

Technological innovation is vital in the pursuit of global competitiveness (Koh and Wong, 2005). The development of the wind turbine industry has become a key area of technological innovation in both developed (such as Germany and the U.S.) and emerging economies (such as China and India) and represents an important element of strategic plans to transit towards more innovation-based and sustainable economies (BMU, 2007a, b; DOE, 2008; IWTMA *et al*, 2009).

Technological innovation has been a major challenge for the development of wind energy worldwide. From basic R&D to applied R&D, and from component manufacturing (e.g. gear boxes and blades) to assembling entire turbines, the wind turbine manufacturing industry requires capabilities to innovate, design and produce new products and services (Li *et al*, 2010).

Western experience suggests that collaboration plays a crucial role in technological innovation for wind energy. Denmark, Germany and Spain, which are among the global leaders in the wind turbine manufacturing industry, emphasise the importance of research networks and the role of industrial associations in their R&D systems

(GWEC, 2012a). Western models are also characterised by incremental innovation that requires intensive trial-and-error learning processes (Kamp *et al*, 2004) and an emphasis on basic R&D rather than focusing on applications only (Burton, 1993).

In contrast, the R&D system for wind energy in China appears to possess some unique characteristics. While most of the leaders in wind energy have pursued substantial R&D efforts since the late 1970s (Lewis and Wiser, 2007), China is a late-comer. Major R&D programmes for wind energy in China have started to grow in number and scale only since the enactment of the nation's renewable energy law in 2005 (Buruku, 2005). However, this late-comer has opportunities to leapfrog the R&D processes. While China's reliance on purchasing production licenses from foreign counterparts has been relatively well document (Liu, 2006), how and to what extent collaboration – another approach to facilitating technological innovation – has however been under-researched.

This study explores how and to what extent collaborative governance can contribute to technological innovation, with a particular reference to wind energy in China. China has a prominent presence in the global renewable energy market. This country has recently emerged as one of the global leaders in renewable energy, notably as a low-cost manufacturing centre for industries such as solar photovoltaic production (The Climate Group, 2009). By end 2011, China's total installed capacity of wind energy reached 62 GW and it has overtaken the U.S. as the country with the highest installed wind energy capacity (GWEC, 2012b). Wind energy, although capable of making a significant contribution to the achievement of sustainable energy (Li *et al*, 2011), has remained a fringe energy source in China. Wind energy contributed to only 1.5 percent of the country's total electricity output with a total generation capacity of about 73 TWh in 2011 (Li *et al*., 2012; CNREC, 2012). Limits on technological innovation capacity, problems of quality assurance, and the lack of a reliable supply of components have been identified as major barriers constraining the growth of wind energy (Li *et al,* 2010; Mah and Hills, 2008).

Given the key role of collaboration for technological innovation in the Western experience, it is important to examine the evolution of collaborative activities for the wind turbine industry in China. Collaboration, which relies on the cooperation between diverse stakeholders for problem solving (Thomson and Perry, 2006), is a complex process and many of its operational dynamics are yet to be fully understood. This paper therefore aims to understand and explain the mechanisms of collaborative governance in the context of wind energy in China. This paper adopts a comparative case study approach (Yin, 2003). We present an integrated framework for linking the concepts of collaborative governance and innovation systems, and apply the framework to compare and contrast the evolution of R&D systems for wind energy in three Chinese provinces, Xinjiang in the northwest, Shanghai on the east coast and Guangdong in the southeast. Our analysis focuses on collaborative activities between government, industry and universities. We assess the extent to which a collaborative approach has influenced technological innovation, and identify factors and conditions which are critical in the collaboration process. Specifically, we address the following key questions:

(1) How and to what extent does the Chinese model of collaboration work and contribute to technological innovation?
(2) What are the mechanisms for collaboration? What are the favourable conditions that facilitate collaboration and what are the barriers? Are there local variations in terms of the collaborative mechanisms?
(3) Are there differences between the Chinese and Western models? If so, what are the differences and what explains the apparently distinctive form of collaborative governance in China?

The three provinces are selected not only because they represent a diversity of political, socio-economic and environmental contexts across China (Table 1) but also because their R&D systems differ. In terms of three key aspects of R&D, namely gross domestic expenditure on R&D (which includes national and local public expenditure), science and technology appropriations by the local government, and R&D personnel by region, Xinjiang lags well behind Shanghai and Guangdong while Guangdong is the most advanced of the three (Table 2). For example, the gross domestic expenditure on R&D in Xinjiang in 2008 was 1.6 billion yuan, only about 3 percent of that of Guangdong (CSTS, 2009).

The case studies presented here draw on data and information derived from desktop research, semi-structured interviews and field visits. Twenty-three semi-structured interviews were conducted in seven field trips to Beijing, Xinjiang, Shanghai and Guangdong between 2006 and 2010. The interviewees were carefully selected informants and stakeholders who occupy roles, positions, or status in organisations, social networks, or communities of the political system and are therefore knowledgeable about the issues studied (Johnson, 1990). They included government officials, senior executives from utilities, wind farm developers, wind turbine manufacturers, academics, and scholarly/ industrial associations. As some interviewees agreed to be interviewed only anonymously, this study indicates interviews by number. The first two letters indicate the location (BJ for Beijing, XJ for Xinjiang, SH for Shanghai, and GD for Guangdong), the two digits indicate the interview numbers, and this is followed by the year of the interviews. The list of interviews is provided in the appendix.

Table 1: The basic features of the three Chinese provinces selected for this study

	Xinjiang	***Shanghai***	***Guangdong***
Location	Northwest; inland	Central; coastal	Southeast; coastal
Capital	Urumqi	N.A.	Guangzhou
Provincial status	Autonomous region	Municipality	Province
GDP (billion yuan) (2008)	420	1,370	3,570
Population (million) (2008)	21.3	18.9	95.4
Area (km^2)	1,664,900	6,341	179,757

(Sources: Cheung, 2002; HKTDC, 2009, 2010a, 2010b; Shanghai Statistics, 2008; Zhang, 2002)

Table 2: R&D statistics in China and major provinces (2008)

	National Total	**Beijing**	**Xinjiang**	**Shanghai**	**Guangdong**
Gross Domestic Expenditure on R&D (100 million yuan)	4,616.0	550.3	16.0	355.4	502.6
Local government Science and Technology Appropriation (million yuan)	105,186 (2.14%)	11,219 (5.73%)	1,484 (1.40%)	12,027 (4.64%)	13,252 (3.51%)
R&D Personnel by region (1,000 person/ years)	1,965.36	189.55	8.81	95.13	238.68

(%)：percentage of local public expenditure (地方财政支出)

(Source: authors; data from CSTS, 2009)

The following section develops an integrated framework that builds the linkages between the concepts of collaborative governance and innovation systems. We then provide a brief overview of the evolution and characteristics of R&D systems in Western economies and in China. This is followed by a detailed comparison of the local R&D systems for wind energy in three Chinese provinces.

COLLABORATIVE GOVERNANCE FOR TECHNOLOGICAL INNOVATION: TOWARDS AN INTEGRATED FRAMEWORK

A scanning of the literature suggests that two strands of research have emerged that are instructive in providing a better understanding of the complexity of technological innovation. These are systems of technological innovation and collaborative governance.

Systems of Technological Innovation

The literature on technological innovation systems first emerged in the late 1970s. Central to this literature is its systemic perspective. This suggests that technological innovation requires technological advancements as well as co-evolution in the institutional, policy, behavioural, organisational and other elements of technological systems (Cames *et al,* 2004; Praetorius *et al,* 2009). Technological innovation is a societal transformation process that requires interactions of “a dynamic network of actors” in the “generation, diffusion, and utilisation of technology” (Carlsson and Stankiewicz, 1991: 93). Networks between firms and non-firms actors (including universities, research centres, government agencies, financial institutions and others) are central to technological innovation (Kristinsson and Rao, 2007) because they can generate knowledge which forms the basis for innovation (Fisher *et al*, 2001). They can also facilitate rapid responses to turbulent conditions in markets (Fisher *et al*, 2001).

Networks can take various forms. Some are based on user-supplier relationships (Fischer *et al*, 2001) while others may be of a political nature such as policy networks (Jacobsson and Lauber, 2006; Jacobsson and Johnson, 2000). Networks are often driven by the complementarity of the actors involved. Key network processes include the interactive exchange of information and knowledge, learning, trust building, partnership, and empowering practices (Fisher *et al.*, 2001).

While the literature has identified the presence of research leaders in firms (Schmidt *et al*., 2003), institutional arrangements (particularly for vocational training and dealing with powerful trade unions of the established sectors), and personal contacts (Fisher, *et al*., 2001) as some of the facilitating factors of innovative networks, barriers are also many. These include the conflicting motives of collaborating partners, a lack of coordination, a lack of capabilities to absorb external knowledge, and a lack of managerial competences to recognise technological innovation is a competitive strategy (Schmidt *et al*., 2003).

Collaborative Governance

Collaborative governance is an important concept that may complement the literature on the technological innovation systems to illuminate how networks contribute to technological innovation.

Collaboration is a process in which diverse stakeholders, including public, private, and societal actors pool together their inputs, resolve problems collectively, and achieve not only individual ends but also achieve additional, shared benefits (Thomson and Perry, 2006). Collaborative governance is rooted in the governance perspective, which emphasises the need for governments to reach out downwards to localities, and to move out to civil society and to engage with markets (Pierre and Peter, 2000; Stoker, 1998; Satterthwaite, 1999). Governing through collaboration is therefore a multi-actor, multi-sector approach to problem-solving (Mah and Hills, 2010a).

The literature on collaborative governance helps to explain the key processes and conditions required for effective collaboration (see for example Ansell and Gash, 2008; Mah and Hills, 2010), and can inform the conceptualisation of the mechanisms of innovation networks. Resources, structure, and processes are the core elements of these mechanisms.

The literature distinguishes three types of resources – human, technical and financial - which are required for effective collaboration. Human resources include the personnel, skills, abilities, and experience. Technical resources refer to information and knowledge about the natural resources and their management. Financial resources may include funds obtained from members, governmental, and nongovernmental sources (Koontz *et al*., 2004).

The literature suggests that collaborative groups may develop a variety of structures which may include institutional, organisational or administrative arrangements (Koontz *et al*., 2004; Phillips *et al*., 2000). Some collaborative structures are loose federations and ad hoc committees whilst some are formal organistaions within a well-defined adminstrative framework (Koontz, *et al*., 2004).

The literature on collaborative governance is also instructive in shedding light on the evaluative aspects of collaboration. Collaboration involves a continuum of partnership forms depending on the complexity of purpose, intensity of linkages and formality of agreement (Sych, 1999). Networking and cooperation are lower forms of partnerships which often involve only communication and coordination but do not necessarily improve performance (Denise, 1999). In contrast, collaboration – the highest form of partnership – emphasises the achievement of not only individual ends but also additional, shared benefits (Thomson and Perry, 2006).

The perspectives of innovation systems and collaborative governance provide complementary insights relating to technological innovation. There are however three major gaps in the literature. Firstly, there is a lack of an integrated framework that links the key concepts from the two perspectives to guide analysis on technological innovation. Secondly, the mechanisms of collaboration for technological governance have remained under-researched. Thirdly, most of the literature on technological innovation and collaborative governance is in the Western context. Work in the Asian context is relatively limited. Technological innovation for wind energy in developing countries may possess industry- and country-specific characteristics that may limit the generalisability of the concept of collaborative governance outside the Western context.

To partially fill these gaps, this study bases on the two theoretical perspectives and develops an integrated framework. Our framework suggests that governments, enterprises and civil society (such as industrial associations and universities) need to interact in on-going collaborative relationships that create favourable mechanisms for technological innovation. We introduce a concept of resource-structure-process mechanisms of collaborative governance. Resources, structures and processes are three key integral elements that affect the functioning of collaboration. Key resources that include human, technical and financial resources, key structures that include learning networks and collaborative institutions, key processes such as resource pooling, learning, information exchange, trust building and leadership development are critical conditions.

R&D COLLABORATION FOR WIND ENERGY: AN OVERVIEW, THE WESTERN MODELS, AND THE CHINESE CONTEXT

Technological innovation is the key to achieve global competitiveness for many economies. Technological innovation can reduce cost and enhance production skills (Edquist, 2005; Kamp *et al*., 2004). It can also improve product performance and characteristics through introducing changes in processes or organisations (Edquist, 2005; Kamp *et al*., 2004). Technological innovation is not however a simple process. It is subject to financial risk, long payback periods, and risks of failure in the R&D process (Lewis, 2007).

Wind turbine industries in many countries share most of the barriers that technological innovation in general has to overcome. However, technological innovation is a particular challenge for the wind turbine industry for a number of reasons. Wind turbines contribute a significant portion, usually some 70 percent, of the total capital cost of wind farms in China (Liao *et al*., 2010). Product performance of wind turbines, in terms of electricity output, is largely dependent on micro-siting analysis, site planning, and in-situ fine-tuning of equipment (Wan *et al*., 2009). Cost reductions and improvements in product and service performance are therefore prioritised areas for technological innovation for wind turbines.

Western models

Technological innovation systems cannot be homogenous across countries as they are to a large extent influenced by contextual factors such as economic structure and the knowledge capacity of the systems (EU, 2011). However, collaboration for R&D appears to be a common strategy for wind energy development in several leading Western countries such as Denmark, Germany, Spain and the U.S. (GWEC, 2012a). Their collaborative models appear to share certain characteristics.

One shared characteristic relates to the role of public service organisations as collaborative institutions. The Risø National Laboratory in Denmark (Nielsen *et al.*, 1998), the Fraunhofer Institute for Wind Energy and Energy System Technology (IWES) in Germany, and the National Renewable Energy Laboratory (NREL) in the U.S. (Loitera and Norberg-Bohmb, 1999) are some of major public service organisations active in this field. These collaborative institutions appear to be crucial in strengthening the ties between governments, industry and universities, pooling resources, and facilitating intensive learning and information exchange between turbine producers, turbine owners and researchers (Kamp *et al*, 2004). Through providing collective technical services to SMEs, these collaborative institutions play a critical role in creating a level playing field for new entrants and promoting diversity in technology (Cruz-Castro *et al.*, 2002).

Another feature of the Western models is the active role of industrial associations in the formation of not only technical networks but also policy networks. While some of those industrial associations provide for example training courses for wind electricians (Bergek and Jacobsson, 2003; Kristinsson and Rao, 2007), some play a key role in influencing policy making as policy networks. The active industrial associations in Germany and Denmark such as the Danish Wind Industry Association have been able to enroll both turbine manufacturers and wind farm developers, and to influence the institutional and policy framework to the benefit of the entire wind energy industry (Bergek and Jacobsson, 2003; Nielsen *et al*., 1998).

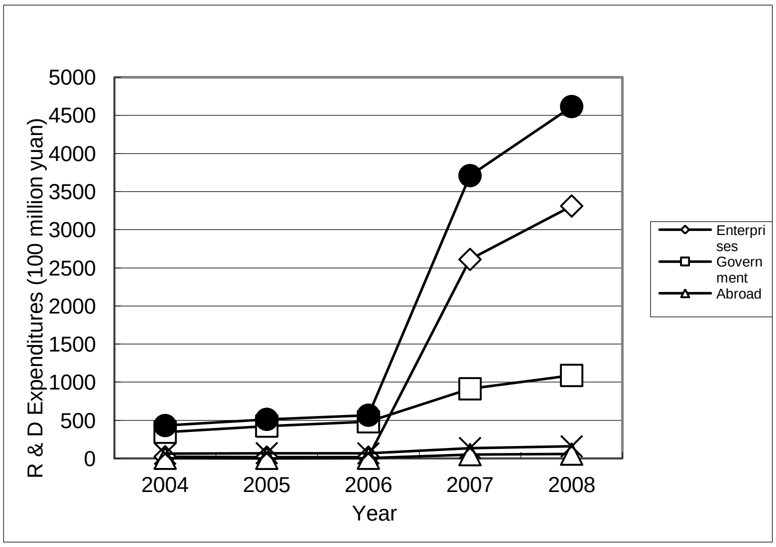
Thirdly, a sense of trust and respect for collaboration has been established in those Western models in which information sharing, of for example wind turbine performance data, has been institutionalised in public service organisations. In contrast, such data has been regarded as “business secret” in China (Interview: BJ/01/2010). Such trusting relationships are regarded as critical in promoting sharing of data, knowledge, and experience (Interview: BJ/01/2010).

R&D systems in transitional China

R&D systems in China have been transformed since the start of the economic reforms in 1978 (Liu and Jiang, 2001). Before the reforms, China’s R&D system was vertically organised and the central government developed R&D plans and allocated such work to relevant research institutes (Chang and Shih, 2004). Horizontal linkages between research institutes and industries virtually did not exist (Liu and Jiang, 2001).

Since the early 1980s, the central government has been decentralising its R&D responsibilities and administrative authority (Wu, 2007). Enterprises have become much more prominent in China’s R&D system particularly since 2006 when the strategy of “enterprise-led indigenous innovation” was introduced in the national 2006 Science and Technology Programme. Since then, investment by enterprises has overtaken the government as the main source of R&D funding. While government R&D investment doubled from approximately 48 billion yuan in 2006 to approximately 109 billion yuan in 2008, R&D investment from enterprises increased approximately 200-times from 1.7 billion yuan in 2006 to 331 billion yuan in 2008 (Figure 1). Horizontal ties between enterprises, research institutes and universities have also been strengthened (Wu, 2007; Zhang *et al,* 2009). There are expanding networks of universities, research institutions and enterprises in many high-tech industries (Liu and White, 2001a, b), including the wind energy industry.

Figure 1: Sources of R&D expenditures in China (2004-2008)



(Source: compiled by authors; data from China Science &Technology Statistics Data Books, 2005-2009, from http://www.sts.org.cn/sjkl/kjtjdt/index.htm)

It is in this transitional context that China has stepped up its efforts to develop a technological innovation system for wind energy, particularly following the enactment of the Renewable Energy Law in 2005 (Baker & McKenzie *et al,* 2007). The Chinese government has leveraged private R&D spending through various kinds of subsidies, tax incentives and other policies. National R&D programmes such as the High-Tech Industry Development Program and Torch Program have incorporated wind turbine manufacturing as key components (Goldwind, 2009).

The Chinese model, which has been characterised by its emphasis on domestic turbine manufacturing industry and its reliance on purchasing foreign production licenses to leapfrog innovation processes, has achieved some successes (Liu, 2006). The costs of wind energy have dropped substantially as the domestic market has been rapidly localised. At present, domestic wind turbine manufacturers dominate the Chinese market, accounting for about 70 percent of the market (Li *et al,* 2010). Wind costs per kWh ranged from 7,000 (for domestic turbines) to 10,000 (for imported turbines) yuan in the mid 2000s (Liu, 2006), but by 2010 some projects have reported cost reductions to below 4,000 yuan (CWEI, 2010). Chinese manufacturers have also started to emerge as global players in recent years. Three manufacturers - Sinovel, Goldwind and Dongfang - were ranked among the top 10 global manufacturers of wind turbines in 2009 (REN 21, 2010).

Despite these achievements, innovation capacity and quality control remain major concerns. The reliance on foreign technology in the past resulted in a relative weak capacity for innovation particularly in relation to basic R&D (Interview: XJ/1/ 2008). While the leading domestic manufacturers have started to develop 5 MW or larger turbines (REN 21, 2010), manufacturers in the West have already installed wind turbine of 7.5 MW (REN 21, 2010). Chinese wind turbine manufacturers also still rely on foreign counterparts for certain core turbine technologies such as gear boxes (Liu, 2006; Interview: GD/01/2010). Other concerns include the quality of domestic turbines, a lack of reliable supply of components, and an under-developed network of ancillary services such as certification bodies (Li *et al*, 2010; Mah and Hills, 2008).

R&D COLLABORATION MODELS FOR WIND ENERGY: LOCAL DIVERSITY ACROSS CHINA

(a) Xinjiang: a *hierarchical* model

Located in the northwest interior of China, Xinjiang is economically backward, environmentally fragile (HKTDC, 2010b) but possesses some of the best wind resources in China (HKTDC, 2010b; Editorial Committee, 2005). The province is renowned for being the cradle for the Goldwind Science and Technology Co. Ltd. (金风 *Jinfeng*) – one of China's leading domestic wind turbine manufacturers since the early 2000s and ranking second only to Sinovel in 2009 (CWEA, 2010). Goldwind accounted for approximately 20 percent of the Chinese market in 2009 (CWEA, 2010) and sold more than 9,000 wind turbines by end 2010 (Goldwind, 2011).

Several factors have been important in the development of the wind energy industry in this remote province. While central policies for supporting the domestic wind turbine industry, particularly through the tendering pricing policy, have been a key factor in the growth of Goldwind (Lewis, 2005, 2006), another key feature has been the hierarchical form of government-enterprise-university collaboration.

A distinctive feature of this hierarchical form of collaboration is the pivotal role of the central government in collaboration between Goldwind and other parties. The pivotal role of the central government has been most pronounced in the establishment of the National Windpower Engineering Technology Research Center (NWTC). The NWTC was established in 2005 in Urumqi, the provincial capital, as China's sole national wind energy laboratory. The NWTC is affiliated to Goldwind and has served as an important collaborative institution for Goldwind. It has enabled Goldwind to build up its capacity for technological innovation through reaching out and establishing its domestic and global learning networks (Interviews: BJ/01/2010; XJ/06/2007).

Goldwind is a Chinese company whose beginnings can be traced back to a small company, Xinfeng, which was wholly owned and founded by the Chinese government in 1998 (Goldwind, 2009). Being the hosting institute for China's national wind energy laboratory, Goldwind was able to establish a pivotal position in the industry which was later found to be instrumental in allowing the company to develop networks with a broad range of stakeholders in China and abroad. Goldwind have intensive networks with government officials, universities, industrial associations, wind turbine manufacturers, component suppliers, as well as end-users (Interviews: XJ/02/2007, XJ/06/2007). Xinjiang Agriculture University, Delft University of Technology in the Netherlands, and international consultants in wind resource assessment and engineering such as Garrad Hassan and Aerodyn (Goldwind, 2009) are some examples of Goldwind's collaborators. These extensive networks have allowed Goldwind to access external resources including R&D funds from government and non-governmental sources, R&D knowledge, personnel, skills, experience, and market information (Interviews: XJ/02/2007, XJ/04/2007).

Placement programmes and secondment arrangements were critical for Goldwind to build up its learning network with its suppliers and end-users. Research students and graduates from the wind energy technology programme of Xinjiang Agriculture University were offered placements in Goldwind (Interview: XJ/4/2007). Vertical linkages with its component suppliers and end-users were also established through secondment arrangements. The company sent small teams of engineers to work closely with suppliers and wind farm developers on site to integrate feedback from end-users. Goldwind collaborated with its end-users to identify and assess R&D problems, formulate solutions, fine-tune product design and subsequently improve the R&D quality and business services (Interviews: XJ/01/2008; XJ/02/2007; XJ/06/2007; XJ/07/2008). These learning networks have been regarded as critical for Goldwind to strengthen its capacity for innovation, rather than simply for imitation (Interview: XJ/02/2007).

(b) Shanghai: an *institutionalised* mode

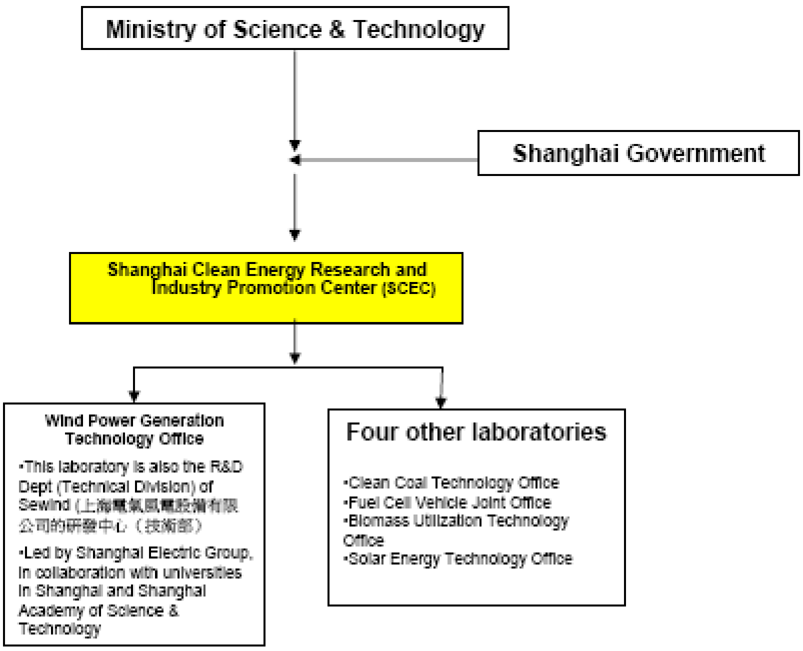
Unlike Xinjiang or Guangdong which have a relatively long experience in wind energy, Shanghai is a latecomer to the domestic wind turbine manufacturing industry. Sewind (上海电气风电设备有限公司 *Shanghai Dianqi Fengdian Shebei Youxian Gongsi*), a subsidiary of the Shanghai Electric Group (上海电气 *Shanghai Dianqi*, SE) which is a major state-owned conglomerate, was set up in 2005 as the first major wind turbine manufacturer based in Shanghai. The city does however possess a number of distinctive strengths for its entry into this emerging, and highly competitive industry (Interviews: SH/01/2006, SH/02/2006). One of its strengths is its institutionalised R&D model.

An illustrative example of this model is the establishment of the Shanghai Clean Energy Research and Industry Promotion Center (上海清洁能源研究与产业促进中心 *Shanghai Qingjie Nengyuan Yanjiu yu Chanye Cujin Zhongxin*, SCEC) in May 2006. The SCEC is modeled on the US National Renewable Energy Laboratory (NREL) and is expected to serve as a public service platform for closer government-enterprise-university collaboration (SCEC, 2009).

The SCEC is highly institutionalised in terms of its organisational structure and funding sources. It was established under a special collaboration arrangement between the Ministry of Science and Technology in Beijing and the Shanghai government. Such Ministry-Municipal collaboration (部市合作 *bushi hezuo*) is first-of-its-kind in China (Interview: SH/02/2006). It has been widely regarded as a unique institutional "product" of the traditional ties between the central and Shanghai governments which not many other provinces possess (Interview: SH/02/2006; SCEC, 2009).

Furthermore, the SCEC is sophisticated in its internal structure when compared to the NWTC. It has twelve full-time staff members and has established five laboratories, one of which is the Wind Power Generation Technology Office which in effect is Sewind's R&D department (Figure 2). In terms of funding sources, the SCEC is also highly institutionalised as it receives annual public funding of between 100 to 200 million yuan every year from the Science and Technology Commission of Shanghai Municipality (上海科学技术委员会 *Shanghai Kexue Jishu Weiyuanhui*, STCSM) (Interview: SH/05/2008).

Figure 2: Organisational structure of the Shanghai Clean Energy Research and Industry Promotion Center (SCEC)



Sewind, though a late-comer, has started to close the gap with other leading domestic manufacturers such as Goldwind. It has manufactured more than 400 wind turbines which have been installed in 21 wind farms in China (Shanghai Electric, 2010). It has been able to mass-produce 2-MW wind turbines since 2010 (Shanghai Electric, 2010), and has been expanding its business to include offshore wind turbines. It set up a manufacturing base for offshore wind turbines in Jiangsu Province in 2009 (Shanghai Electric, 2011). While this study does not have access to data to assess the causal connections between the Shanghai model of R&D and Sewind's R&D achievements, the R&D collaboration model in Shanghai appears to facilitate R&D in several areas.

Firstly, the SCEC has become a key collaborative platform in Shanghai. Facilitated by the SCEC, Sewind collaborated with three major universities in Shanghai (Shanghai Jiao Tong University, Tong Ji University and Shanghai University) and the Shanghai Academy of Science and Technology, and pooled together R&D skills, expertise and laboratory facilities among the parties (Interviews: SH/03/2008, SH/04/2008).

The ability to deliver R&D outputs in a relatively short period of time appears to be one of the major collaborative benefits to Sewind (Interviews: SH/03/2008, SH/04/2008). According to a university researcher who led one of those collaborative R&D projects, the project managed to deliver a R&D output in one year, requiring only half the time originally anticipated (Interviews: SH/03/2008, SH/04/2008). Another collaborative benefit appears to be access to industrial and market information. Sewind found that the SCEC is an important platform for information exchange. The information network has enabled Sewind to respond quickly to market changes (Interviews: SH/02/2006; SH/06/2006).

This kind of information network is also beneficial to policy-makers in Shanghai. The SCEC conducted or commissioned regular studies on the R&D needs of the industry. These studies, based on site visits and interviews with stakeholders, have contributed to an effective feedback process between wind turbine manufacturers, end-users and research institutes, and have been a source of intelligence for the Shanghai Science and Technology Commission to identify R&D gaps and to set strategic priority areas for R&D funding programmes (Interview: SH/06/2006).

Another distinctive feature of Shanghai's model is the relatively active role of academic associations. While such bodies were much less active in Xinjiang and Guangdong, these associations, particularly the Shanghai Consulting and Academic Activities Center for Academicians of the Chinese Academy of Engineering (上海市中国工程院院士咨询与学术活动中心 *Shanghaishi Zhongguo Gongchengyuan Yuanshi Zixun yu Xueshu Huodong Zhongxin*; hereafter the Shanghai Center for ACAE) and the Shanghai Energy Research Society (上海市能源研究会 *Shanghaishi Nengyuan Yanjiuhui*, SERS) have been active in offering advice on energy policies to the Shanghai Government on a regular basis. The Shanghai Center for ACAE, for example, produced a commissioned report titled "Consultation Report on the Strategies of Energy and Clean Energy Motor Vehicles in Shanghai" in 2006.

These two associations are the local branches of their corresponding associations at the national level, and these institutional linkages with national associations have allowed them to access to expertise outside Shanghai. These emerging policy networks have served as advisors, consultees and consultants for the Shanghai government, and have helped the SCEC to prioritise R&D funding resources for renewable energy (Interviews: SH/07/2008; SH/08/2008).

(c) Guangdong: a *market* model

Possessing an extensive coastline, Guangdong was one of the early movers in the development of wind energy in China. The first wind farm was built on Nan'ao Island in the 1980s. Guangdong had a total installed wind energy capacity of 500 MW by the end of 2009 (GD DRC, 2010). Mingyang – which ranked seventh in China in 2010 in terms of total installed capacity (Li *et al*, 2011) – is the leading wind turbine manufacturer based in Guangdong. A number of smaller private entities have also entered this emerging industry in the province which is renowned for its entrepreneurship (Interview: GD/01/2010).

The Guangdong model of government-industry-university collaboration is distinguished by its market-oriented elements. While Guangdong has been catching up in local government R&D investment (Guangdong STS, 2011) (Table 2), the Guangdong Government tends to place emphasis on creating a level playing field, encouraging a large number of market players, promoting market competition and placing less emphasis on picking a winner.

A distinctive initiative in Guangdong's market model is its Enterprises' Science and Technology Commissioners Action Plan (企业科技特派员计划 *Qiye Keji Tepaiyuan Xingdong Jihua*). This action plan was introduced in 2008 by the Guangdong government to provide incentives for enterprise-university collaboration. It involves selecting young R&D personnel from Chinese universities, appointing them as "commissioners" and stationing them in designated enterprises for a period of one year. The commissioners are expected to carry out a broad variety of "missions" that may include formulating R&D strategies for their designated enterprises, establishing a long-term enterprise-university collaboration system, participating in R&D, and nurturing R&D personnel (Guangdong STC, 2008a).

In October 2008, the first batch of 143 Science and Technology commissioners was deployed to 140 enterprises in Guangdong (Guangdong STC, 2008a, 2008b). Since then, three more groups of commissioners have been deployed and the action plan has gradually grown in scale. By July 2010, about 1,000 commissioners had been assigned to 872 enterprises (Guangdong STC, 2010).

It is however premature to evaluate the effectiveness of the action plan because only a small number of the commissioners have been dispatched to wind turbine manufacturers (Guangdong STC, 2008a, 2008b, 2010). Much of implementation data of the action plan are also not publicly accessible (Interview: GD/02/2011). However, the action plan has been welcomed in general by the wind energy industries and the researchers in the field (Interviews: GD/01/2010, GD/03/2008; GD/04/2008).

In contrast to the models in Xinjiang and Shanghai which have tended to pick winners, one of the potential strengths of the Guangdong model is its creation of a level playing field for a large number of enterprises of all sizes that include not only SOEs but also SMEs. The action plan in effect allows local enterprises and universities to have relatively equal access to state funding support. This encourages diversity of innovation pathways through a broad search of technological options and creation of knowledge by a relatively large number of actors (Jacobsson and Bergek, 2004; Interview: GD/01/2010).

The Guangdong model is also characterised by the presence of a number of institutional arrangements for government-enterprise-university collaboration. The latest development in this action plan is the strengthening of the institutional capacity for R&D. The government has planned to establish about 30 “Enterprises’ Science and Technology Commissioners Work Stations (企业科技特派员工作站 *Qiye Keji Tepaiyuan Gongzuozhan*) by end 2010 in Guangdong. Any enterprise that has employed three “commissioners” or more is eligible to apply to set up a “work station” within its company with public funding support.

A new university regulation that institutionalises incentives for academics to join the action plan is another new institutional arrangement. A major barrier for academics in Xinjiang and Shanghai to collaborate with industries is the lack of incentives in the current appraisal system in Chinese universities which tend to reward academic outputs rather than collaboration with the private sector (Interviews: XJ/01/2008, SH/04/2008). To overcome this institutional barrier, the South China University of Technology in Guangzhou introduced a new university regulation titled "Selection Measures of the Enterprises' Science and Technology Commissioners (企业科技特派员选派办法 *Qiye Keji Tepaiyuan Xuanpai Banfa*)" in 2008 (GD STD, 2008b). The new regulation provides preferential arrangements in terms of promotion and welfare for scholars who have served as a "commissioner".

Table 3. Overview of the local models of collaborative governance for technological innovation in China

	Xinjiang	**Shanghai**	**Guangdong**
Modes	**Hierarchical**	**Institutional**	**Market**
Key collaborative institutions	National Windpower Engineering Technology Research Center (NWTC)	The Shanghai Clean Energy Research and Industry Promotion Center (SCEC)	Enterprises' Science and Technology Commissioners Action Plan
Key players	▪ Goldwind, its research collaborators in China and abroad, its suppliers and end-users ▪ Central and local governments	▪ Sewind and its research collaborators ▪ Central and local governments ▪ Two academic associations	▪ Mingyang, and a number of small private entities ▪ Local government
Key resources	▪ *Human resources*: graduate students and talent training ▪ *Technical resources*: technological, industrial and market information; end-user feedback ▪ *Financial resources*: Research funds ▪ Others: trust	▪ *Human resources*: talent training through personnel transfer between Sewind and universities ▪ *Technical resources:* technological and industrial and market information ▪ *Financial resources*: research funding	▪ *Human resources*: young academics ▪ *Technical resources:* technological information ▪ *Financial resources*: research funding
Key structures	▪ Domestic and global learning networks ▪ Student placements & secondment ▪ Personal ties (between Goldwind and suppliers)	▪ A collaborative institution (the SCEC) which is highly institutionalised ▪ An emergence of a policy network on energy	▪ The action plan (and its 30 planned "work stations") serve as a collaborative platform that tends to facilitate a large number of players and market competition, rather than picking the winner ▪ Incentives provided by a university for university researchers
Key processes	▪ *Resources pooling*: public and private R&D resources ▪ *Learning*: through 1) routine interaction between a manufacturer and its component suppliers and end-users; 2) personnel transfer between Goldwind, universities and its learning networks	▪ *Resources pooling:* public and private R&D resources ▪ *Learning*: informed R&D policy-making facilitated by feedback from stakeholders; feedback was collected through commissioned studies, site visits, and regular stakeholder engagement meetings	▪ *Resources pooling*: public and private R&D resources ▪ *Learning*: tend to promote diversity of technologies with the presence of a larger number of market players

UNDERSTANDING COLLABORATIVE GOVERNANCE FOR TECHNOLOGICAL INNOVATION

Our analysis of the three case-studies has examined the government-enterprise-university collaboration for wind energy technology in China. Our analysis contributes to a better understanding of collaborative governance for technological innovation. We have three major findings.

Our first finding relates to the conceptualisation of the mechanisms of collaborative governance in the specific context of technological innovation. Our integrated framework has been tested in the three case-studies. Our comparative analysis of the three case-studies has found that the resource-structure-process mechanisms that we highlight in our framework can be applied and are broadly similar in our three case studies. As Table 3 shows, although the R&D models in the three provinces can be distinguished into different modes, the mechanisms that determine the functioning of collaboration in the three case studies all comprise three basis integral elements, resources, structures, and processes. The applicability of our framework in the case studies suggests that the conceptualisaiton of the mechanisms can be generalised outside the Western context, at least to China.

Specifically, this finding re-inforce the view in the Western literature that collaborative governance has an important role to play in pooling different types of resources together. These resources include human resources (such as personnel and experience), technical resources (such as R&D knowledge) and financial resources (such as R&D funding) as shown in our case studies. This finding also re-inforces the work of for example Jacobsson and Lauber (2006) and Koontz *et al*. (2004) which highlight the importance of networks and institutional arrangements as structures which may facilitate collaboration. Our case studies show that learning networks, which can be in various forms, are a critical structure. Such learning networks include technological networks (such as those established between Goldwind and research institutes in China and abroad), information networks (such as the manufacturer-end-user network in Xinjiang), and policy networks (such as the emerging one in Shanghai). We found that another structural element which is critical is the collaborative institutions. Those institutions include NWTC in Xinjiang, SCEC in Shanghai, and the Enterprises' Science and Technology Commissioners Action Plan in Guangdong. Our findings also re-inforce the literature that resource pooling and learning are two key processes in collaborative governance for technological innovation (Fisher *et al.*, 2001).

Our second finding relates to the distinctive forms of collaborative governance models in China and the ways in which these differ from Western models. The Chinese models appear to be distinguished by four characteristics: a limited role for public service organisations, a lack of market competition, relatively inactive industrial associations, and an emergence of policy networks.

Western experiences suggest that public service institutions such as Risø in Denmark are central to facilitating collaboration for achieving shared benefits for the wind energy industry. In contrast, the Chinese models appear to help enterprises to achieve individual ends (for example Goldwind and Sewind were able to achieve some collaborative benefits in terms of resources pooling and relatively rapid delivery of R&D outputs) rather than promoting shared benefits, such as testing prototypes and quality assurance.

Although the NWTC in Xinjiang and SCEC in Shanghai are public service platforms, they are enterprise-led, and their functions and activities are guided by enterprises' priorities rather than the public interests of the industry. Similarly, there is no evidence to suggest that the Enterprises' Science and Technology Commissioners Action Plan in Guangdong has been able to provide those crucial public services.

Another characteristic of the Chinese models is the dominating role of SOEs. The Xinjiang and Shanghai models attempt to pick winners among the locally based SOEs rather than encouraging a level-playing field for a large number of private entities. It would be premature to assess the effectiveness of the Chinese approach with the data available to this study, particularly in light of the fact that China has succeeded in grooming the domestic industry in a relatively short time. However, this Chinese approach has raised concerns because it has marked contrast with the Western models which emphasis that a large number of new entrants, market competition, and a broad search of technological options are critical elements of technological innovation (Jacobsson and Bergek, 2004).

The Chinese models are also characterised by a weak form of civil society. Unlike Western experiences in which industrial associations have played a major role in strengthening technological networks as well as policy networks, our findings suggest that industrial or academic associations in China have played a much more limited role. For example, in Shanghai, although some academic associations were able to access the energy policy-making system, their roles are mainly limited to consultation.

When members of the policy network are consulted and to what extent their advice can influence policy decisions is largely arbitrary and subject to the discretion of the government (Interviews: SH/07/2008; SH/08/2008).

Although this study does not provide a detailed assessment on the effectiveness of the Chinese models, our findings relating to the Chinese characteristics give rise to one important question: do these Chinese features limit China from fully deploying collaboration as a governing mechanism for facilitating technological innovation? Our findings indicate that the limited role for public service organisations, and the presence of relatively inactive industrial associations indicate that China has not advanced to higher-order forms of collaboration which are distinguished from lower-order ones by the achievement of shared benefits (rather than individual ends only) and the development of shared understanding of problems and commitments (Ansell and Gash, 2008; Mah and Hills, 2010; Thomson and Perry, 2006). These higher-order forms of collaboration, however, have been regarded as critical to the long-term sustainability of the Chinese domestic industry (Li *et al*, 2010; Interviews: BJ/01/2010; BJ/02/2009; GD/01/2010).

Why, then, the Chinese model fail to achieve a higher-order of collaboration? A possible reason is the under-investment of public resources in Chinese models. The case of the NWTC illustrates this observation. Although the NWTC is a national laboratory, direct state funding support for NWTC is limited. The Chinese government only provided a one-off set-up cost of 8 million yuan. Goldwind has been responsible for most of the operational costs amounting to several million yuan every year (Interview: XJ/06/2007). As a result, many of the public services that were intended to be carried out by this national laboratory have not been developed. For example, the NWTC's plan to provide publicly accessible laboratories has yet to be realised. The existing laboratories are earmarked for Goldwind's needs as a priority and have already been operating at full capacity for the company's own business. Corporate priorities rather than for the shared benefits of the industry, has strongly influenced the R&D activities of the NWTC (Interview: XJ/01/2008).

These observations in China can contribute to the literature on the changing role of the state in new forms of governance which move away from the centralised, hierarchical approaches (Koontz *et al*, 2004; Pierre and Peter, 2000; Rabe, 2002; Skelcher, 2000). In China, the growing reliance on enterprise-led collaboration models since 2006 has shed important light on these questions: where should state activities reduce? Where should they expand? And what would be the impacts? Our findings suggest that the retreat of Chinese government in direct R&D funding has led to the problems of under-investment of public services such as testing. Under China's enterprise-led models of R&D, these public services did not give sufficient attention to those public services. On the other hand, the Chinese government has retained control over the energy sector and the civil society generally (Lieberthal, 2004; Mah and Hills, 2009). These political and institutional features of transitional China appear to have hindered new entrants and industrial associations from adopting a more proactive role in our case studies. In contrast, the literature suggests that the state may need to take on new roles in collaborative governance particularly through empowering civil society and creating a level playing field for market competition (Ashman, 2001; Brinkerhoff, 1999; Watson, *et al*., 2006). Our findings therefore suggest that while the Chinese government has relied too much on enterprises for services which are public goods in nature, it has not expanded enough in taking up some new functions such as empowering civil society and introducing competition to the power market.

Our third finding relates to the importance of contextual factors in explaining the local diversity of collaborative governance models in China. Our analysis has distinguished three local models of government-business-university collaboration: the hierarchical model in Xinjiang, the institutionalised model in Shanghai, and the market model in Guangdong. We found that certain contextual factors can explain these local variations.

In Xinjiang, the relatively backward local economy has led to the prominent role of the central government in its hierarchical model. In Shanghai, the agglomeration of top-ranked tertiary institutions has created a conducive environment for a more deliberative style of energy policy-making (Shanghai Almanac Editorial Board, 2007; Shanghai Center for ACAE, 2006). This has opened up opportunities for associations such as the Shanghai Energy Research Society to play a more active role in the institutionalised model. In Guangdong, the tradition of being in the vanguard of China's economic reforms over the past three decades (Cheung, 2002; Yeung, 1998) has been conducive to its market model of R&D which tends to place more emphasis on competition. These observations contribute to the understanding of the importance of contextual factors in determining forms of collaborative governance.

Our findings have a number of policy implications. Firstly, an appropriate conceptualisation of the mechanisms can help policy makers to build up an inventory for policy change. The key resources, structures, and processes identified can be regarded as the key conducive conditions for the successful use of a collaborative approach for technological innovation. Secondly, local diversity and contextual factors may be a critical issue for technological innovation in the context of wind energy in China. Policies should be designed in ways that are sensitive to local contexts in order to make good use of local opportunities and to overcome constraints. Particularly, policies should be in place to provide incentives for provinces to mobilise local resources, foster learning, and cultivate networks which are locally grown but are able to reach out. Thirdly, there is a need to better define the comparative strengths of government, enterprises and universities, and to develop a better designation of their respective tasks and responsibilities. Our observations suggest that the government would need to take on more roles in providing services which are of a public good nature for the whole industry. On the other hand, the government may need to reduce its control over electricity market and civil society so that new entrants and industrial associations can take up more proactive role in driving technological innovation.

Our findings are country- and sector-specific. While there are limitations regarding the wider applicability of our findings to Western models, mechanisms of collaboration in the Chinese and Western models share some important characteristics, most notably the importance of a resource-structure-process mechanisms that determine the functioning of collaboration.

Appendix: List of Interviews

Code	Interviewees Background	Types of interview	Date of interview
BJ/01/2010	A former senior executive of Xinjiang Wind Energy Company; also a senior executive of the National Windpower Engineering Technology Research Center (NWTC) and a wind energy expert to the Xinjiang government	FI	Oct 14, 2010
BJ/02/2009	A senior executive of the Chinese Renewable Energy Industries Association, and a senior engineer of China Hydropower Engineering Consulting Group Co.	FI	Oct 22, 2009
XJ/01/2008	A professor of a university in Xinjiang, and a R&D director of Goldwind	FI	Oct 24, 2008
XJ/02/2007	A middle-rank executive of Goldwind Science & Technology Co. Ltd	FI	Oct 19, 2007
XJ/03/2007	A senior official in the Division of Hi-tech Industrial Development, Science and Technology Department of Xinjiang	FI	Oct 20, 2007
XJ/04/2007	A professor in the Mechanical and Traffic College of Xinjiang Agricultural University; also a senior engineer of the National Wind Power Engineering Technology Research Center of China (a collaborator with Goldwind on R&D)	FI	Oct 26, 2007
XJ/05/2008	Same interviewee as in XJ/03/2007	TI	Oct 23, 2008
XJ/06/2007	Same interviewee as in BJ/01/2010	FI	Oct 24, 2007
XJ/07/2008	Same interviewee as in BJ/01/2010	FI	Oct 25, 2008
XJ/08/2008	A senior government official in the Development Research Center of the Xinjiang Uyghur Autonomous Region	FI	Oct 23, 2008
SH/01/2006	A senior official, General Research Division, The Development Research Centre of Shanghai Municipal Government	FI	Sep 28, 2006
SH/02/2006	A senior engineer of the Shanghai Clean Energy Research and Industry Promotion Center	FI	Sep 27, 2006
SH/03/2008	A manager of Sewind	FI	Jun 6, 2008
SH/04/2008	A professor in the Department of Electrical Engineering, Shanghai Jiao Tong University	FI	Jun 5, 2008
SH/05/2008	Same interviewee as in SH/02/2006	FI	Jun 2, 2008
SH/06/2006	A researcher of Shanghai Clean Energy Research and Industry Promotion Center	FI	Sep 27, 2006
SH/07/2008	An officer, Academic Activity Department, Shanghai Consulting and Academic Activities Center for Academicians of Chinese Academy of Engineering	FI	Jun 4, 2008
SH/08/2008	A professor, Shanghai Energy Research Society	FI	Jun 2, 2008
SH/09/2008	A Senior Engineer of Shanghai Wind Power Co. Ltd.	FI	Jun 2, 2008
GD/01/2010	A professor, New Energy Centre under the School of Electric Power of the South China University of Technology	FI	Aug 12, 2010
GD/02/2011	An anonymous official from Guangdong Science and Technology Commission	TI	Jan 4, 2011
GD/03/2008	A manager from Hui Zhou Chao Zhi Neng Technology Development Co., Ltd.	TI	Dec 18, 2008
GD/04/2008	Same interviewee as in GD/01/2010	TI	Dec 11, 2008

The interview formats included face-to-face interview (FI) and telephone interview (TI).

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