Water Resource Development and National Innovation Competitiveness
---- Evidence from Countries' Comparison

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Abstract

As water shortage and water pollution is posing greater and greater pressure on the survival and well-being of mankind, the water issue has become the focus of the world. However, synthetic index to measure the development of water resource at the country level is still rarely seen. In this paper, the water resource development index will be constructed in the framework defined as driving forces, state and response (DSR). As is taken into consideration when constructing a sustainable development index, the social factors and economic indicators will be combined in this paper with the natural resource indicators, thus enabling us to have a general look at the wider perspective — the whole mechanism of how water resources are influenced by human activities.

Besides, innovation has become one of the important aspects of international competitiveness. And the relationship between innovation and economic development has been discussed a lot. Nevertheless, the innovation capacity is seldom connected with the ecological or environmental issues, leaving much to explore and expect. Based on a 15-year country comparison dataset, we manage to figure out the correlation framework between national innovation capacity, indicated by national innovation index published by Renmin University of China, and water resource development. From the comparison of water resource development and innovation system across major countries in the world, we summarize the water resource support pattern of the developed countries and give some suggestions to its development in China.

Keywords: Water resource development index; DSR framework; National innovation index; Water resource support pattern

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INTRODUCTION

1.1Background of sustainable development

The deterioration and rapid exhaustion of natural resources has become a major concern across the world with the growing energy crisis and environmental issue giving rise to the instability within and among countries. That is when and why the concept of "sustainable development" is brought up and thusly becomes the hot topic of recent decades.

In 1987, the United Nations released the Brundtland Report, which defines sustainable development as "development which meets the needs of the present without compromising the ability of future generations to meet their own needs". It contains within it two key concepts: the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs." The United Nations 2005 World Summit Outcome Document refers to the "interdependent and mutually reinforcing pillars" of sustainable development as economic development, social development, and environmental protection.

All definitions of sustainable development require that we see the world as a system—a system that connects space and a system that connects time. The deforestation of Amazon Rainforest is very likely to affect the climate in Europe as well as in China. The policies made and the measures taken today will have a profound impact on how the world is doing in the next 20 or even 50 years later. Following the time dimension, unsustainability, which rarely implies an immediate existential threat, still needs to be watched out for due to the threats it may pose to the distant future and our descendants.

Threats to sustainability of a system require urgent attention if their rate of change begins to approach the speed with which the system can adequately respond. The sustainability of humankind is now threatened by both of these factors: the dynamics of its technology, economy and population accelerate the environmental and social rates of change, while growing structural inertia reduces the ability to respond in time. To put it simply, an "unsustainable situation" occurs when natural capital (the sum total of nature's resources) is used up faster than it can be replenished. In the case of water resources, widely known as non-renewable, whether or not we can strive for a sustainable development depends to a great part on how we carefully plan the usage and recycling of water as well as how we take steps to solve the pollution issue.

1.2Water source development and national innovation

Water, the basic element of the life support system of the planet, is indispensable to sustain any form of life and virtually every human activity. The availability of water in adequate quantity and quality is a necessary condition for sustainable development. Of all the social and natural resource crises we humans face, the water crisis is the one that lies at the heart of our survival and that of our planet Earth. However, according to research of the United Nations, the world water resource is suffering from both the booming population and the increase of the per capita water use. The Global water consumption has increased about sevenfold during the 20th century and prospects are becoming even more severe for our generation. To meet the competing demands for this scarce resource and reduce the vulnerability of the worldwide eco-system, societies will need to take every effort to balance producing more from the natural resources with protecting these resources.

Stepping into the 21st century, as science and technology begin to play a crucial role in the modern economic development, people are relying on some new and sensible ways to solve the intractable questions about maintaining a sustainable development, such as technological breakthrough and comprehensive planning. Here comes another consideration: what is the driving force behind the progress in technology and economy? And is there any possibility that those potential, yet important, factors affect directly or indirectly the preservation of our natural resources? And this is how it occurs to us that some exploration shall be carried out between innovation, widely taken as the fountain and driving force of modern economic development, and water resource condition.

1.3 Innovation Capacity Index

The notion of innovation country is point out by the academia of the world aimed at emphasizing on the innovation as the driving force of the world's development. The innovation country refers to the country which places the science and technology innovation as the basic strategy and improves the innovation capacity rapidly, forming strong superiors in the international competitiveness.

Among the composite synthetic indicators of the technological capabilities of nations, the most successful attempt to rank countries' position on the ground of economic and technological indicators comes from the World Economic Forum (WEF). The Technology Index (Tech) has been calculated for the first time in 2001/2002 for 75 countries from 1997 to 2000. In the 2006/2007 GCR edition, Tech considered 125countries, divided in two groups: core economies and non-core economies, according to the number of granted patents. Besides Tech, ArCo, the Technology Achievement Index and the European Innovation Scoreboard (EIS) are also frequently mentioned indices in the measurement of innovation.

All these indicator systems have their own angle in analyzing innovation capacity, but none of them have a time series long enough to see the trend of innovation capacity in the world. Based on the theory of innovation index, Renmin University of China (RUC) designs the analysis system as below and make use of the World Competitiveness Yearbooks from 1994 to 2010 to measure and compare the innovation capacity of the main 57 countries and regions in the world in a broader time span.

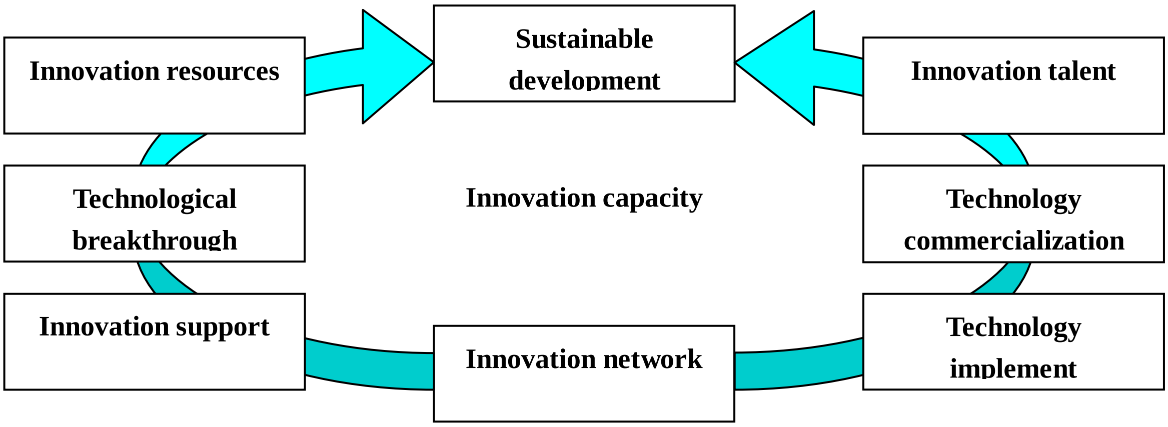

Chart 1 **The relationship between innovation factors in the international innovation index system**

The detail of the analysis system we designed is as the table below.

Table 1 **The international innovation index system**

FACTORS	CODE IN IMD	INDEXES	UNIT
INNOVATION RESOURCES	7.1.01	TOTAL EXPENDITURE ON R&D	US$MIL
	7.1.04	BUSINESS EXPENDITURE ON R&D	US$MIL
	7.2.01	TOTAL R&D PERSONNEL NATIONWIDE	FTE
	7.2.03	TOTAL R&D PERSONNEL IN BUSINESS ENTERPRISE	FTE
	7.4.61	FUNDING FOR TECHNOLOGICAL DEVELOPMENT	MARK
TECHNOLOGICAL BREAKTHROUGH	7.4.01	NOBEL PRIZES	PERSON
	7.4.02	NOBEL PRIZES PER CAPITA	PERSON
	7.4.03	BASIC RESEARCH	MARK
	7.4.62	SCIENCE DEGREES	%

INNOVATION SUPPORT	7.3.03	DEVELOPMENT AND APPLICATION OF TECHNOLOGY	MARK
	7.3.63	DATA SECURITY 2002	MARK
	7.3.65	PUBLIC AND PRIVATE SECTOR VENTURES	MARK
	7.4.64	LEGAL ENVIRONMENT AFFECTING R&D	MARK
	7.5.04	PATENT & COPYRIGHT PROTECTION	MARK
TECHNOLOGY IMPLEMENT	7.3.64	TECHNOLOGICAL REGULATION	MARK
	7.4.63	SCIENTIFIC ARTICLES	NUMBER
	7.5.01	PATENTS GRANTED TO RESIDENTS	NUMBER
	7.5.03	SECURING PATENTS ABROAD	NUMBER
	7.5.05	NUMBER OF PATENTS IN FORCE	NUMBER
	7.5.61	PATENT PRODUCTIVITY	NUMBER
TECHNOLOGY COMMERCIALIZATION	6.1.06	AGRICULTURAL PRODUCTIVITY (PPP)	US$
	6.1.08	PRODUCTIVITY IN INDUSTRY (PPP)	US$
	6.1.10	PRODUCTIVITY IN SERVICES (PPP)	US$
	7.3.61	HIGH-TECH EXPORTS	US$ MIL LIONS
	7.3.62	HIGH-TECH EXPORTS AS A PROPORTION OF MANUFACTURE EXPORTS	%
INNOVATION TALENT	7.2.05	QUALIFIED ENGINEERS	MARK
	7.2.06	AVAILABILITY OF INFORMATION TECHNOLOGY SKILLS	MARK
	7.4.04	SCIENCE AND EDUCATION	MARK
	7.4.05	SCIENCE & TECHNOLOGY AND YOUTH	MARK
SUSTAINABLE DEVELOPMENT	6.1.12	LARGE CORPORATIONS EFFICIENCY	MARK

	6.1.14	SMALL AND MEDIUM-SIZE ENTERPRISES EFFICIENCY	MARK
	7.1.03	TOTAL EXPENDITURE ON R&D	%
	7.1.61	BUSINESS EXPENDITURE ON R&D AS PERCENTAGE OF GDP	%
	7.3.04	RELOCATION OF R&D FACILITIES	MARK
INNOVATION NETWORK	6.4.01	CREATION OF FIRMS	MARK
	7.1.02	TOTAL EXPENDITURE ON R&D PER CAPITA	US$
	7.2.02	TOTAL R&D PERSONNEL NATIONWIDE PER CAPITA	FTE
	7.2.04	TOTAL R&D PERSONNEL IN BUSINESS PER CAPITA	FTE
	7.3.01	TECHNOLOGICAL COOPERATION	MARK
	7.3.02	COMPANY – UNIVERSITY COOPERATION	MARK

METHODOLOGY

In analyzing the sustainability of an economy, experts always claim that the world around us is a complex adaptive system composed of a multitude of systems that interact in various ways and propose a systems view to capture and understand essential relationships through carefully-selected indicators. In the study of water resource competitiveness, we should follow the same analytical pattern to grasp the mainstay of the whole issue and interpret it in the approachable and understandable form of indicator system.

In the efforts to construct sustainable development indices, OECD proposed the PSR (Pressure-State-Response) indicator system; the Department for policy coordination and sustainable development (DPCSD) of the United Nations suggested a DSR (Driving force-State-Response) system; the European Environmental Agency (EEA) and Statistical Office of European Communities (Eurostat) jointly released the DPSIR (Driving force-Pressure-State-Impact-Response) indicator system.

The DSR model is based on a logic and holistic framework of action–response relationships between the economy, society, and environment, and responds to the following questions: What environmental impacts exist? What is the current status of the environment? What is being done to mitigate and solve environmental and socioeconomic problems as well? In the research of Adrián Barrera-Roldán and Américo Sald´ıvar-Valdés (2002), they employed the DSR method to construct a system in the measurement of sustainability and selected a number of core indicators dynamically embracing, integrating, and correlating the natural, economic, and social subsystems. See Chart 2.

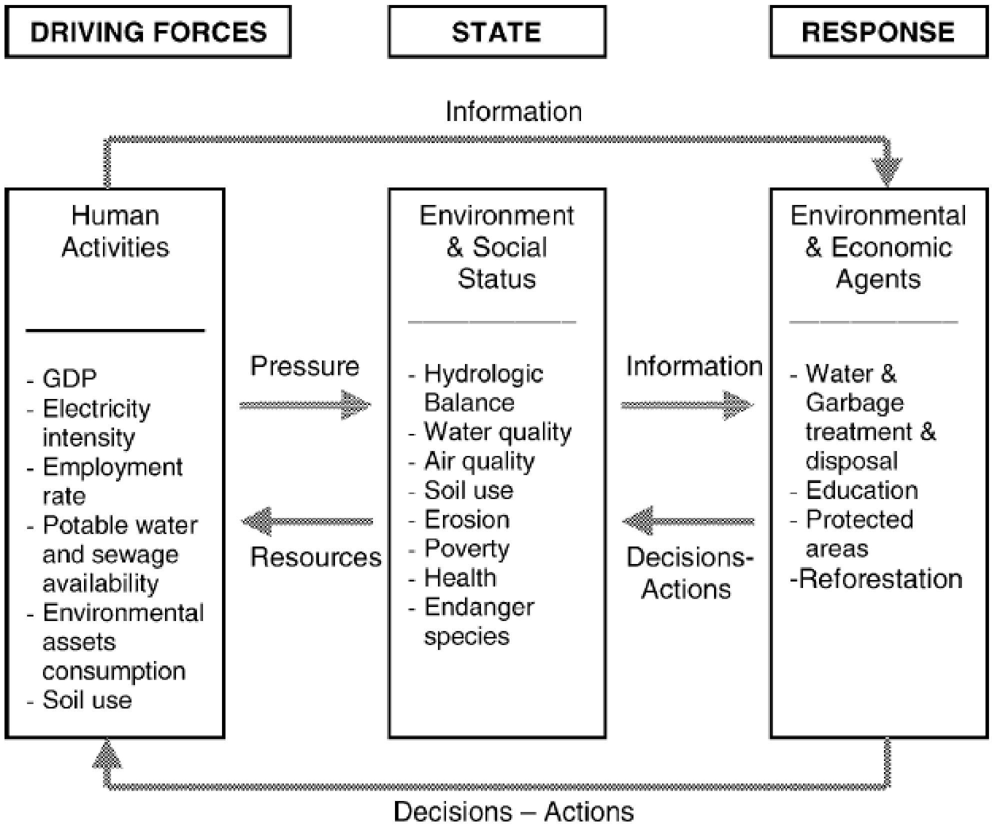

Chart 2 **Indicators classification according to the DSR framework (Adrián and Américo)**

In the light of previous research, we also employ the DSR framework in this paper to explore the conditions and competitiveness of water resource in different countries following the systematic philosophy in measuring sustainability. The indicator system is developed and showed in the following table and the data of the indicators for 57 countries and districts can be obtained from the IMD 2010 database.

Table 2 **The indicator system concerning water resources**

Factors	Indexes
Driving Forces	Population Economic Growth Society Development Health Condition Sustainable Development
State	Water Resources Access to water Renewable Energy Waste Water Water Consumption Intensity
Response	Water Transportation Pollution Environmental Laws Ecological Balance Quality of life

RESULTS AND CONCLUSIONS

3.1Analysis of water resource competitiveness ranking

The ranking of general water resource competitiveness is shown in Chart 3. Europe has taken 4 places out of the top 5, and the only non-European top-5 country is Canada. Singapore and Japan, the best of the Asian countries in this list, rank 8th and 10th respectively and fits well with their strong economic powers. The recently most talked about new powers (Brazil, China Mainland, India and Russia) seem to fall short of the praises and attention they have got in the area of water resource competitiveness with the rankings of 34th, 36th, 44th and 47th among the 57 countries and districts.

The driving force part of water resource competitiveness analysis portrays the general condition of a country or district's synthesized power including the economic and sustainable-development perspective. The ranking of the 57 countries or districts in concern is displayed in Chart 4. As can be seen from the chart, the active Asian economies are giving outstanding performances by occupying the top 3 of the list and taking 6 positions in the top 20. The European countries have shown remarkable competitiveness, especially those with high welfare and solid social security, i.e. Sweden and Norway, which is consistent with their economic status and overall national strength. The United States, as the world's No.1 economy, comes in the 5th

place.

The state part of this analytical mechanism helps to show the current general condition of water resources in the countries and districts we would like to compare. Indicators like the available gross water resource quantity, access to water, water consumption intensity and waste water treatment plants are involved in this part. When the water issue is scanned in the context of sustainable development, we still should never ignore the bigger picture of the whole energy condition. That's why the indicator "share of renewable in total energy requirements" is also part of the measurement system.

As is indicated by Chart 5, those high-welfare European countries, like Norway Sweden and Finland, again show strong competitiveness concerning the current situations of water resources. An interesting finding in the comparison of the state part ranking and the driving-force part ranking is that there are some drastic changes for several countries. The United States, Singapore, Israel, and China Mainland, those doing great in the general economic and social condition (the driving-force part), all suffer from severe drops in the ranking of the state part. To be specific, the ranking decline of the above countries is 27, 34, 29 and 27 respectively. On the other hand, however, some other countries are showing gratifying enhancement in the ranking of the state part comparing to the former ranking. Brazil and Columbia are the representatives with the ranking jumps from 42 to 10 and from 41 to 14. The gap between the highest and lowest scores (67.89) is also greater than in the driving-force part (47.85), which implies that the competitiveness of the current water resource conditions can vary a lot among different countries.

The response part intends to exhibit how society responds to the water source conditions through environmental and economic policies. Changes in these policies will generally change the incentives to use certain technologies to mitigate the pressure which is forced on the surrounding environment. With two countries getting scores above 90 and four countries above 85, a number of countries and districts are doing great in the response part. However, Venezuela only gets 6.1 points in this part and is left with a gap of 86.56 with the No.1 Finland. Both those high-welfare European countries and the emerging economies get relatively good rankings.

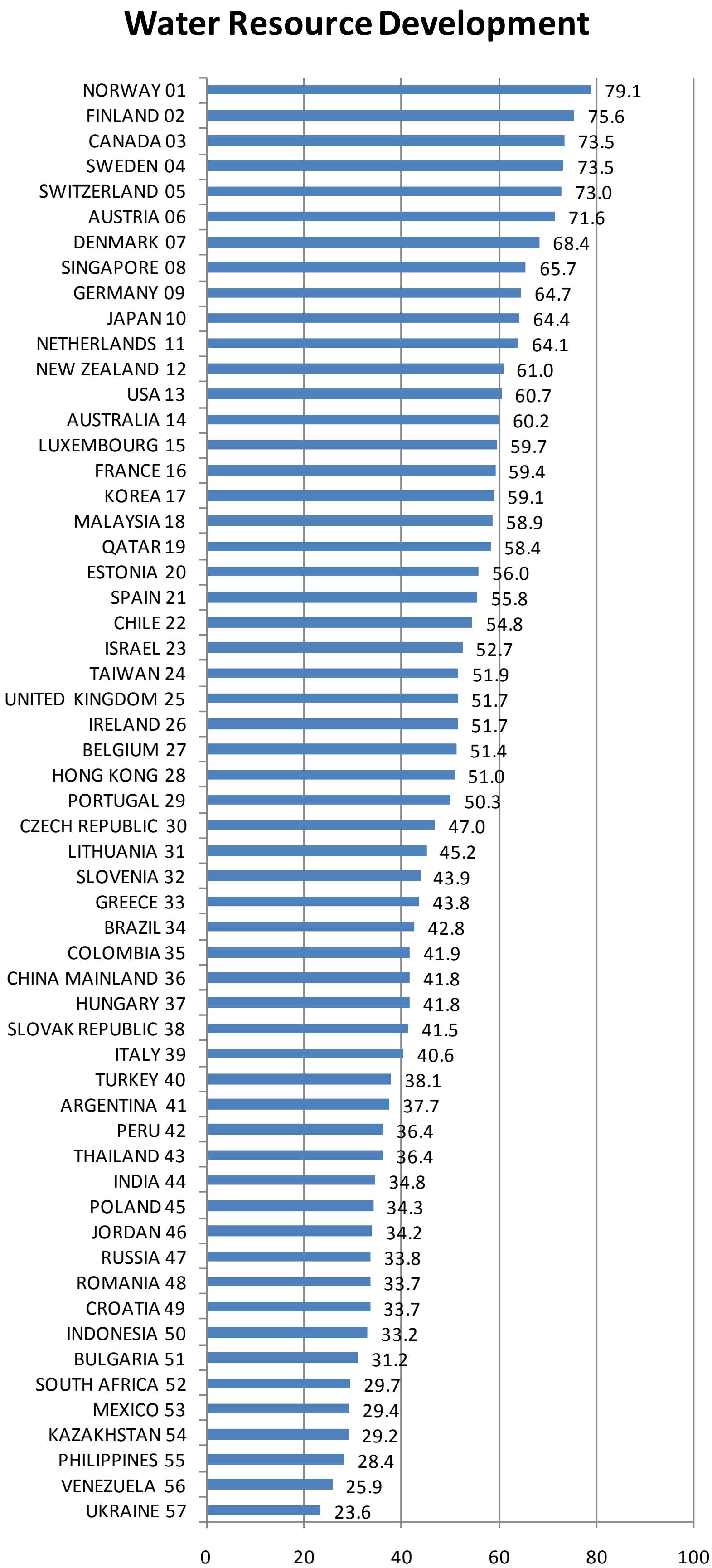

Chart 3 **The ranking of water resource competitiveness**

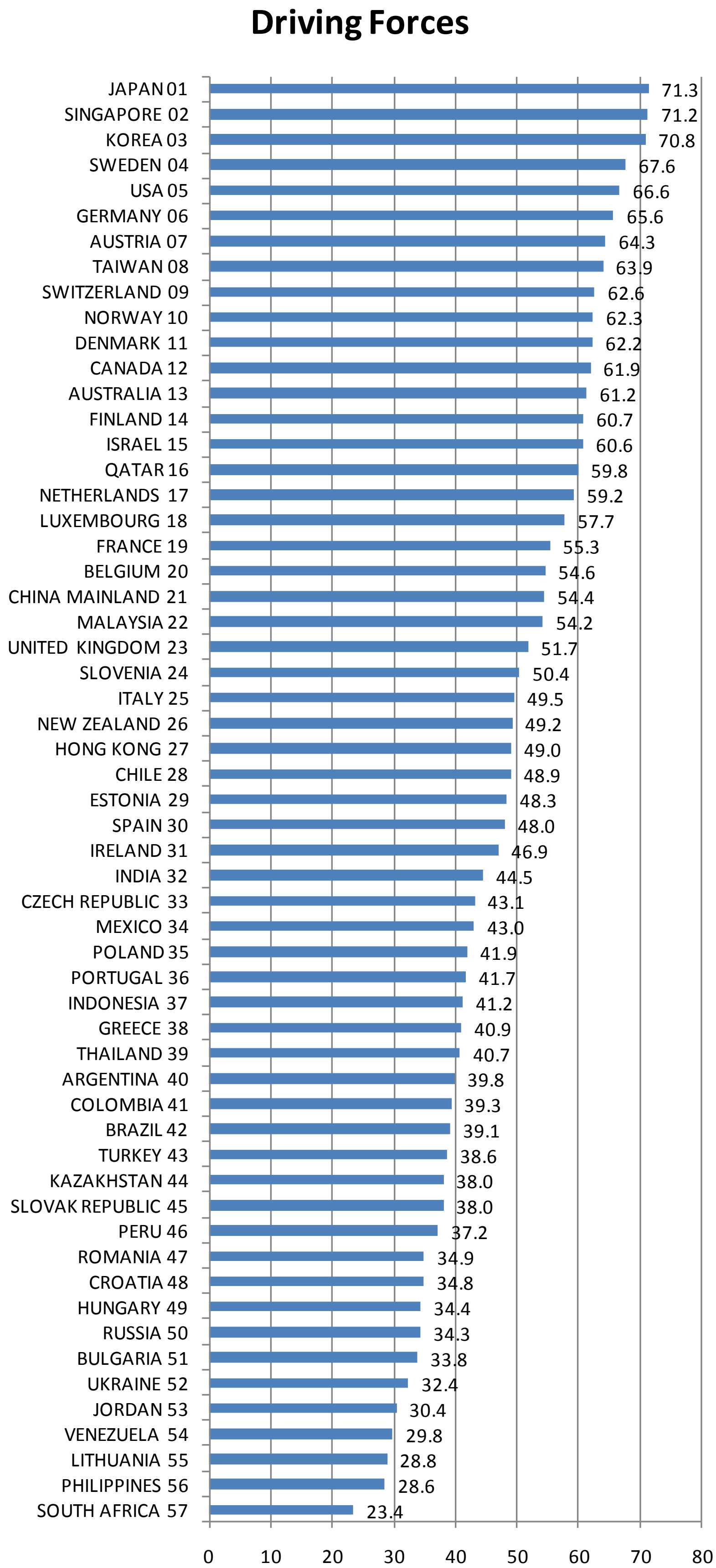

Chart 4 **The ranking of "driving force" part**

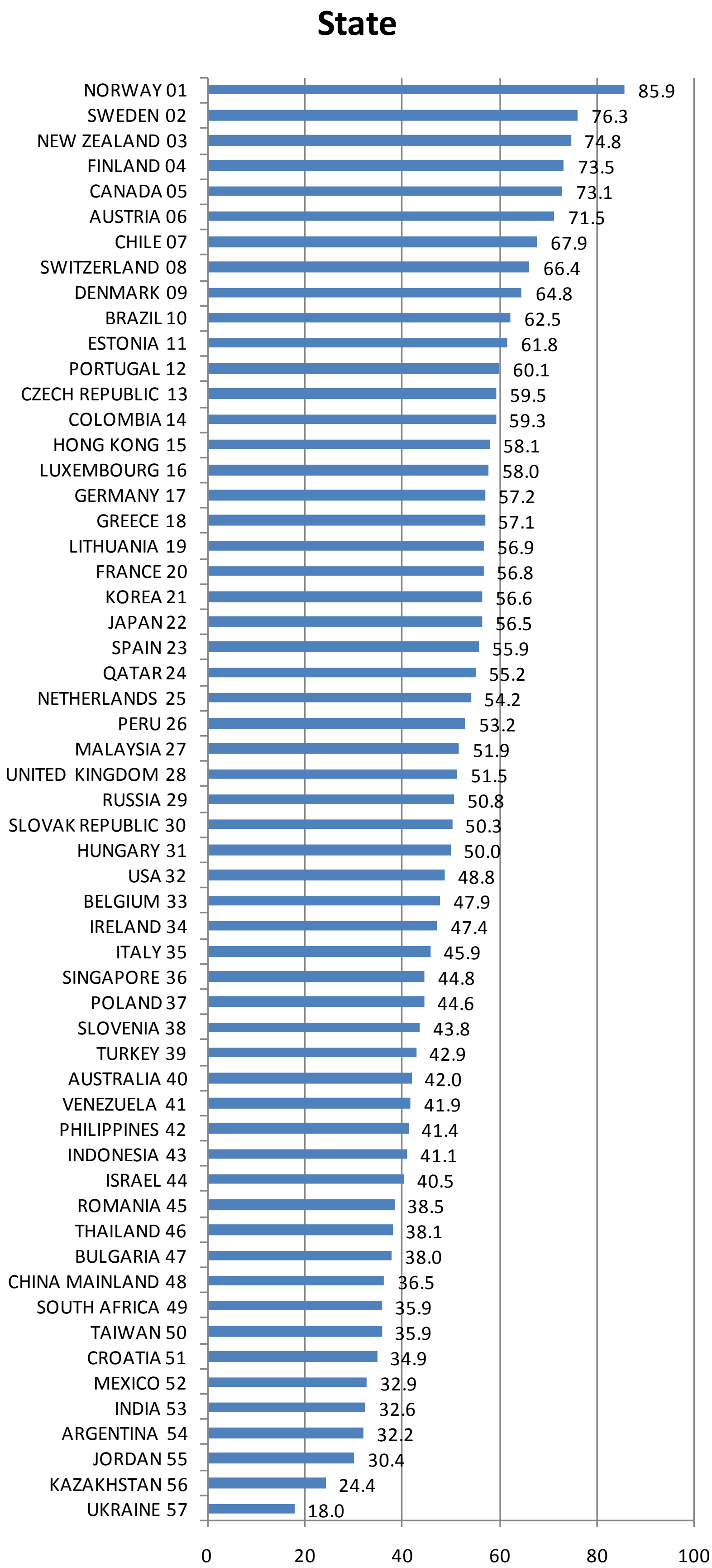

Chart 5 **The ranking of "state" part**

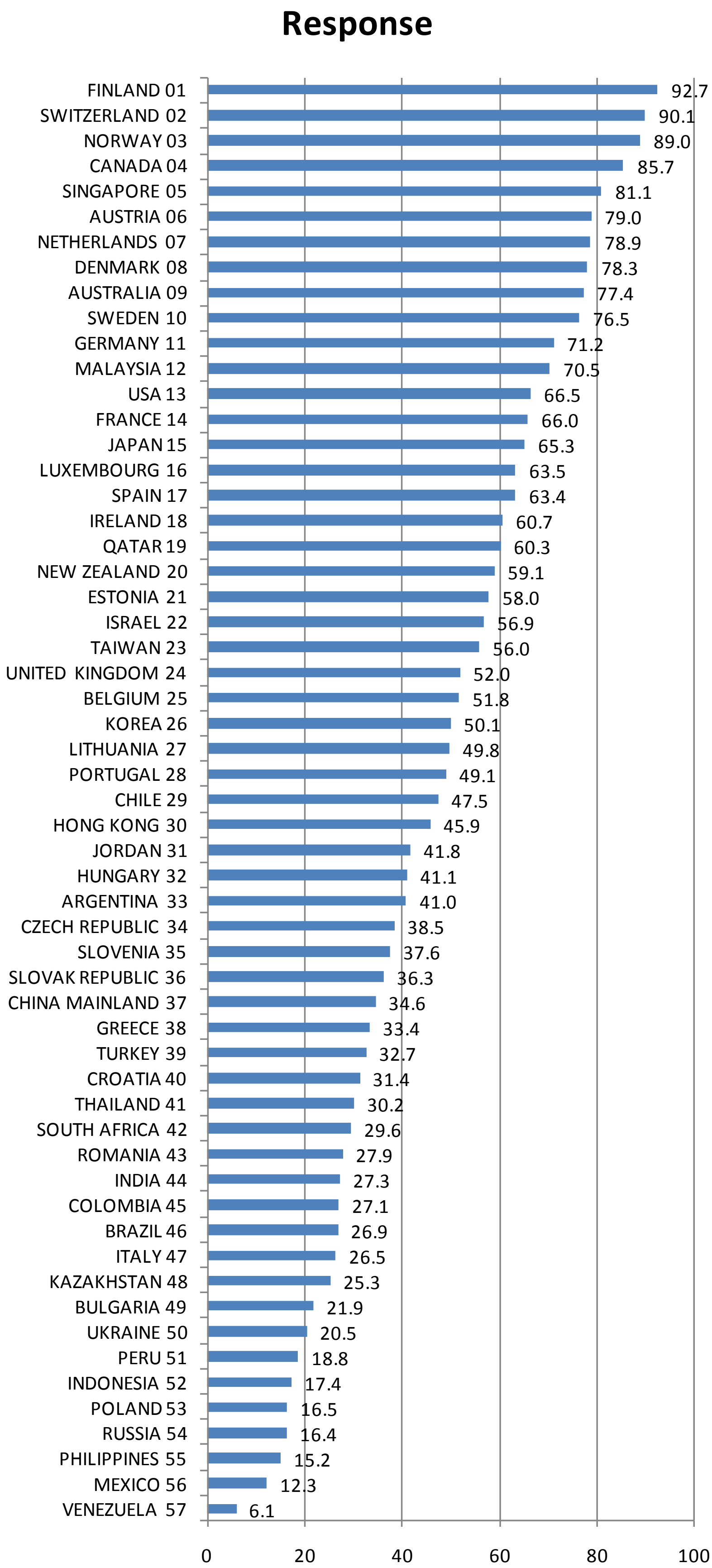

Chart 6 **The ranking of “response” part**

3.2Relationship analysis of water resource and innovation

According to Chart 7, the coefficients between driving force and state, state and response, driving force and response haven't displayed strong linear correlation. Especially the points on the graph of driving force and state, which seem rather dispersed and irregular, have not formed the typical demonstration of linear correlation. The graph of innovation index and water resource development is better in the sense of linearity of the points. Some abnormal points, which jointly pose a counteracting force to the formation of linear correlation of the two indices, can also be identified in the graph.

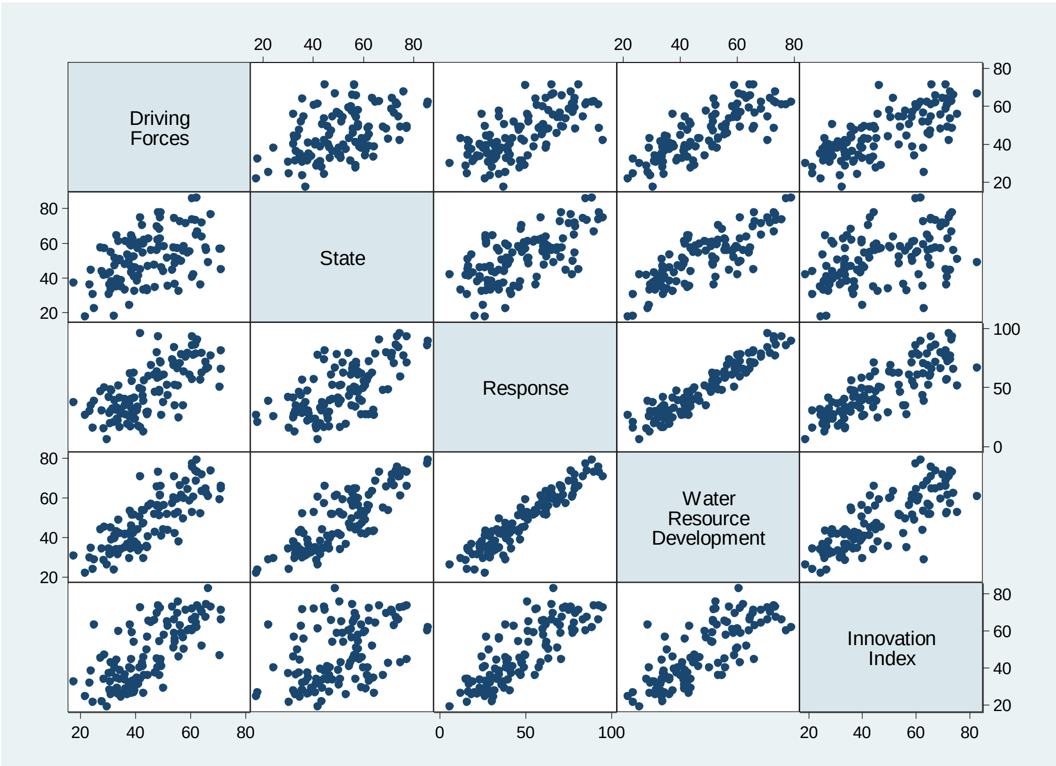

Chart 7 **Relationship between water resource development and national innovation capacity**

Among the 8 factors that constitute the innovation index, the “innovation support” and “innovation network” are showing relatively strong correlation with the general water resource competitiveness as well as the three sub-indices. An interesting phenomenon shown in the table is that for all the 8 sub-indices and the national innovation index, the coefficients with state, among all their three correlations with DSR, remain the lowest.

(Some further explorations are still to be conducted and supplemented later.)

Table 3 **The correlation coefficients between water resource development index, innovation index and their subindices**

	driving forces	state	response	water resource development	innovation resources	technological breakthrough	innovation support	technology implement	technology commercialization	innovation talent	sustainable development	innovation network	innovation index
driving forces	1												
state	0.4658	1											
response	0.6796	0.6631	1										
water resource development	0.8037	0.8185	0.941	1									
innovation resources	0.5673	0.2278	0.4959	0.5005	1								
technological breakthrough	0.5217	0.3459	0.6158	0.5888	0.6271	1							
innovation support	0.6957	0.533	0.8921	0.846	0.6046	0.7221	1						
technology implement	0.68	0.3199	0.5987	0.618	0.7586	0.6354	0.7153	1					
technology commercialization	0.5772	0.3271	0.6464	0.6146	0.6272	0.7488	0.7022	0.7013	1				
innovation talent	0.5655	0.3588	0.69	0.6443	0.5259	0.5434	0.7893	0.6082	0.5305	1			
sustainable development	0.3446	0.2192	0.3269	0.3446	0.3117	0.3215	0.4353	0.2889	0.2421	0.4734	1		
innovation network	0.6671	0.5002	0.8567	0.8082	0.5995	0.7178	0.9235	0.6858	0.701	0.772	0.3457	1	
innovation index	0.7214	0.4566	0.8227	0.792	0.7659	0.8117	0.9369	0.8257	0.8152	0.8343	0.5028	0.9173	1

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