AN INSTITUTIONAL PERSPECTIVE ON WATER SECTOR PERFORMANCE IN THAILAND

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Suwit Khunkitti, declare that this thesis is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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DEDICATION

"… The main tenet is to have water … because life exists at that place. If there is water, people can live. If there are no electricity and water, people cannot live. If there is electricity but no water, people cannot live …"

"… หลักสำคัญว่าต้องมีน้ำบริโภค น้ำใช้ ... เพราะว่าชีวิตอยู่ที่นั่น ถ้ามีน้ำคนอยู่ได้ ถ้าไม่มีน้ำคนอยู่ไม่ได้ ไม่มีไฟฟ้าคนอยู่ไม่ได้ แต่ถ้ามีไฟฟ้าไม่มีน้ำคนอยู่ไม่ได้ …"

17 March BE2529 (CE1986)

"… There is enough water flowing around in Thailand, but we need to manage them. If managed well, there will be more than enough to fulfil our needs …"

"… น้ำในประเทศไทยที่ไหลเวียนนั้น ยังมีอยู่ เพียงแต่ต้องบริหารให้ดี ถ้าบริหารให้ดีแล้ว มีเหลือเฟือ ..."

4 December BE2532 (CE1989)

H.M. Bhumibol Adulyadej (King Rama IX, the Great)

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GLOSSARY

BB	Budget Bureau
BCE	Before the Common Era
BE	Buddhist Era
CDD	Community Development Department
CE	Common Era
DDPM	Department of Disaster Prevention and Mitigation
DEA	Data Envelopment Analysis
DOM	Department of Meteorology
DGR	Department of Groundwater Resources
DIW	Department of Industrial Works
DMU	Decision-making Unit
DOLA	Department of Local Administration
DOPA	Department of Provincial Administration
DWR	Department of Water Resources
ECT	Election Commission of Thailand
EGAT	Electricity Generating Authority of Thailand
EWG	East Water Group
IWRM	Integrated Water Resources Management
LDD	Land Development Department
MDG	Millennium Development Goal
MOAC	Ministry of Agriculture and Cooperatives
MOE	Ministry of Energy
MOI	Ministry of Industry
MOInt	Ministry of Interior
MONRE	Ministry of Natural Resources and Environment
MOW	Ministry of Water
MWA	Metropolitan Waterworks Authority
NCPO	National Council for Peace and Order
NESDB	National Economic and Social Development Board

NESDP	National Economic and Social Development Plan
NIF	Non-Institutional Factors
NRCT	National Research Council of Thailand
NSO	National Statistical Office
NWRB	National Water Resources Board
NWRC	National Water Resources Committee
OAE	Office of Agricultural Economics
OCS	Office of the Council of State
ONWR	Office of the National Water Resources
OPM	Office of the Prime Minister
PAOs	Provincial Administration Organizations
PCD	Pollution Control Department
PFP	Partial Factor Productivity
PPF	Production Possibility Frontier
PWA	Provincial Waterworks Authority
RBC	River Basin Committee
RBO	River Basin Organization
RID	Royal Irrigation Department
SDG	Sustainable Development Goal
SFA	Stochastic Frontier Analysis
SOC	Secretariat of the Cabinet
SPI	Socio-Political Institutions
TFP	Total Factor Productivity
WMA	Wastewater Management Authority
WSI	Water Sector Institutions
WSP	Water Sector Performance

ABSTRACT

In recognition of the criticality of water in ensuring socio-economic prosperity of a vastly agrarian country (Thailand), the Thai policy makers have made massive investments over the years to establish and manage country's water systems. Notwithstanding this, the Thai water systems have continued to perform poorly. For example, the performance (assessed by employing a Multi-stage Malmquist-based DEA method developed in this research) of the Thai water sector, comprising 25 key water basins, deteriorated considerably over the period 1987-2017, for all of its functional stages, namely, water supply, water usage, and water-benefits (i.e., earning of water-dependent farmers). Further, efforts by successive Thai governments to improve water sector performance, primarily by restructuring the proximate water-specific institutions, have largely failed. Despite this failure, the faith of the Thai policy makers in the appropriateness of this approach (i.e., restructuring of proximate water institutions) to improving water sector performance appears to have remained unshaken. This faith – this research contends – is unfounded and hence unlikely to improve water sector performance. The water sector performance can only be improved – this research further holds – by improving the efficacy of country's socio-political institutions (reflecting country's socio-political imperatives, its cultural traditions and belief systems) that provide the raison d'être for the water-sector institutions, in fact for the water sector itself. The veracity of this argument is ascertained in this research through the application of two conjoint sets of empirical analyses, namely, correlation and causality (supported by Spearman's rank correlations coefficients) and multi-stage and cross-sectional econometrics. These analyses clearly establish the centrality of socio-political institutions in determining water sector performance. Inspired by this finding, this research delineates the contours of a sound and pragmatic institutional framework (reform model) that could considerably and enduringly improve the performance of the Thai water sector. Further, although this research has focused on the water sector of Thailand, its relevance extends to other countries and to other types of infrastructure. Increasing emphases around the world on institutions and governance as means to improve socio-economic outcomes is a testimony to the soundness of the discourse developed in this research.

CHAPTER 1 INTRODUCTION

1.1. Background

Water is critical for every aspect of human life. At the individual level, water is central to life processes and human survival. It makes up more than two-thirds of human body weight, and thus is the single most important substance for human life processes; for example, human organ systems depend on water for their functioning, it regulates body temperature, it transport valuable nutrients to the entire body, it removes toxics from the body, and it serves as a lubricant in almost all body processes. The importance of water is not just confined to human body, but also to human mind, through spirituality. Since ancient times water has represented many spiritual ideas that are embedded in many cultures. It plays a key role in most religious beliefs, values and rituals. In fact, water is central in supporting indigenous communities and their traditional cultures (Donahue & Johnston 1998). These together helps define people's identity and determine a person's 'way of life' (Schelwald-van der Kley & Reijerkerk 2009).

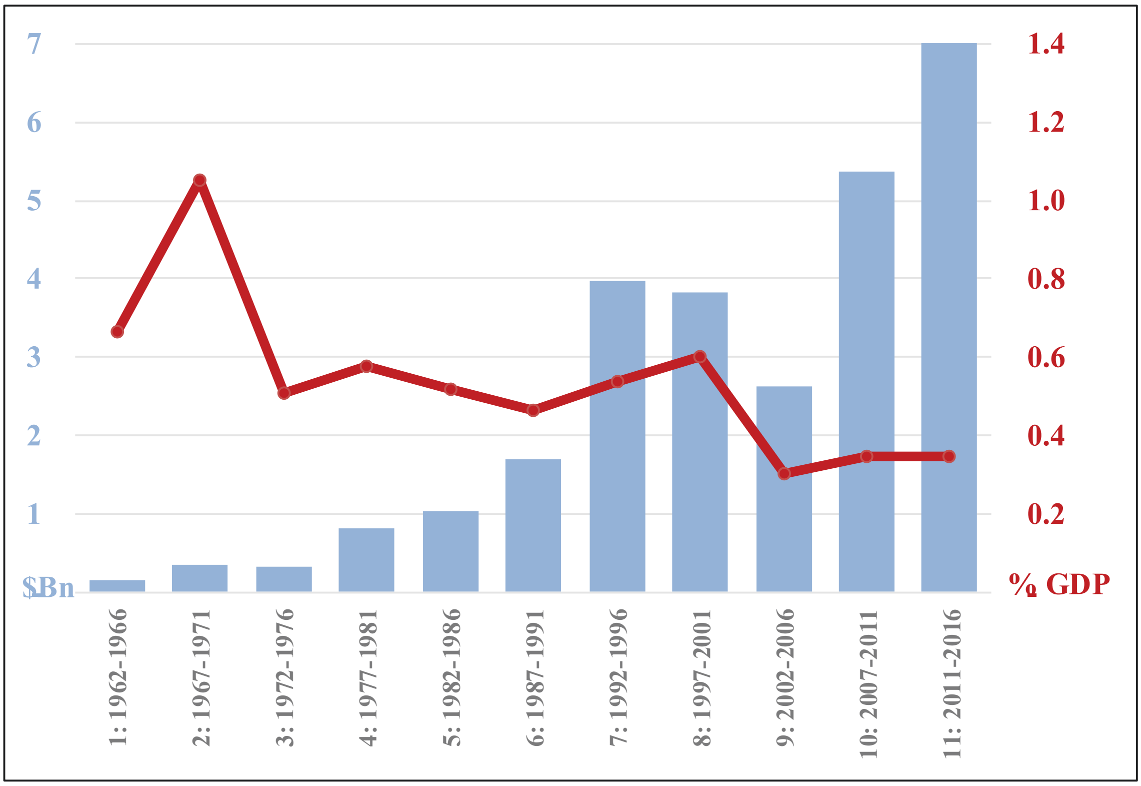
At the societal level, water plays an important role in various aspects of development of a nation. It has played a central role in the history of humankind, and has supported social, cultural, economic and political changes in almost every civilization (Cech 2010; Hassan 2010; Schelwald-van der Kley & Reijerkerk 2009). For example, the human settlements since prehistoric times occurred along the river banks, river islands and canals. Water became central to social and cultural development of these settlements, particularly in terms of the creation of community social norms and national identities through rituals, festivals and religious practices. Water is also fundamental to the expansion of economic activities through, for example, agricultural production from irrigation systems, trade from transportation of freight through barges and ships, and electricity production from hydropower plants. Such socio-cultural-economic developments have also led to the creation of the 'state' as a political unit, followed by the establishment of formal institutions such as bureaucracy, laws and regulations in order to manage people and natural resources, including water. Such an importance of water was reflected throughout the developmental history of various country around the world (Cox 1987; de Villiers 2001; Shiva 2016; Ward 2003) (see further discussions in Chapter 2).

In Thailand, the country of focus of this research, approximately 90 percent of water is used in the agriculture sector, and the remaining 10 percent, in industrial production, services sector, and households (DWR 2016). This illustrates the dominance of agriculture in Thailand's socio-economic complex. Approximately one-third of its land area is suitable for agriculture, as compared with 11 percent world-average (FAO 2018). The direct agricultural output has contributed approximately 10 percent annually to the nation's gross product over the past three decades (NESDB 2018b). The indirect contribution to the economy is even higher, due to the use of agricultural products in food and non-food manufacturing as well as exports (Singhapreecha 2004). Further, the agriculture sector employs more than one-third of the nation's labor force (ILO 2018). This is relatively high compared with many other countries; the world-average data shows that the agriculture sector produces less than 4 percent of world's total output and employs approximately one-quarter of global labor force (ILO 2018; WB 2018). Thailand is also one of the world's largest rice exporters; it also export several other food products, which contributes significantly to its total export income. As the agriculture sector is the major user of water in Thailand (90 percent), its socioeconomic development is thus heavily dependent on the use of water resources. In fact, Thailand is one of the top ten countries in the world in terms of water consumption; most of the water is used to support agro-industrial and food production processes (Thai PBS 2014).

Such an importance of water resources was reflected throughout the developmental history of Thailand. Irrigation has been central to the socio-economic development of the country and its march towards modernity (Sangkhamanee 2012). For example, since the 14th century, new areas were gradually developed close to water sources and people were relocated from major urban areas to allow expansion of rice production, mainly for export (Phongpaichit & Baker 2002). During the 19th century, the Royal Irrigation Department was formed to develop several canal networks, build large reservoirs and dams, and expand irrigation areas in order to support population expansion and created needs for water (DRI 2002). Such a development philosophy that focus on agriculture has created significant demand for water throughout most of the 20th century. The sustained and rapid economic development in Thailand, particularly over the past forty years, have stimulated a considerable expansion in the demand for water in all sectors, including irrigation, electricity generation, and domestic and industrial usage.

To meet rising water demand, significant government efforts have been made to improve water resources in the country. The first-ever major investments in the water sector was made in the year 1889 to develop irrigation scheme in the previously non-cultivated area between Ayutthaya and Bangkok (Brummelhuis 2007). Since then significant investments have been made to increase the quantity of water supply by developing untapped resources. Figure 1-1 shows the investments made to improve water resources over the past half century, classified according to eleven national development plans covering the period between 1962 and 2016.[1]

Figure 1-1 Investments in developing water resources in Thailand



Sources: Compiled and estimated by the author from various sources (BB various; Budhaka, Srikajorn & Boonkird 2001; DWR 2016; Sethaputra et al. 2000; WB 2018)

Note: Values in this figure are the government budgets shown in terms of a 5-year period, according to the national development plans

Overall, more than $27 billion (approximately $2.5 billion annually) of investments have been made since the first plan was launched in 1961. The amount of investments increased substantially over this period; from approximately $150 million during the first plan (1962-1966), to $7 billion during the eleventh plan (2011-2016). In the initial stages of

[1] The National Economic and Social Development Plan is formulated on a 5-year basis as a guiding vision for all sectors (including water sector) to develop and implement policies and management strategies of the nation (NESDB 2018a). The first plan was launched in 1961. The current plan is the Twelfth National Economic and Social Development Plan, covering the period 2017–2021.

the development (1962-1971), most of these investments were aimed at developing large infrastructure projects, including the Chao Phraya, Mae Klong, Bhumibol and Sirikit dams as well as large-scale irrigation in various parts of the country (Sethaputra et al. 2000). These investments accounted for approximately 0.9 percent of GDP at that time. While investments in water resources since the third development plan continued to increase significantly, these investments account for just around 0.3-0.6 percent of GDP. This is because of the significant economic growth driven by export-oriented industrialization in Thailand after the 1970s, which outpaced the investments in water resources.

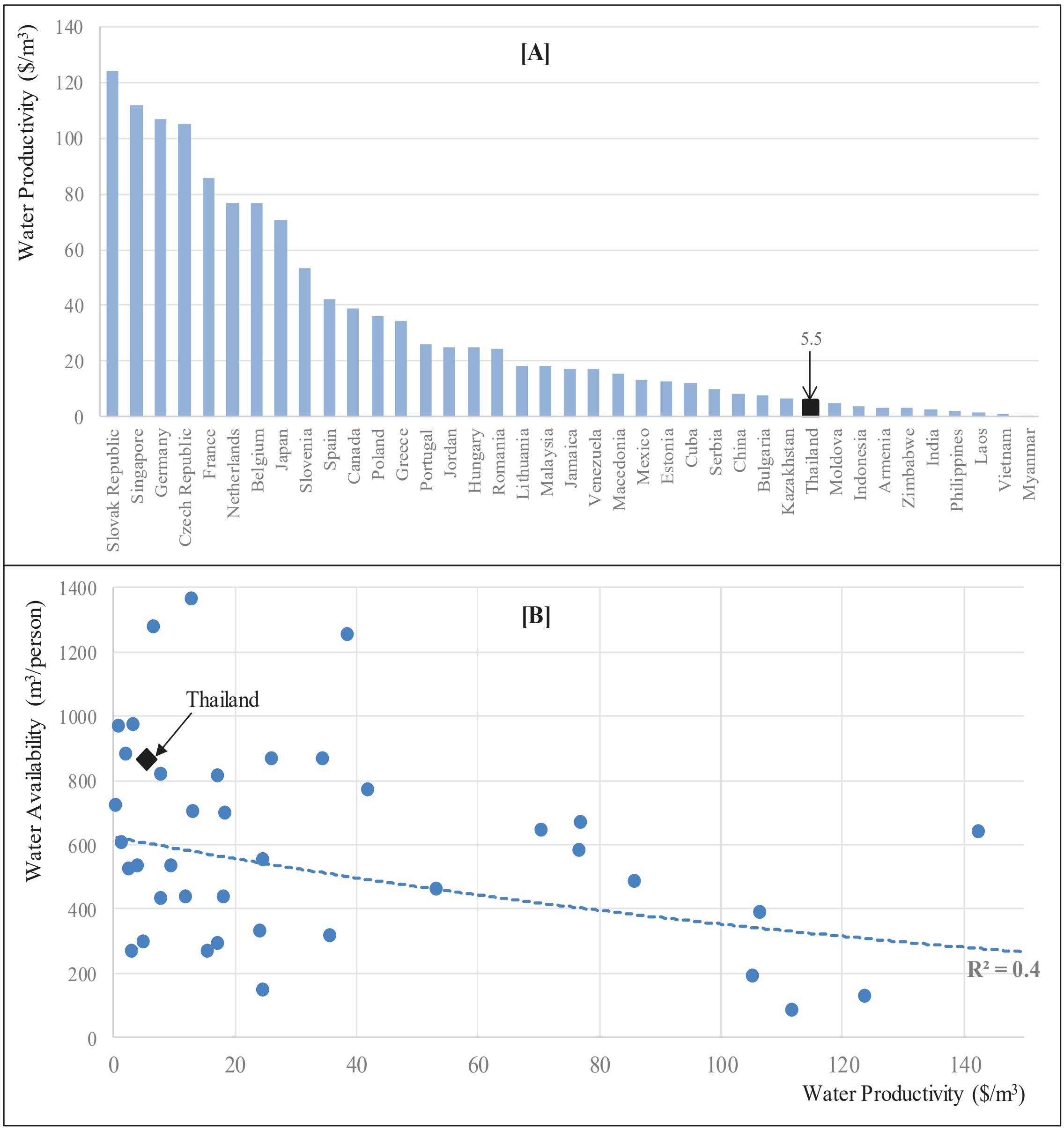
Despite these investments to increase access to, and to better manage, water resources, the country is faced with endemic water resource problems. One of the most critical problems is growing imbalance between water demand and supply. Water demand has grown much faster than supply, driven by increased population, urbanization and industrialization. In addition to these typical factors that are associated with socioeconomic development, the demand-supply gap has been exacerbated by government policies. The Government's paddy pledging policy, for example, encourages farmers to grow rice during off-season, putting further upward pressure on water demand. At the same time, increased large-scale water supplies are no longer possible due to several other reasons, e.g., natural (physical) limits to supply augmentation, deforestation-led reduction in rainfall, and climate change-induced variations in temperature and rainfall patterns. As a result, the government has been forced to manage water demand-supply balance by limiting the flow of water from dams into the irrigation canals, especially during the dry season.

In addition to above-noted water resource problems, changed rainfall patterns have caused a number of water-related disasters, such as flood and landslide throughout the country. Over the past century, Thailand has been affected by 47 major flood events, which accounted for more than two-third of total disasters that occurred in the country (LDEO, 2013). More than 2000 human lives were taken, and almost 41 million people were affected from these water-related disasters. Moreover, such water-related disasters cost billions of dollars of socioeconomic damages to the country, through lost agricultural production, interrupted industrial production, and increased unemployment. The major flood in 2011 alone affected 15 percent of the agricultural production area, 3 million households, and 10 thousand factories, leaving more than 600 thousand people out of work (Nehru 2011).

The symptoms of these water-related problems in the backdrop of significant investments imply that the water sector has persistently performed poorly, both from the economy-wide and sector-specific perspectives. Water sector performance from the economy-wide perspective is typically measured in terms of water productivity of the economy (Barker, Dawe & Inocencio 2003), that is, the amount of economic output produced per unit of water used. Figure 1-2 compares water productivity of Thailand with other 40 select countries.[2] It shows that water productivity of Thailand is among the lowest in the world (Figure 1-2A), where $5.5 of equivalent amount of output are produced from 1 cubic meter of water. This is significantly lower than the productivity levels of some countries that are in the same region, such as Singapore (112) and Malaysia (18).

[2] The selection of countries in Figure 1-2 is based solely on data availability, and consistency of this data.

Figure 1-2 Water productivity: cross-country comparison



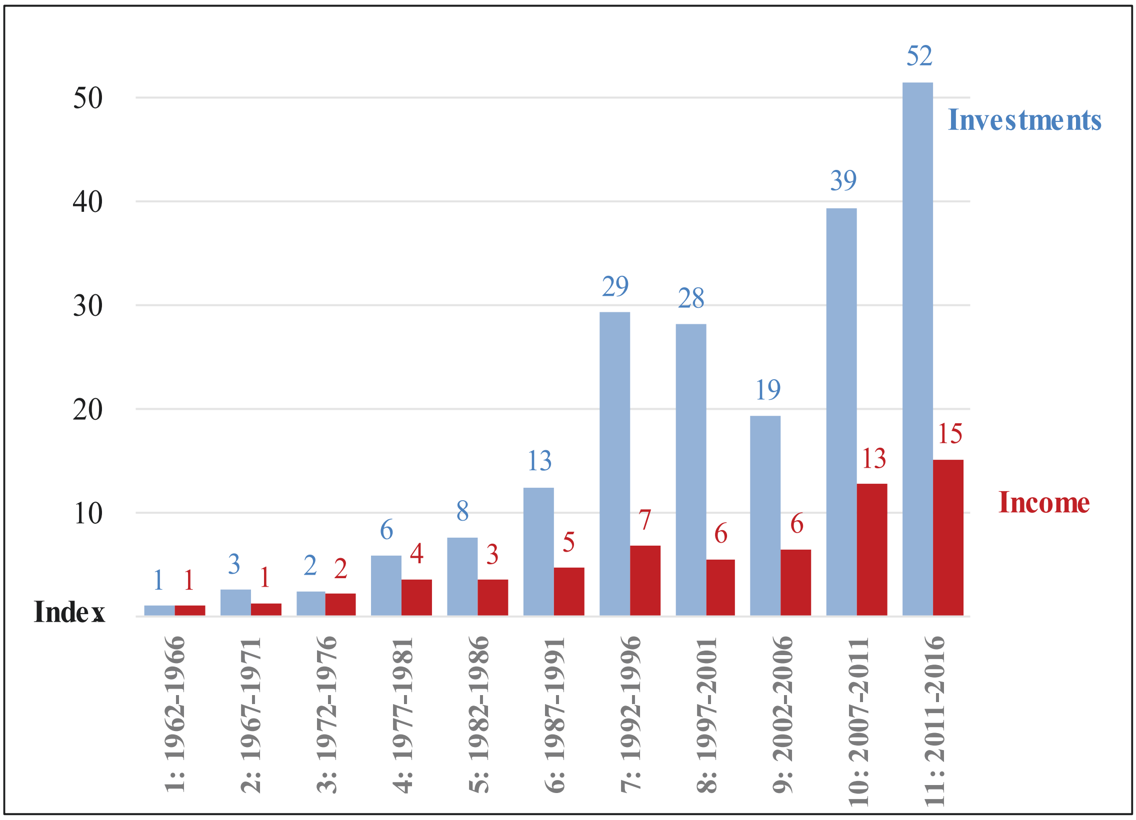
Source: WB (2018)
Note: Dollar values in this figure are based on constant 2010 prices

It is widely accepted in the economics profession that productivity of the resource is inversely related to the scarcity of that resource. This means that countries with less water availability tend to have high productivity levels compared with countries with abundant water resources, and vice versa. This relationship is shown in Figure 1-2B, with the correlation (that is, R^2) between water productivity and water availability of 0.4. Even in this case (Figure 1-2B), water productivity of Thailand is relatively low compared with countries with the same amount of water resources.

Water sector performance from the sector-specific perspective is a much more expansive concept, depending on the objective and scope of analyses (see Chapter 4 for further discussion). This research argues that the main objective of water sector is to enhance the livelihood of population that earn most of their income from water-dependent farming activities (as the agriculture sector consumes more than 90 percent of water). In this sense, the extent of income from the agriculture sector associated with investments in water resources can be used as a proxy for water sector performance.

Figure 1-3 presents the index of water sector investments and per-capita income in the agricultural sector. It shows that during the first three national development plans (1962-1976), investments and income grew at approximately the same rate. After the fourth development plan however growth in investments far outpaced the income growth. By the end of the eleventh development plan, investments have increased by 52 times (compared with the first plan), while income increased by just 15 times.

Figure 1-3 Index of water sector investments and agricultural sector income



Sources: Figure 1-1 and WB (2018)
Note: Per-capita income growth in the agriculture sector is a proxy for agricultural sector income

Several studies have been undertaken over the years to identify the causes of poor performance of the water sector in Thailand (Biltonen 2003; Christensen & Boon-Long 1994; Clark & Semmahasak 2013; Cookey 2016; Duangmanee & Koontanakulwong

2013; Kanjina 2008; Molle 2007; Nikomborirak & Ruenthip 2013). Table 1-1 presents the key features of these studies, in particular the symptoms and causes of poor performance of the water sector, and suggestions for improving performance. A review of this table suggests that there is a diverse range of causes of poor performance of the water sector. These causes are: 1) absence of legal framework for governing water resources, resulting in inefficiency in water usage; 2) multiple organizations to manage water resources, resulting in unclear allocation of roles and overlapping mandates; 3) fragmented organizational structure, resulting in weak coordination between agencies; 4) weak capacity of water sector agencies, resulting in uneven water infrastructure development, and inability to enforce regulations; 5) less-than-sufficient integration of bureaucratic agencies with local communities, resulting in either passive participation by both parties or conflicts in managing water resources.

Table 1-1 Existing studies on water sector performance in Thailand: Key features

Study	- **Focus** - **Scope** - **Methodology**	**Symptoms of poor performance**	**Causes of poor performance**	**Suggestions for improved performance**
Christensen & Boon-Long (1994)	- Identify problems in Thailand's water management system - National - Diagnostic survey (June-November 1993)	- Overuse of water - Excess wastewater discharges	- Lack of water allocation; an 'open access' resource - Multiple water sector organizations, causing overlapping mandates - Poor capacities of water sector agencies, causing uneven water infrastructure across basins - Vested interests, causing conflicts in water management and lax enforcements of laws	- Introduce economic instruments to manage water demand and supply - Adjust water sector institutions to support economic-based management of water
Biltonen (2003)	- Assess water system from an institutional perspective - Mae Klong and Bang Pakong basins (1994-2000) - Data analysis	- N.A.	- Conflicts between hydropower producer and irrigators for water usage	- Managing water needs to be undertaken from a whole of basin perspective - Establish farmer organization to represent the interests of irrigators - Need better coordination of diverse agencies in managing water resources
Molle (2007)	- Examine the role of 'power' in river basin management - Chao Phraya and neighboring basins	- Floods and droughts	- Large basin tends to expand its power onto neighboring basins even though the direction of water flows is small-to-large basin	- N.A.

Study	- Focus - Scope - Methodology	Symptoms of poor performance	Causes of poor performance	Suggestions for improved performance
	- Empirical analysis based on a political ecology approach			
Kanjina (2008)	- Explore the implementation of the river basin management - Mae Sa River Basin Management Group - Participant observation	- N.A.	- Structure of management group is dominated by bureaucrats from state agencies - Rigid bureaucratic boundaries , resulting passive participation of state agencies - No dialogue between state agencies and local stakeholders, resulting in unfruitful participation	- Need to ensure a proper representation and active participation of both local communities and civil sector
Clark & Semmahasak (2013)	- Examines the potential of adaptive governance approach to water management - Chiang Mai province - Critical analysis of opinions of farmers and policy officials	- N.A.	- Weak water governance leading to local level disputes	- Introduction of a joint management committee, comprising various stakeholders to resolve disputes, and participate in policy-making process
Duangmanee & Koontanakulwong (2013)	- Analyses water demand and supply situation in Thailand, relative to the world	- Imbalance in water demand-supply despite high rainfall and large capacity of water storage	- Lack of systematic administration and management across 25 basins	- N.A.

Study	**- Focus** **- Scope** **- Methodology**	**Symptoms of poor performance**	**Causes of poor performance**	**Suggestions for improved performance**
	- National - Literature analysis	- Inefficiency in water usage		
Nikomborirak & Ruenthip (2013)	- Examine the structure of water (flood) management - Thailand - Document analysis	- Flood	- Management structure is highly fragmented, resulting from an *ad hoc* and *transitory* approaches to fix the problem - No law to govern water resources management	- Need an act to consolidate the management and administration of water resources
Cookey (2016)	- Evaluate performance of policies, legislations, regulations, and organizations governing water sector - Songkhla Lake Basin - Structured questionnaire and in-depth interviews	- N.A.	- Fragmented organizations - Weak coordination between organizations - Unclear allocation of roles and responsibilities among organizations - Weak capacities to enforce regulations - No integration between water sector organization and water user groups	- Establish a single water management organization - Clearly defined functions of this organization - Clearly defined roles and responsibilities

Note: N.A. – Not Applicable

It is clear from the above-noted observations (from the review of Table 1-1) that existing studies tend to attribute poor performance to sector-specific factors, that is, factors that are within the narrow domain of the water sector. Most of these factors are associated with water sector organizations, that is, lack of a clear organizational mandate, insufficient capacity of these organizations to manage water resources, fragmented management structure among these organizations. Other factors are: insufficient regulation, and less than satisfactory participation of all stakeholders. These studies then suggests ways to improve performance of the water sector by redressing these factors, for example, by introducing a committee that comprises of various stakeholders to jointly manage water resources, or by establishing a single water management organization.

This research contends that focusing on sector-specific factors to improve the performance of water sector is deficient. While it is true that these sector-specific factors are important drivers of sectoral performance, the influence of a broader society-wide factors should not be overlooked. That is, the organizational structure of water sector (sector-specific factor) that affect performance did not come into existence from a vacuum, it was shaped by a multitude of factors (social-cultural-economic-political) that have evolved from the past. For example, the fragmented and powerless water sector organizations could be the outcome of lobbying by powerful interest groups and political intervention. These, in turn, could be influenced by political instability of the country, which in itself may have social and cultural roots.

Focusing solely on water-sector-specific factors is unlikely to provide meaningful insights into the underlying causes of water sector performance, and hence guidance for suggesting policy measures to improve performance. There is therefore a need to identify the varied influences that shape the sector-specific factors in order to gain insights that can help guide the formulation of effective water policies. The need for this research is further reinforced by the fact that the Thai government has recently approved a budget of more than $1 billion to develop the country’s water management systems (PWC 2018). Further, the government is currently developing strategic plans to carry out water management for the next 20 years, and plans to spend considerably more to increase water security for its citizens (Apipattanavis, Ketpratoom & Kladkempetch 2018). A comprehensive research into the underlying factors of water sector performance could enable policy makers to design policy framework that may be used as a basis for effective water sector management in Thailand.

1.2. Research objectives

Against the above backdrop, the main objective of this research is to delineate the influence of socio-political institutions on the performance of the water sector in Thailand, with the view to recommend an institution-inspired policy framework for governing the Thai water sector and for improving its performance. In order to achieve this objective, the following specific objectives have been set in this research.

1. To examine the role of water throughout the human development history, with a view to demonstrate its importance from a multidimensional (social-cultural-economic-political) viewpoint.

2. To review the historical evolution of the water sector in Thailand, with a view to gain insights into the nature of changes that have taken place in its institutional settings, both formal and informal institutions.

3. To examine the performance of the water sector in Thailand, with a view to delineate factors that have influenced such performance.

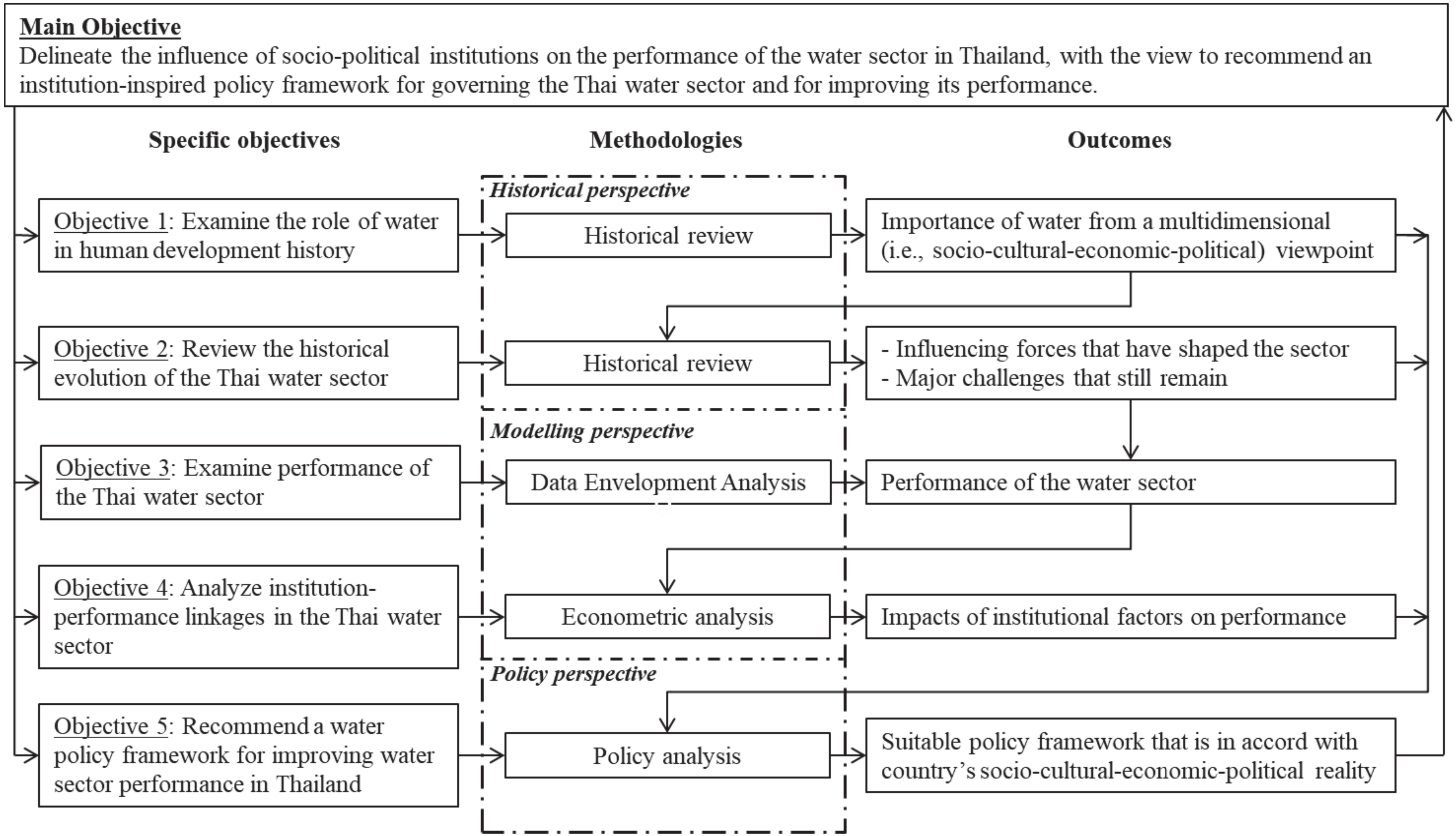
4. To analyze the institution-performance linkages in the Thai water sector, with a view to assess the impacts of both water sector institutions and socio-political institutions on water sector performance.

5. To recommend a water policy framework for improving water sector performance that accords with the country's social, cultural, economic and political realities.

1.3. Research methodology

In accordance with the multidisciplinary nature of this research, a combination of methodologies is employed to address various research objectives. Figure 1-4 provides a broad overview of the methodological framework employed in this research. These methodologies are divided into three parts – historical perspective, modelling perspective, and policy perspective.

Figure 1-4 Research Framework



1.3.1. Historical perspective

The historical review in this research involves two aspects – the role of water in human development history (Chapter 2), and the evolution of water sector institutions in Thailand (Chapter 3).

The first objective of this research is to review the history of water throughout the human development history. This review is intended to demonstrate the importance of water from a multidimensional viewpoint, including social, cultural, economic and political. The review is conducted at the global level, as well as for Thailand, beginning from the early civilization to the recent times. For Thailand, the review is conducted for two major time periods: pre-modern and modern Thailand. Pre-modern Thailand covers the following periods: pre-historic Thailand (before 1238 A.D.), the formative years of the country during the Sukhothai era (1238-1438), the expansion of the country during the Ayutthaya era (1351-1767), and the transitioning period during the Thonburi era (1768-1782). Modern Thailand covers the period over the past two centuries, covering the Rattanakosin era (1782-present).

The second objective of this research is to review the historical evolution of the water sector institutions in Thailand. The focus of this review is to: 1) identify changes in key institutional factors, particularly organizational structure and regulatory regimes, that resulted in the establishment of water resource management practices over the historical development of the water sector, 2) identify key influencing forces that have shaped the water sector, and 3) identify major challenges that still remain. The review is divided into two time periods that coincide with major changes in the water sector institutions in Thailand. These time periods are: pre-national economic and social development plan (before 1961) and post-national economic and social development plan (after 1961). This review will enable identification of the underlying influences that have shaped water institutions in Thailand, and how these institutions could influence the performance of the Thai water sector.

1.3.2. Modelling perspective

Two different modelling approaches are used in this research – to examine the performance of the water sector in Thailand (Chapter 4), and to analyze institutions-performance linkages (Chapter 5).

The third objective of this research is to examine performance of the water sector in Thailand, with a view to delineate factors that have influenced such performance. It analyses the performance in terms of the effectiveness of investments in the water sector in enhancing livelihoods of rural Thai population over the period 1987-2017. The analyses is undertaken for 25 water basins in Thailand, and at different stages of the water sector. In the first stage, resources (in the form of investments) are used to develop water infrastructure. This infrastructure is then available for producing agricultural outputs in the second stage, which are then transformed into outcomes (in the form of rural household income) in the third stage. Performance assessment of such a multi-stage water sector has an advantage over an assessment of a single-stage water sector (where resources are converted directly into outcomes) in that it enables to identify any ineffectiveness that may occur at different stages across the sector.

In order to achieve the third objective, this research adopts a multi-stage Malmquist-based Data Envelopment Analysis (DEA) method, developed by Färe, Grosskopf & Whittaker (2007) to assess the performance of Thai water sector. This method has been extensively used to assess performance of the water sector at micro level (e.g., individual companies), and at various segments of the sector (e.g., water distribution, wastewater treatment, sewerage services). A detailed review of these micro-level studies is provided by Abbott & Cohen (2009). Some macro-level studies also use this method to assess the performance of the whole water sector at the levels of municipalities, towns and states (see, for example, Garcia-Sanchez 2006; Garcia-Valinas & Muniz 2007; Sawkins & Accam 1994; Woodbury & Dollery 2004). No study however exists that assesses water sector performance of the country at the watershed or basin levels – the scope of analysis of this research. Further, no study exists that comprehensively assesses performance of the Thai water sector.

The fourth objective of this research is to analyze the institutions-performance linkages in the Thai water sector, with a view to assess the impacts of both water sector institutions and socio-political institutions on water sector performance. Specifically, it aims to statistically investigate the influence of institutional factors that determine performance of the water sector in Thailand. The main purpose of this investigation is to demonstrate the importance of wider socio-political institutions on shaping performance of the water sector. It will also help in identifying the sources (that is, inside or outside the domain of water sector) that inhibit the formulation of efficacious water policies, and thus affecting the performance of water sector.

Econometric analysis is employed in this research to investigate these linkages. This method has been widely adopted to statistically analyze the relationship between institutions and economic performance (see, for example, Commander & Nikoloski 2010; Efendic, Pugh & Adnett 2011; Knack & Keefer 2006). Several recent studies have established the appropriateness of this method to assess performance of the water sector (see, for example, Bonacina et al. 2014; Krause 2009; Massarutto & Ermano 2013; Saleth & Dinar 2004). Econometric analysis is suitable for this research because it enables to quantify the effect of various sector-specific factors as well as socio-economic-political factors on water sector performance. Such information is extremely useful to develop insights into the nature of linkages between these factors and the performance of water sector, which in turn can be used to identify any policy disconnects.

1.3.3. Policy perspective

The fifth objective of this research is to recommend a water policy framework for improving water sector performance. Based on the synthesis of the outcomes of previous objectives, the analyses of these outcomes, and the review of the Thai existing policy development settings, this research presents a set of recommendations for improving water sector performance in a way that accords with the country's social, cultural, economic and political realities.

1.4. Scope of this research

This research analyses the influence of institutional factors on water sector performance in Thailand, a rich water resource and agriculture-based country. The analyses focus on the entire water sector, which comprise 25 basins on the supply-side, and the agricultural users on the demand-side. Only agricultural users is chosen on the demand-side because it accounts for more than 90 percent of water used in the country.

The timeframe for analysis varies for each specific objective, depending on the focus of analysis, data availability and other related considerations. For instance, the historical review dates back to the pre-historic times to: 1) establish the importance of water, and 2) understand how water sector institutions evolve. The discussion on the evolution of water sector institutions give particular focus on development in relatively recent times, that is, since the establishment of the national planning body – the National Economic and Social Development Board in the early 1960s. This time period allows an understanding to be developed of the changes that have taken place in the institutions, structure, and regulatory arrangements since the beginning of modern water management practices in Thailand.

The quantitative analyses (that is, assessment of performance, and analysis of institution-performance linkages), on the other hand, focuses on relatively shorter time period, from 1987 to 2017. This selection is constrained solely by data availability.

1.5. Data considerations

This research requires a broad range of data relating to history, performance and institutions of the water sector, as well as wider socio-economic-political related data. The data are available in the form of historical records, national statistical information, macroeconomic, and time-series trends of the water sector in Thailand. These data are collected from a variety of published sources, including, for example, the Royal Irrigation Department (RID), Ministry of Agriculture and Cooperatives, Department of Water Resources (DWR), Department of Groundwater Resources (DGR), Ministry of Natural Resources and Environment and the relevant literature including research papers and publications, books, and journal articles. The socioeconomic data is collected from the Office of National Economic and Social Development Board (NESDB), the Bank of Thailand (BOT), and the National Statistical Office (NSO). These data are supplemented by personal correspondence with professionals working in the Thai water sector. The overview of data considerations for each specific objective is shown in Table 1-2. Further details of data sources and preparation, for objectives 3 and 4 of this research (modelling perspective), are discussed in sections 4.4 and 5.4.

Table 1-2 Overview of data considerations relevant to this research

Objectives	Data requirements	Data availability	Data gap	Strategies to overcome data gap	Data sources
1 and 2	Information on water sector development in the past	Partial	Yes	Text analysis & interview	Government offices (RID, DWR, DGR, NESDB, BOT, NSO) Relevant literature (books, journal articles, reports, legislation and policy papers
3	*Input-output data for water sector*				
	Total investments	Yes	No		BB & RID
	Irrigated area	Partial	Yes	Data apportion (Section 4.4)	RID & DWR
	Water storage capacity	Partial	Yes		RID & DWR
	Agricultural production	Partial	Yes		OAE
	Household income	Partial	Yes		NESDB & NSO
4	*Data on influencing factors*				
	Water sector institutions	No	Yes	Interview	See Appendix A for the list of experts
	Socio-political institutions	Partial	Yes	Estimate (Section 5.4.1)	ECT, SOC, OCS, NESDB, RID
	Non-institutions	Partial	Yes		DWR, DOM, NESDB
5	Results from above objectives	N.A.	N.A.	N.A.	N.A.

Notes: #BB – Budget Bureau; DOM – Department of Meteorology; DWR – Department of Water Resources; ECT – Election Commission of Thailand; NESDB – Office of the National Economic and Social Development Board; NSO – National Statistical Office; OAE – Office of Agricultural Economics; OCS – Office of the Council of State; RID – Royal Irrigation Department; SOC – Secretariat of the Cabinet.

1.6. Significance of this research

This research provides a holistic analysis of the water sector in Thailand, including the historical perspectives as to the importance of water and the evolution of water sector institutions, the examination of the performance of the water sector, the assessment of the impacts of institutional factors on water sector performance, and the analysis of how the effectiveness of water sector Thailand could be improved. In order to do so, this research employs a multidisciplinary methodology, demonstrating how multiple disciplines (for example, engineering, economics, social science and political science) could be combined to analyze policy issues. It also illustrates how complex issues can be analyzed in an integrated way.

This research also provides useful insights for policy analysis in the water sector. Policy makers, policy analyst, and professionals involved in the management of water sector could be some of the beneficiaries of this research. Policy makers will get better understanding of the impacts of alternative water resource management practices; this could assist them to develop informed and practical policy responses to further water resource agendas. Policy analysts and water professionals will be able to use data and the analytical framework to further their research and analyses.

1.7. Organization of thesis

Chapter 2 provides a viewpoint on the role of 'water' in Thailand from a multidimensional perspective. Specifically, it highlights the role of water from social, cultural, economic and political viewpoints, in order to demonstrate the importance of water from each of these perspectives. These viewpoints are developed on the basis of a historical review of the country's sociocultural, economic and political factors.

Chapter 3 reviews the historical evolution of the water sector in Thailand, with a view to gain insights into the factors that have shaped the structure of the water sector, in terms of its institutional settings, both formal and informal institutions. The review also includes consideration of laws, regulations, policies, and organizations responsible for policy development, policy implementation, and management of water resources in Thailand. The focus of this review is to identify changes in key institutional factors that resulted in water resource management practices over the historical development of the water sector.

Chapter 4 analyses the performance of the water sector in Thailand. Specifically, it assesses whether past investments in the water sector have led to beneficial outcomes for rural population, especially those that rely on water-dependent farming activities.

Chapter 5 assesses the institution-performance linkages in the Thai water sector in order to assess the impacts of both water sector and socio-economic-political institutions on water sector performance. This assessment is based on the application of an econometric model that is capable of isolating the influence of institutional factors from other external factors on water sector performance.

Chapter 6 demonstrates how insights gained from the analyses in the previous chapters could be used to develop a water policy framework that accords with the country's social, cultural, economic and political realities.

Chapter 7 presents the summary of the main findings of this research, and also provides some recommendations for future research.

CHAPTER 2 ROLE OF WATER IN HUMAN DEVELOPMENT HISTORY

2.1. Introduction

A history of water is an integral part of the history of human civilization. Water is essential for human survival and has profoundly influenced the development of societies from the dawn of prehistoric times. Against this backdrop, this chapter aims to examine the role of water in shaping human history, especially its social, cultural, political and institutional transformations. Furthermore, it attempts to explore transhistorical paradigms of water management in the context of Thailand. This chapter particularly discusses the key role that water has played in shaping religious beliefs, values and rituals – both globally and in Thailand.

This chapter is organized as follows. Section 2.2 analyses the historical evolution of water and its cultural implications in the global context. Section 2.3 then examines how people in Thailand have developed water resources to fulfil their needs, and what factors have affected such development. Section 2.4 provides a summary of the major findings of this chapter.

2.2. History of Water: A Global perspective

Water has indeed been critical for human life, culturally, economically, socially and historically since the advent of humanity. In order to ensure ‘access to water, social organizations and water management policies and technologies have co-evolved throughout global history (Hassan 2010). From the early civilization period (about 10,000 years ago), many societies used water for agricultural and navigation purposes. Several civilizations also developed artificial irrigation technologies and practices in their major river systems, for example, River Nile, the Euphrates, the Indus and the Yellow Rivers (Hassan 2010). However, in the initial stages, people relied on surface runoff, small rivers, canals and groundwater for meeting their living needs. Besides, there are numerous examples of collaborations among people in communities through their participation in digging canals, and making dykes and embankments. In Egypt, for example, there is concrete evidence that the state, during the middle kingdom, was involved in operating large-scale irrigation projects as early as 1880 BCE (Kemp 1989). At that time, *Sadd El-Kafara* dam was constructed across the desert *Wadi Garawi*, and barrages and a network of canals and dams were built as a part of the centralized system of water management. Likewise, rice cultivation and planting existed in China more than 6,000 years ago and this was associated with the development of irrigation systems such as canals, ditches, wells and ponds for controlling and managing water resources (Hassan 2010).

These developments were followed by the emergence of water-lifting technology. In this period, innovative devices that helped to transport water and used animal as a source of energy were developed (Hassan 2010). For example, the *shaduf* was among the earliest water-lifting techniques. It was originally developed in Mesopotamia and applied the principle of gravity to lift water from one level to another. Another water-lifting technology was the *noria or saqiya* (water wheel). It used a system of gears to transfer energy from one spatial dimension to another, both horizontally and vertically. Another water invention in this period, dating to the third century BCE, was the *Archimedean screw* that was first utilized in Egypt. It aimed to reduce labor work from moving substantial amounts of water by using windmills, instead of turning the screw by hands. Interestingly, the Archimedean screw pump was operational in the *Viinikanlahti* wastewater treatment plant in Finland until 2007 (Ketko & Juuti 2007).

With the rise of Islam in the seventh century CE, the development of water technologies became a vital part of the economic quests. For instance, the *Karez or Qanat* system was introduced into the arid areas of today's Afghanistan and Pakistan in order to overcome the problem of evaporation loss (Schelwald-van der Kley & Reijerkerk 2009). It was an ancient underground irrigation system that comprised of wells and underground water channels which were commonly owned and operated by the local people. Similar social water supply systems could also be found in the Chinese deserts in the west of the Himalayas over 2,000 years ago.

The dynamic growth of cities, population and agricultural growth in the later years raised several 'water problems' and this resulted in the advent of water technologies to solve new challenges arising from water such as quality issues. For example, 4,000 years ago, the Indians are known to have used boiling to purify water (Hassan 2010). Apart from using water for agricultural purposes, domestic water supply became an integral part of people's daily lives and religious rituals. For instance, the followers of Islamic religion use water five times a day for their mind and body purification.

A major development during the early years of industrial revolution was steam engine, to support the growth of industry and economy (Hassan 2010). Expansion in trade and growth in the manufacture of industrial commodities further resulted in the development of better water-related technologies and modes of transportation. The utilization of water as steam to power complex engines for industrial activities, draining swamps, lifting water and transportation were some of the remarkable innovations of this era (Pirenne 1969). The paradigm of 'hydraulic engineering' also emerged in this period with the spread of water technologies; it later paved the way to the industrial age.

The rise of industrial revolution highlighted the remarkable turning point in our history. It significantly transformed manufacturing processes in Europe and the US, from using hand production systems to machines. This contributed to the invention of modern production methods based on increased use of steam engines, machine devices and automated factory systems, especially for textile production. This industrialization also led to an unprecedented increase in the population, provided a bigger role for the middle class, and significantly supported scientific development. Apart from extensive use of steam power, the use of hydroelectric power also became the norm during this time. It also marked a fundamental shift in global water management practices. By 1911, several big dams had been built in the U.S., and this later spread to the rest of the world (Hassan 2010). Coincidentally, the building of large dams also led to significant concerns over engineering methods, management practices, and social and economic impacts associated with big projects. History is replete with examples of conflicts over issues of building and managing dams, as well as, how to respond to ecological and social impacts once the water projects have begun. For instance, the recent controversial Xayaburi Hydropower Project in Laos has raised concerns over the dam's transboundary impacts. Vietnam and Cambodia have continually claimed that Laos never conducted a comprehensive analysis of the transboundary impacts (Herbertson 2013). The ensuing disputes involve many stakeholders including countries, local authorities, private sectors, utilities, and consumers.

Furthermore, water has increasingly being conceptualized and priced since 1990s as a 'good'. The Fourth Dublin Principle on water and the environment in January 1992, under principles No. 1 and 4, states that fresh water is a finite and vulnerable resource and has an economic value and should be recognized as an economic good (WMO 1992). Subsequently, the Dublin-Rio principles which were released during the Earth Summit in June 1992 were based on the argument that water is a public good and has a social value; thus, water development and management should be based on a participatory approach. Further, water is also the basic right; all human beings must have access to clean water and sanitation. These Principles have provided a ground-breaking shift in the importance of water, particularly its economic dimension associated with water use in general, and irrigation development in particular. Water – as a commodity – has implications on 'human rights'. Indeed, when water is valued as commodity in the market, water pricing is used as a tool to manage water balance and insecurity (Rios et al. 2018). This economic aspect of water has however influenced debates between impoverished or vulnerable groups and the government who set a water pricing scheme. In other words, given that water is priced, it implies that not every person is entitled to access safe and affordable water.

Undeniably, water problems can lead to food scarcity, energy calamity, and eventually economic and governmental uncertainty. To respond to this challenge, a new paradigm in water management, termed "integrated water management", emerged in the 1960s. This paradigm, renamed as Integrated Water Resources Management (IWRM), regained considerable attention in the following years due to its holistic approach for sustainable water management. By the early 1990s, the IWRM approach, in one form or another, was used throughout the world (GWP 2000; Mitchell 1990) – a testimony to its growing appeal. According to the technical Committee of the Global Water Partnership, IWRM is defined as "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." This concept urges for a holistic management of water resources. Furthermore, the World Summit on Sustainable Development in Johannesburg in 2002 released the Ministerial Declaration which called "for every country to have an IWRM plan in place by 2005". In this regard, this plan stresses the necessity to pay full attention to surface and groundwater, quality and quantity matters, ecology, linkages between land and water resources and diverse socio-economic functions of water resources management (Mostert 2006). This new paradigm expects to lessen problems of 'water conflict' between states, countries, or people groups surrounding the utilization, consumption, or control of water resources.

In September 2000, the United Nations Millennium Declaration was adopted. Under this Declaration, one of the objectives was "to stop the unsustainable exploitation of water resources by developing water management strategies at the regional, national and local levels, which promote both equitable access and adequate supplies" in order to protect the common environment (UN 2000, p. 6). Following this declaration, the eight Millennium Development Goals (MDGs) were announced for the year 2015. In the MDGs, Goal 7 focused on ensuring environmental sustainability and target 7C aimed to halve the proportion of the population without sustainable access to safe drinking water and basic sanitation by 2015 (WHO 2018). After the expiry of MDGs in 2015, the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development were proposed and enforced in January 2016 as targets to end all forms of poverty, combat inequalities and tackle climate change, while ensuring that no one is left behind (UN 2018). The SDG Goal 6 states that access to water and sanitation must be ensured for all. This new water-related goal establishes the criticality of water and mandates the governments to increase investments for the effective management of freshwater ecosystems and sanitation facilities at all levels of the water chain including the local level, especially in several developing countries in Sub-Saharan Africa, Central Asia, Southern Asia, Eastern Asia and South-Eastern Asia. In other words, based on this paradigm, water and irrigation development projects should be promoted to enhance people's wellbeing in order to alleviate poverty.

The above discussion on changes in water governance in response to historic events, supported by technological advances, new paradigms and formal institutions for water management – this thesis contends – cannot totally explain the reasons for changes in water governance over the times. In order to fully appreciate the reasons for such changes – this research further contends – it is important to look at the role of informal institutions, i.e., culture contexts, traditions and beliefs, especially how these institutions have influence the dynamic interactions between resources, technology and institutions, and how such interactions have contributed to the transformation of the water sector at the global and country levels. For example, in order to overcome droughts and famines, how complex systems of remedies were adopted by many societies since the ancient times? How – besides scientific fixes – rituals and cognitive strategies played important roles, as the intervention of higher natural or metaphysical powers, in reducing concerns and uncertainty about water resources (Hassan 2004). Throughout the history of mankind, common-pool resources (soils, forests, lands, water) have been protected by the mutual belief-systems of members of each society, for example, belief in the Goddess of Water, Goddess of Rice and the guardian spirit of the forest. These belief-system manifested themselves in the form of cultural mythologies, worship and ceremonial practices in each society; these mythologies and practices held various societies together – as cohesive culture units. Therefore, understanding cultural context is significant for designing policies or tools for water management. According to Jinapala & Somaratne (1992), the study of river basin called “Ruhuna” in Sri Lanka showed that there is a traditional system to manage the water which is “Rajakariya”. In addition, the power of the myth or legend regarding water resources can be found in many parts of the world. Rap (2017) argues that the myth was indeed important for the success of irrigation policies and water reform in Mexico. The main reason for the success was that the Mexican policy of irrigation management could gain support and cooperation from public agencies and people as the policy was underscored by respect for culturally-sacred water-rituals of the Mexican people. Similarly, Aniah, Aasoglenang & Bonye (2014) argues that the role of shamen, sacrifices and the belief that water resources is a home of the God enabled people in the northeast region of Ghana to manage their natural resources more effectively.

Further, history also shows that mediation by mediators, empowered by supranatural or shamanistic powers, for solving water resources problems or conflicts, also contributed to the transformation in the role of mediators into chiefs and kings ruling the communities (Hassan 2004). This was a path of societal and political development that the king was legitimated by cosmogonic theologies highlighting the divine origin of kingship. Also, water resources were not merely the main criteria to determine the location of a city, but also assisted to form nation states by gathering people into political units. A good example was that activities along the Nile facilitated the establishment of a nation state that unified farming communities in southern Egypt and the Delta in 3000 BCE (Kemp 1989). Besides, the emergence of the state led to developments of trade, transportation, warfare and technology that paved the way to how people managed their water resources. More importantly, the rise of cities inside the state significantly empowered the elites to control and manage their subordinates and administer different farming systems. This led to the emergence of specific ideological, managerial, bureaucratic and military arrangements in their political domains (Hassan 2004). This also contributed the emergence of different institutional arrangements for water management.

'Water' has been a continuing source of inspiration for people in the society and has been closely linked to the activities and rituals of many religions. For example, Buddhists believe that water represents purity, clearness and calmness; therefore, they use water during the holy ceremonies and meditation (Schelwald-van der Kley & Reijerkerk 2009). In addition, the concept of water ethics and the human rights to water have been broadly supported by the religious paradigms as we can see in the notions and practices of Christianity and Islam (Hassan 2010). These paradigms provide a foundation for a spiritual approach to water – as a pure and blessed substance that people have to protect. This was also the catalyst for the movement for ecological protection, particularly to preserve natural systems, since the 1970s. Undeniably, MDGs and SDGs of the United Nations which promote the human right to water sanitation and water justice with poverty eradication, gender equality, hunger eradication, good health, climate action, and sustainable communities, are part of the religious concepts. In Asia, community irrigation systems have been prevalent and it demonstrates the endogenous combination of local wisdom and social solidity to effectively manage water resources (Barker & Molle 2004).

However, the rise of advanced technology and formal institution in water management has impacted the relationship between water and its cultural contexts. In the past, for example, water was a part of people's beliefs, practices and culture around the world. Belief in scientific management of natural resources and design of (formal) institutional arrangements to achieve this has made culture, social arrangement and religious beliefs less important consideration for designing water management policies. This – this research argues – has contributed significantly to failures in water management. Why? Because informal institutions are critical to the design of effective water governance, policies and practices. According to Ostrom (1998), common-pool resources should be managed through self-organized groups – including the types of locally organized irrigation systems as complex adaptive systems, in contradiction of forms of organization that require central direction. This implies that ecological and social systems are closely interacted.

The above discussion suggests that water management policies and practices have evolved significantly since the prehistorical times. In the initial times, much of these policies and practices were informed by the cultural and religious contexts of water (i.e., its informal institutions). The later years however witnessed a complete transformation, with water being treated as an economic commodity – to be managed through pricing system. Such commodification of water has resulted in a neglect of the influence of informal institution. Hence, emerging water resource problems – this thesis holds.

2.3. History of Water: A Thai perspective

Water is central to the life of Thai people. Ever since the early settlements, the Thai people have chosen to stay near bodies of water such as canals, rivers, seas or lakes for meeting their agricultural, navigation and domestic needs. This section reviews how people in Thailand have developed water resources to fulfil their needs, and what factors have affected such development. This review is conducted for two major time periods – pre-modern and modern Thailand. Pre-modern Thailand includes: pre-historic Thailand; the formation of the country in Sukhothai era (1238-1438); the expansion of the country in the Ayutthaya era (1351-1767); and the transitioning period of Thonburi era (1768-1782). Modern Thailand includes the past two centuries, specifically the Rattanakosin era (1782-present).

2.3.1. Pre-modern Thailand

Water resources in Thailand have developed considerably since pre-historical times. During the pre-historical period (5,000-6,000 years ago), the early communities formed settlement near the rivers, to supported their agricultural activities (Varitwuttikul et al. 2017). Ample historical evidence is also available at several archaeological sites to support this observation, such as, Non Nok Tha in Khon Kaen Province, and Ban Chiang in Udon Thani Province.

Later, the development of an irrigation systems and metal devices, and changed economic conditions led to changes in the ways of paddy cultivation, with emphasis on reducing labor and increasing productivity, as can be seen in the case of Sakon Nakhon Basin (DRI 2002).

During the ancient Lan Na period (13^{th}-18^{th} centuries), irrigation management for rice cultivation can be traced back to the reign of King Mengrai, the great king who founded the Lanna Kingdom in 1270, by constructing weirs and ditches *(Muang Fai)* in the Northern region (Arsvai 1978). The suitability of weirs in the North was due to its mountainous geographic terrain where water could be supplied by small rivers which were branches of big rivers such as the Chaophraya River, the Ping, Wang, Yom and Nan. Therefore, primitive irrigation systems, which were temporary weirs across the streams in combination with the small ditches leading to paddy fields, were constructed by the people in the Northern region (DRI 2002). Normally, the rulers built the large-scale *Muang Fai* as water sources for small-scale *Muang Fai* which were constructed by the local people. In order to operate these water facilities, a pattern of participatory water management was established. It was based on rules and regulations for water use that were formally and informally set up by the rulers and their citizens. The weir-ditch agreement was established in many localities and the rules were parts of King Mengrai's law (Ounvichit 2005). It is interesting to note that rules and laws relating to irrigation also commonly attempted to link *Muang Fai* with supranatural power by proposing that every *Muang Fai* have God and Goddess to protect; therefore, people should not harm them. These spiritual undertones were given further credence by the establishment of a system of penalties and punishments if people broke the law. For instance, people who lost the case of water fight in *Muang Fai* had to pay a fees of about 33,000 Bia (DRI 1967).

The influence of Khmer in irrigation practice can also be found during period of the 15th-18th Buddhist centuries, in the form of the *Barai*, a large-sized reservoir, for storing water for consumption and agricultural cultivation in the Mun and Chi river basins, and the present-day Lopburi and Saraburi provinces (Varitwuttikul et al. 2017). Further, water control and retention technology was also developed during these times. For instance, dikes were constructed to supply water for domestic consumption and to divert water to irrigated areas and reservoirs. The attempts of the Khmer to expand their control over agricultural areas and trading routes reflected its political, administrative, and cultural domination across these areas.

From 1238 until 1438 was the era of the Sukhothai Kingdom was founded. Its capital was located at Sukhothai City and Si Satchanalai and the major topographical characteristics of these areas are foothill plains. Communities settled around the Ping, Yom and Nan river basins. It is interesting to note that the capital city of Sukhothai was located far from the rivers. The nearest river was the Yom River which was 12 kilometers away from the city (Paobphet 2016). This made Sukhothai often encounter water shortage problems and led to the development of a complex and unique irrigation system. In terms of water management system, dikes or *Sarid Phong* can be founded throughout Sukhothai – to divert water flowing from the mountain in the Southwest of the Kingdom (DRI 2002). Furthermore, moats and ponds called *Traphang* were constructed to collect water from drainage canals. In this regard, clay pipes were used to deliver water to some ponds. As areas located between the Yom and the Nan rivers often encountered flood (almost every year), an embankments or *Phanangs* were built for flood protection of cultivated areas. Indeed, this complex network of irrigation was not only built to serve the purpose of water storage, but it also helped to protect the city from enemies. In term of politics, Sukhothai was governed in the style of paternal kingship, and was ruled by nine consecutive kings. This kingdom lasted approximately two centuries until its political domination declined, and eventually it merged with the Ayutthaya Kingdom in 1437.

The importance of water in the Thai context becomes evident if one takes note of the fact that 'river' in Thai language is called "*Mae Nam*" or Mother Water. Water is used for blessing in many forms and symbols in Thai culture such as festivals, rituals, literature, dancing, folk art, and architecture. For example, the *Loy Krathong* Festival was initiated by Nang Noppamas, the favorite concubine of King Loethai (1257-1323), during the Sukhothai period. The objective of this festival is to give respect and gratitude to the Goddess of Water on every full moon of the twelfth lunar month (Thadaniti 2014). Further, the *Songkran* Festival also originated during this period, as a cultural heritage from the Buddhist religion. This water festival marks the start of the Thai traditional New Year. Besides popular 'water fights', *Songkran* is a religious festival; it is a Family Day and a day for visiting the temples. On this day, it is considered sacred to sprinkle Buddha images and statues with water. This ritual is called *Song Nam Phra*. This ritual is then followed by *Rod Nam Dam Hua* which involves sprinkling family members with water and for showing respect and gratitude. More importantly, since the Sukhothai Kingdom until the present, water lies at the heart of the coronation ceremony of the new King. At the time of coronation, the King takes a ceremonial bath with a shower of consecrated water which means to purify himself before proceeding to the next important rites (Chetchotiros 2019). Indeed, water collected from specific sources (locations) in the country regarded as sacred for use in this ceremony. In the coronation ceremonies for King Rama I to Rama IV of the Rattanakosin period, water from the five ponds and from the country's five major rivers – the Pasak, Chao Phraya, Bang Pakong, Ratchaburi and Phetchaburi – was used for the holy events. These festivals and ceremonies reflect that water is at the core of Thai way of living, and is considered to be the most important component of the royal rites for Thai Kings.

The kingdom of Ayutthaya existed from 1350 to 1767. Ayutthaya was strategically located on an island surrounded by three rivers: the Chao Phraya, the Lopburi and the Pa Sak which connected the city to the sea. Within the city's wall, several canals were dug up for transportation and water management. This ensured that the city was not only protected from flooding but also from attacks from the naval forces of nearby kingdoms. This arrangement made Ayutthaya grow in power and influence, both politically and economically, over its 400 years era as the city became a hub of administration, economy, and transportation. Ayutthaya was praised by the Westerners at that time as the best port in Southeast Asia (Paobphet 2016). Indeed, enormous expansion of international trade and foreign communities took place during this period. Furthermore, because of its location at the fertile floodplains of the Chao Phraya river basin, rice was Ayutthaya's main agricultural product (Arsvai 1978). In order to support rice cultivation, water management practices involved digging up canals from the early periods, for example, Samrong canal in 1498 and Bang Kruay canal in 1538 (Suebwatana & Pritinarakorn 1988). In the later years of the kingdom, several more canals were excavated for serving the purposes of consumption, transportation, trade, and agriculture, such as Wat Pak Chan canal in 1661 in the reign of King Narai, and Mahachai Cholamas canal in the reigns of King Prachao Sua and King Tai Sra in 1704.

Besides, water control systems were constructed in many areas. For example, *Than Thong Daeng Reservoir* in Saraburi Province was built during the reign of King Prasat Thong (Varitwuttikul et al. 2017). Interestingly, King Narai had established Lopburi city as the capital of the Ayutthaya Kingdom in 1666 and had given top priority to water for consumption. A dam was built to store water throughout the year and a pipe was installed to transport water from the dam into the city for distribution to important places (PWA 2019). Further, *Haui Sap Lek* and *Thale Chupson* reservoirs were constructed during the reign of King Narai, outside the city of Lopburi; it used pipelines to send water to the lower areas for domestic consumption and recreation inside the palace, as well as paddy cultivation and transportation (DRI 2002). This was the first use of pipelines for transporting water from water-source to the city, for the general public use.

In 1767, the Kingdom of Ayutthaya came to an end following a loss of war to the Burmese invaders. Later, King Taksin proclaimed independence from Burma and established the capital at Thonburi. The Kingdom of Thonburi (1767-1782) still placed the Chao Phraya river as the deciding factor for the location of the capital city. Thonburi, located between the Chao Phraya delta and Ayutthaya, was a strategic location that protected the city from naval invasion and supported trade to achieve economic prosperity. Moving the capital to Thonburi also facilitated the initial development of water resources at the Chao Phraya delta (Varitwuttikul et al. 2017). The overall pattern of water management in this era was however similar to the pattern in the Ayutthaya period (DRI 2002). There is evidence that suggests that many canals were dredged as shortcuts, city moats and connecting routes between the rivers, with an objective to support transportation, commerce and nation's defense, such as Khu Muang canal in the east of the Chao Phraya river.

Noticeably, while there is substantial evidence of cooperative efforts in water management in the Northern region, evidence of such co-operation among rice-growing peasants for irrigation is rather scant, apart from some cooperation during periods of harvesting and transplanting that required man power (Brummelhuis 2007). In terms of state involvement in irrigation policy, the government had limited control over irrigation activities operated primarily by peasants in the countryside communities, as the governments focused more on establishing public works and managing military affairs (Tanabe 1977). In fact, Ayutthaya's administrative entities was Jatusadom – composed of Wiang (the City), Wang (Bureau of the Lord Chamberlain), Klang (Bureau of the Exchequer), and Na (the Bureau of Paddy Fields) since King Ramathibodi I (King U-Thong) in 1351. Later, in the reign of King Borommatrailokkanat (1448 - 1488), massive reforms were implemented in Ayutthaya by retaining these fourfold divisions under the Samuha Nayok (civil administration) and Samuha Phra Kalahom (military administration). Although Kromna (Bureau of Paddy Fields) had existed since the establishment of the Kingdom, its task was mainly for collecting levies on rice crops as income for the king (Brummelhuis 2007). The *Senabodi Kromna* (Director-General of Bureau of Paddy Fields) could however intervene in rice cultivation when there was a crisis such as wars or droughts. This institutional arrangement demonstrated that there were a formal agencies to deal with agricultural issues in order to collect revenue for the Kingdom since the Ayutthaya era.

2.3.2. Modern Thailand

Following the end of the reign of King Taksin of Thonburi in 1782, King Rama I founded the Rattanakosin Kingdom and shifted the capital from Thonburi to Bangkok which is located on the east side of the Chao Phraya river. The irrigation and water management policies in this period were similar to the previous era which focused on the dredging of existing canals for transportation, agriculture and domestic consumption. Furthermore, all canals around Bangkok were used for security purpose as city moats to protect the Kingdom from foreign invasion. The Bang Lamphoo canal was excavated by foreign labor to serve as a city moat. During the early Ratanakosin era, the Kingdom still encountered several wars with Burma (Paobphet 2016). Particularly, wars were declared seven times in the reign of Rama I. Therefore, canals at that time served military purposes, besides serving consumption and transport needs.

In the reign of King Rama II (1809-1824), the excavation of canals continued to serve military purposes, as well as facilitating transportation of goods (e.g., sugar, spices and salt (Varitwuttikul et al. 2017). In the next reign, of King Rama III (1824-1851), international trade began to prosper again. In 1825, the first treaty with the West (the *Burney Treaty*), was signed with an aim to establish free trade in Siam and to greatly reduce taxation on foreign trading ships. Indeed, the existing canals and more new canals considerably facilitated transportation and trade of agricultural products. Notably, King Rama III ordered the installation of the first water gauge station in Siam, in front of the Tham Mikkarat Temple in Ayutthaya, in 1831, in order to measure water level for solving problems of regular flood in the Central Plain of the country (DRI 2002).

When King Rama IV came to the throne (1851-1868), several transformations happened in Siam. For example, during his reign, the pressure of Western expansionism, especially from Britain and France, intensified for the first time in Siam. The fear for colonization led King Rama IV to adopt Western innovations and initiate the modernization policy for the country, both in technology and culture. On 18 April 1855, the *Bowring Treaty* was signed between the United Kingdom and the Kingdom of Siam. This treaty aimed to liberalize foreign trade in Siam. One of the important impacts of this treaty was a dramatic growth of commercial sectors and export of agricultural products such as rice, sugar and pepper (Varitwuttikul et al. 2017). In particular, the rice market in Siam considerably expanded due to the enforcement of the Bowring Treaty. Table 2-1 shows the increasing volume of rice exports between 1857 and 1909.

Table 2-1 Rice Exports, 1857-1909

Period	Average Volumes per Year (1,000 Loads)
1857 - 1859	990
1860 - 1864	1,841
1865 - 1869	1,630
1870 - 1874	1,870
1875 - 1879	3,530
1880 - 1884	3,580
1885 - 1889	5,320
1890 - 1894	7,250
1895 - 1899	8,000
1900 - 1904	11,130
1905 - 1909	14,760

Source: Ingram (1964)

This trade expansion significantly encouraged the King to develop irrigation system for improving agricultural productivity. Hence, several canals were excavated to provide new areas for people to occupy cultivated land (Phongpaichit & Baker 2002). Phadung Krungkasem canal and Hua Lam Phong canal were among the canals that were developed during this period.

The reign of King Chulalongkorn (1868-1910) represented a period when Siam was directly threatened by Western expansionism. The King introduced many major reforms in order to ensure Siam's survival in the wake of Western colonialism. Indeed, the awareness of colonization pushed Siam to move into modernity. Expansion of irrigation is believed to be a major element of modernization and progress during those years. Therefore, water management became more formal institution in this period. Due to the strong relationship with foreign countries, innovative technologies for water resources management, and irrigation experts, were introduced throughout this period (Varitwuttikul et al. 2017). Besides, the Bowring Treaty led to the expansion of rice trading which required more areas and water resources for paddy cultivation, particularly in the areas of the Chao Phraya plain. It eventually encouraged the government to drive for modern irrigation schemes. In 1889, a plan was made to develop *Thung Luang* or *Rangsit*, the non-cultivated areas on the east bank of the Chao Phraya between Ayutthaya and Bangkok. It marked the first private investment in irrigation in Siam (Brummelhuis 2007). The Siam Land, Canals, and Irrigation Company, established by the nobility, bureaucrats and foreign investors, began to build networks of canals in this area in 1891. The government initially gave responsibility to the company to operate and maintain the canal for a period of 25 years. After that, all the concession areas plus the works and installations would be given to the government. However, the Rangsit Scheme faced several problems, especially about land ownership between the company and the state, as well as, the company and the local people – because the canal was developed before royal permission was given (Paobphet 2016). Importantly, it seemed that the company placed more focus on profits from land accumulation than the development of irrigation.

Later, Homan van der Heide, a Dutch expert, was hired and appointed to be the first Director-General of *Krom Klong* (the Department of Canals) which was established under the ministry of Agriculture in 1902. The Department's mission was canal dredging and expansion in order to provide water supplies for cultivation purposes, and to support transportation. Indeed, this was the first direct state intervention in irrigation works. Further, in 1902, the Canal Conservation Act of Rattanakosin Era 121 was proclaimed for protecting canals from any damage and giving authority to the Minister of Agriculture to gather money from vessels passing the maintained canals (DRI 2002). After the establishment of *Krom Klong*, Homan van der Heide proposed the Great Chao Phraya Scheme in 1903. However, this project could not be implemented due to lack of funds as the government gave priority to defense and railway projects (Brummelhuis 2007).

During the reign of King Mongkut (Rama VI) (1910-1925), droughts often occurred in the Central plain, causing significant damage to rice cultivation. The King responded by setting up the Committee which accelerated the development of irrigation. Subsequently, Sir Thomas Ward, an English expert, was recruited to assist in water management. This led to a significant progress in irrigation in these years. For example, the Act for Water Hyacinth Eradication was issued in 1913 – for canal maintenance. The Canal Department was transformed to *Krom Thod Nam* or the Barrages Department in 1914 with the missions to ensure the drainage, land improvement, flood mitigation and hydropower generation (DRI 2002). Later, in 1915, the Barrages Department implemented the South Pasak Irrigation Project.

In the next reign, of King Prajadhipok (Rama VII) (1925-1935), in 1927, the Barrages Department was replaced by the Royal Irrigation Department and given the responsibility of canal development, water diversion, water distribution, and water pumping for areas meant for agricultural cultivation. In addition, several irrigation projects were carried out across the country; there was a slow-down in these developments during the First World War though. In 1934, the King proclaimed the Weir and Dike Control Act to regulate irrigation activities (DRI 2002).

The great depression of 1929 led to salary cutbacks and reduction in military budget. This caused massive resentment among the bureaucrats, both civil and military (Phongpaichit & Baker 2002). It eventually resulted in the overthrow of the absolute monarchy, when the *Khana Ratsadon* (People's Party), which comprised of junior army, navy and civilian officers, seized political power in June 1932 and announced a constitutional regime and guided democracy, thus ushering in a new epoch in modern Thai politics and administration.

After King Prajadhipok announced his intention to abdicate in March 1935, King Ananda Mahidol came to the throne. During this period, several irrigation projects were developed throughout the country such as the Samchuk project, the Old Mae Ping Irrigation project and several other water development projects in the Northeast. Thailand also begun to train staff and experts in irrigation and established a school for water engineering in 1937 in order to support water management projects in the country (Paobphet 2016). Furthermore, many water management acts were issued, such as, the People Irrigation Act in 1939, the Ditches and Dikes Act in 1941, and the State Irrigation Act in 1942.

The development of water resources in the era of King Bhumibol Adulyadej (1946-2016) was systematically established and supported throughout the Kingdom. The King stressed the importance of water resources for country's development by stating that "water is compared to life of human beings" (DRI 2002). The end of the Second World War in 1945 paved the way for Thailand to develop irrigation systems. Apart from internal pressure for modernization, foreign technical assistance was very important for the development of Thailand in the 1950s and 1960s (Muscat 1994). In particular, foreign aid helped to create and underpin domestic institutional capacities, by providing education and training for the Thai elites and state officials in the newly-established institutions. In other words, external aid and international organizations' activities were crucial in determining policy direction and public-sector orientation. In this regard, expansion of the Department of Royal Irrigation was supported by international assistance, especially by the United States during the cold war years.

The geopolitics of the Cold War led to substantial improvement in the already close ties that existed between Thailand and the United States, as the latter saw the former as a vital buffer state with a strategic location for containing the threat of communism in the Southeast Asian region. The assistance from the U.S. in both money and weapons unavoidably helped to strengthen the military power, particularly during the Vietnam War (Phongpaichit & Baker 1998). For instance, much of the capital invested in the transportation and irrigation networks was provided by multilateral lending agencies, most notably the U.S. Agency for International Development and the World Bank, in this period (Paobphet 2016).

It is important to note that external actors, especially the World Bank mission in 1957, helped to transform the Thai irrigation system. The first National Economic and Social Development Plan (1961-1966) was initiated to promote the private sector, with specific focus on industry and commerce, and to develop basic infrastructure, such as, transport, electricity, and water supply (NESDB 1967). Under the direction of the first plan, the government also established several institutions and agencies such as the Bureau of the Budget, the Board of Investment (BOI) and the National Economic and Social Development Board (NESDB). Since their foundation, these state mechanisms have considerably contributed to promoting the development of irrigation in the country.

In summary, this section has established the importance of water in the development of Thai nation. In the ancient times, Thai people established the settlements and towns along the river banks, river islands and canals which created a unique cultural heritage and national identity of the country. Further, the development of water resources and management practices in each era reflect the changing nature of politics, society and economics – both internally (i.e., domestically) and externally.

2.4. Summary and conclusions

This chapter has attempted to investigate the role of water in shaping human history, in terms of its social, cultural, political and economic transformation – by looking at the underlying societal dynamism of various societies. It has also investigated how water management policies and practices have been developed and organized around the world and Thailand, through the lens of historical development in irrigation. Major findings are presented in Table 2-2, which demonstrates that the role of water resources in the global and Thai contexts has shared some elements in terms of social, economic, political and cultural transformations.

Table 2-2 Role of Water: Global and Thai contexts

Role of Water	Social	Economic	Political	Cultural
Global	- Settlement - Community - Norms	- Agricultural production - **Industrial revolution** - Trade - **Technology** - Transportation	- Nation building - Defense - Institutions - Paradigms - Conflicts	- National identities - Rituals/festivals - Religion/**beliefs** - Ways of life
Thailand	- Settlement - Community - Norms	- Agricultural production - **Economic development** - Trade - Transportation	- Nation building - Defense - Institutions - **Modernity** - **The King's role**	- National identity - Rituals/festivals - Religion - Ways of life

Note: Contrasts are highlighted in 'bold'

The key points are as follows:

- Water has played an important part in the **social** development of the world (including Thailand). In the earlier times, people across the world developed settlements and communities along the river banks, river islands and canals. This led to the creation of social norms across the world. For example, the practice of public participation in agricultural activities and water management emerged from the need to 'share' or to adopt a 'collective' approach to deal with the challenges of the times. The irrigation and water management practices therefore were embedded in a social contexts of human beings in each society.

- Water has been central to the creation of **cultural** heritages of countries around the world. It also helped to create national identities through many rituals and festivals; water festivals are famous in several Southeast Asian countries, for example. In addition, water is viewed as purity and has been used in holy ceremonies and religious practices around the globe. This became a foundation for a spiritual approach to water. Water resource have therefore been managed as a common-pool by the mutual belief-systems, in the form of cultural mythologies, worship and ceremonial practices, of members in each society.

- From **economic** perspective, water has been fundamental resource for expanding agricultural production and trade. Moreover, since the ancient times, rivers and canals have been used as a means for transport within and outside the cities around the world (including Thailand). The development of water-related technologies contributed to the success of Industrial revolution of the late 1700s. The expansion of trade was supported by irrigation and water development. The digging of canals, particularly in Thailand, helped to enhanced trade in commodities since the period of Ayutthaya Kingdom (beginning in the year 1351).

- In the realm of **politics** too, water has played an important role. For example, as people chose to stay and built their communities near water, states were formed as political units. After the establishment of the states, formal institutional arrangements such as bureaucracy, laws and regulations were developed in order to manage people and natural resources, including water resources. Water can also be a source of political conflicts. For example, constructing dams in trans-boundary area, such as Mekong River that share boundaries across several countries, or Chao Phraya basin in Thailand that share area with several provinces, often encountered protests from various groups in society. To deal with such conflicts, formal institutional arrangements get further entrenched.

In short, much of water management policies and practices in the earlier times were informed by the social and cultural contexts of water (i.e., its informal institutions). The later years however witnessed a complete transformation, with water being treated as an economic commodity supported by the rise of advanced technology and formal institutions. The rise of formal institutions in water management has resulted in a neglect of the role of informal institutions. Hence, failures in water management, and emerging water resource problems, this research argues.

CHAPTER 3 EVOLUTION OF THE WATER SECTOR INSTITUTIONS IN THAILAND

3.1. Introduction

While the previous chapter provided an overview of the socio-cultural context of water in global and Thai contexts, this chapter extends the discussion of the previous chapter, especially on the historical evolution of the water sector in Thailand, with a view to gain insights into the nature of changes that have taken place in its institutional settings, both formal and informal institutions. The focus of this discussion is to: 1) identify changes in key institutions that affected water resources management practices over the historical development of the water sector, 2) determine influencing forces that have shaped the water sector institutions, and 3) identify major challenges in the water sector. Further, the historical review in this chapter is conducted for two distinct periods: prior to, and post, establishment of the national planning body – the National Economic and Social Development Board (NESDB), which has been responsible for the formulation of development plans in accord with the national policy priorities since the early 1960s (NESDB 2018a). These development plans, known as the National Economic and Social Development Plans (NESDPs) provide the guiding vision for all sectors (including water sector), to develop and implement policies and management strategies for socioeconomic development of the nation. The establishment of NESDB represents a major transition in the planning paradigm in Thailand.

This chapter is organized as follows. Section 3.2 reviews the historical evolution of the water sector institutions in the period prior to the establishment of NESDB in 1961. Section 3.3 continues with the review of the evolution of water sector institutions in the years after the establishment of NESDB and the emergence of the era of formal planning as guided by NESDPs, from the first plan in 1961, to the current twelfth plan. The specific analysis in these time periods includes: 1) wider institutional environment[3] that govern

[3] The institutional environment refers to the external factors (that is, factors outside the domain of water sector) within which the water sector is governed and operated. These factors can have direct or indirect influence on the water sector, and are drawn from the Thai historical context in terms of socio-cultural beliefs, economic ideologies, political and bureaucratic structural changes.

the water sector, 2) organizational structure[4] of the water sector, and 3) policies, rules and practices in the water sector. Section 3.4 provides some further observations of the water sector institutions, in particular, the overarching issues that need to be addressed are highlighted. Finally, section 3.5 provides a summary of the major findings of this chapter.

Further, in view of the nature of discussion in this chapter, and its link with the discussion in the previous chapter, there are likely to be some repetition of select aspects already discussed in the previous chapter. This is ensuring ease of exposition, and to preclude repeated reference to the previous chapter

3.2. Water sector institutions: pre-NESDP period (before 1961)

3.2.1. Institutional environment

In most of the Thai history, particularly after the formation of the Sukhothai Kingdom (1238) to the early period of the Rattanakosin era (1857), water management was accomplished by moving people closer to or away from water sources as necessary or managing people to suit water conditions. For example, in several instances, people were moved to areas with enough water for rice production and away from flood-prone areas. This could be done easily in these times because there was plenty of land and seasonal relocation was compatible with military activity and wars (Sethaputra et al. 2000). The city-state of Ayutthaya was founded in 1350 and established its capital in 1351 on the Chao Phraya River in central Thailand. Nourished by red soil, fish-filled rivers and ponds and vast rice fields, the kingdom grew by crushing rebellions, conquering new kingdoms, and controlling more trade ports. The kingdom sustained an unbroken 400-year monarchical succession through 34 reigns, from King U Thong (1350-1369) to King Ekathat (1758-1767). During the Ayutthaya period water canals were widely used as a mean of public transportation. Royal families and government officials constructed homes along the network of canals radiating eastward from the palace and Chinese and Indian merchants built their shops and warehouses along the river to the south (Hays 2008). After the fall of Ayutthaya, Thonburi was established as the capital during the Thonburi Period (1768-1782). Thonburi was a fortress town set up on the delta at across

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[4] The term organizational structure refers to the entities that are responsible for policy development, policy implementation, and management of water resources and related-water activities. These include organizations that have been formally established under the national law or directives of local government, or informal groups that have been formed by common interests to manage water and related-natural resources.

the river from modern Bangkok. King Taksin turned to maritime trade to revive the destroyed economy, as income from taxes could not be counted on while people struggled for survival in the post-war situation (Hays 2008).

The Thai never lacked a rich food supply. Peasants planted rice for their own consumption and to pay taxes. Whatever remained was used to support religious institutions. From the thirteenth to the fifteenth century, however, a remarkable transformation took place in Thai rice cultivation. In the highlands, where rainfall had to be supplemented by a system of irrigation that controlled the water level in flooded paddies, the Thai sowed glutinous rice that is still the staple in the geographical regions of the North and Northeast. But in the floodplain of the Chao Phraya, farmers turned to a different variety of rice – the so-called floating rice, a slender, non-glutinous grain introduced from Bengal, that would grow fast enough to keep pace with the rise of the water level in the lowland fields (Hays 2008). Most of the times, in the Ayutthaya period, the country was relatively free from war and a stable production of rice for consumption and export was feasible (Sethaputra et al. 2000). The new strain grew easily and abundantly, producing a surplus that could be sold cheaply abroad. Ayutthaya, situated at the southern extremity of the floodplain, thus became the hub of economic activity. Under royal patronage, corvee labor dug canals on which rice was brought from the fields to the king's ships for export to China. In the process, the Chao Phraya Delta – mud flats between the sea and firm land hitherto considered unsuitable for habitation – was reclaimed and placed under cultivation (Hays 2008).

Water resource development for public use and related activities in Thailand becomes recognizable with universal and systematic formats in the reign of King Chulalongkorn (Rama V) of the Rattanakosin Monarchy. In 1902, His Majesty graciously established the "Canals Department" to be responsible for canal maintenance to prevent the shallowness and canal excavation in the suitable area for transportation and water storage for agriculture. It should also be noted that the European countries and Great Britain had a strong influence on national policies and large-scale project development. In particular, a Dutch expert on irrigation, Yehoman vander Heide, was recruited to study and undertake the irrigation project planning in Thailand. Later His Majesty graciously appointed him as the first Director General of the Canals Department of Thailand and then the construction of a diversion dam across the Chao Phraya River in Chai Nat Province was proposed. In 1914, in the reign of King Mongkutklao (Rama VI), an English engineer, R.C.R. Wilson, was appointed to be the Director General of the Barrages Department to develop irrigation works required for cultivation purposes (DRI 2018). The Thai culture and tradition, since the Ayutthaya period (1350-1767), viewed water resources as belonging to the king, who distributed them on an as-needed basis through a royal institution and later on a government agency (Sethaputra et al. 2000). In 1927, during the reign of King Phrapokklao (Rama VII), His Majesty graciously renamed of the "Barrages Department" as the "Royal Irrigation Department", and water resources development has continued to be the responsibility of this department until the present time (DRI 2018).

3.2.2. Organizational structure of the water sector

At the national level, at the start of the reign of King Chulalongkorn (Rama V) of the Rattanakosin Monarchy, His Majesty graciously established the "Canals Department" in 1902. In the reign of King Mongkutklao (Rama VI), His Majesty graciously consolidated the authority and activities of the "Canals Department" and established "Krom Thod Nam" or the "Barrages Department" in 1914. The Barrages Department began to develop irrigation schemes for cultivation purposes in conformity with the technical principles of modern engineering and implemented the South Pasak Irrigation Project by constructing a large-scale barrage across the Pasak river. It was then that the first barrage of Thailand was constructed in accordance with modern civil engineering principles and named "Rama VI Barrage" – located at Tha Luang sub-district and Tha Rua district in Ayutthaya province. Later, in 1927, in the reign of King Phrapokklao (Rama VII), the King held a view that the operations of the "Barrages Department" were not only to operate after diversion, but also canal excavation and water distribution, as well as water pumping for cultivated areas. Therefore, His Majesty renamed the "Barrages Department" as the "Royal Irrigation Department" (DRI 2018), reflecting that water resource still belongs to the King.

Most of the water management effort, particularly during 1875-1902, was canal digging (for example, the Rangsit canal network) and water regulation for agriculture and transportation. As the population increased, the later efforts concentrated on building reservoirs and expanding irrigation areas, especially after the "Barrages Department" was established in 1924. During this period, water was still so plentiful that wastewater was naturally diluted, and hence was not perceived as an issue. Irrigation and drainage schemes for agriculture and transportation were therefore the main focus of water management (Sethaputra et al. 2000).

3.2.3. Policies, rules and practices in the water sector

During the Ayutthaya (1351-1767), the Thonburi (1768-1782) and the Rattanakosin (from 1782 onward) eras, water was available for consumption, agriculture and transport without a charge. There were however specific policies and rules, decided by the King, to control the utilization of water for agriculture and canal transportation in particular areas or times. During 1875-1902 of the Rattanakosin period, the policies, rules and practices of water use and management were predominantly based on technical knowledge and practices brought by the European countries, Great Britain, in particular. Experts from these countries were recruited to take up the top positions in organizations responsible for water operation. Canal digging and barrage construction were the priorities for water supply activity of those organizations. Shortly before the First NESDP (1961-1966), Thailand's water resources development policy aimed to respond to the demand for water in agricultural and other economic activities by emphasizing supply-side management (Sethaputra et al. 2000). Even after the start of NESDP, no single framework for physical and budgetary planning for water has emerged in Thailand. Each government department and agency therefore has its own plans and programs which it is able to implement with relatively little requirement to coordinate effectively with other departments and agencies. Similarly, the private sector operates relatively free of planning restrictions or guidance (Krairapanond & Atkinson 1998).

3.2.4. Major challenges

In the pre-NESDB years, water resources in Thailand were abundant, more than enough for meeting all needs. Moreover, the country was sparsely populated, comprising concentrated activities in a few specific areas. Main agriculture was paddy production in low-lying areas, where water was plentiful and available for most of the year. There were no significant challenges for water management and use. During times of seasonal floods, when water was too much for rice farming, people with traditional knowledge could easily adapt their lives to such floods. However, from trade considerations, such floods posed challenges in terms of developing and managing the connectivity of internal water body through canal networks with international waters via maritime transport. It was fortunate though that during the Ayutthaya and Thonburi periods, the international trade, which employed maritime transport in connection with the domestic transport via canals, did not exceed the potential capacity of water transportation.

In order to better manage water resources, several laws, aiming to introduce water-use charges, were promulgated during these years. But it have proven extremely difficult to enforce these laws. For example, the Royal Irrigation Act, BE 2485 (1942) and its subsequent amendments allow the RID to impose a charge of up to \$0.02 per m^3 for farmers, as well as all other users. In 1975, the Royal Irrigation Act, BE 2485 (1942) was amended and updated, driven by three main considerations, namely: 1) irrigation activities have considerably expanded beyond agriculture, to include water use for manufacture, piped water service, industry and others; 2) the Royal Irrigation Act, BE 2485 (1942) itself cannot be enforced to collect fee from manufacturer, tap water provider and other activities; and 3) environmental conservation measures for irrigation-related activities needs to be paid for. It was therefore decided that an irrigation fee shall be collected from the owners of those activities or land owners in irrigation areas, even water users for agriculture outside irrigated areas. A fee of no more than \$0.90 $ha^{-1}yr^{-1}$ was recommended. The irrigation fees for manufacture, piped water service or other activities should not exceed \$0.01 per m^3. A fee collection system has been implemented for some activities, for instance, piped water service of the Provincial Waterworks Authority (PWA). The other activities that consume a lot of water from irrigation facility such as golf courses have not yet been subjected to the payment of a fee for water usage.

3.3. Water sector institutions: post-NESDP period (1961-present)

3.3.1. Institutional environment

Thailand has a very centralized government structure and a rather decentralized societal structures. The “Plan and Process of Decentralization to Local Government Act, BE 2542 (1999)” and the local government organizations (e.g., Provincial Administration Organizations (PAOs), Municipalities, Sub-district Municipalities) have been in place for a considerably long time now. Further, these organizations have been given considerable autonomy. But they have not succeeded in implementing their mandates because of central government interventions which are oftentimes driven by ‘central’ consideration and are oblivious of local government needs and issues. A rather large number of government agencies, under different ministries, are involved in water resources development, use, management and administration (Das Gupta & Babel 2003). The institutional landscape for water resource management is governed by at least 34 department-level agencies, under 9 different ministries, with an annual budgets in the range of $1,447 and $2,026 million. Further, water resources are administered and managed with different priorities and programs that sometimes overlap or are in conflict. The irrigation projects of all sizes that are handled by the Royal Irrigation Department sometimes lack proper management of water delivery and this makes a change of priority in irrigation development difficult. Most of the irrigation system is designed to serve the needs of rice farmers in the central region. Large-scale and medium-sized irrigation systems do not adequately meet the current requirements of competitive mixed farming and contract farming linked to agro-industries and to competitive global export markets in all regions. At the same time, the differences in soil and hydrology conditions in the various regions have resulted in inefficient water delivery for irrigation. The irrigated areas are not fully utilized, especially in the dry season. It is estimated that the cropping intensity of irrigation projects is 70 percent in the wet season and 30 percent in the dry season (Boon-Long & Christensen 1994). During 1989-2003, drought affected 134 million people and 7.36 million ha of agricultural land, costing $140.63 million (an average of approximately $10 million per year) (Nikomborirak & Ruenthip 2013).

The Royal Irrigation Department (RID) has played an integral part in instituting modern practices of water management since its establishment in 1927. The main role of RID was to provide water for everyone. In fulfilling its duties, the RID has been guided by river basin management practices in the United Kingdom and watershed management practices in the United States. Consequently, it has endeavored to implement basin-based integrated water resources management practices, involving participation by all relevant sectors – to achieve efficiency, equitability and sustainability (DRI 2018). The RID has however largely failed to achieve its goals, notwithstanding its noble intentions and effort. Consequently, most irrigation projects have been formulated mainly to solve only specific problems, often with little regard for the concept of basin or sub-basin-wide issues.

Some problems have been found from the very start in water resources management at the river basin level. First is the problem of management mechanism at basin level. Unclear policy, legal and institutional framework governing basin areas makes it difficult to effectively implement sound basin management concepts and practices. Inadequate and sometimes conflicting legislation is also a problem. There are numerous agencies involved in basin management, and none has clear responsibility for basin management and development. Second is the problem of participation of stakeholders. The current process of project identification and formulation by line agencies has proven to be unacceptable to the local population and other stakeholders, who demand more information from line agencies and greater participation in the decision-making processes. Many large-scale projects do not go through this public process and hence cannot proceed. There are some issues that line agencies need to consider to reshape their approach. Third is the issue of involvement of stakeholders in the development process. All public water projects are intended to serve the interests of, and benefit, the users, though they may have adverse effect on some other groups or resources. It is therefore important to seek the opinion of all concerned parties or stakeholders, to get them involved from the early stages of project formulation and to continually consul them throughout the development process. This will certainly constitute a big change for line agencies. On the other hand, the stakeholders have to adopt a more cooperative and objective stance and be keen to compromise, instead of letting outside influence overshadow their real interests, as has occasionally been the case. Fourth is the issue of conflict management. With more democratic practice of public involvement in water resources development, many conflicts happen during public hearings or consultations. The conflicts centered on environmental issues, compensation for those affected by the projects and demands from interest groups. Currently, there is no effective mechanism for conflict management, in the form of either institution, legislation or procedure. As competition for water will no doubt increase in the near future, conflicts will multiply; thus, conflict management is a necessity. Finally is the issue of sense of ownership and sharing of responsibility. As long as water is freely accessible and the government provides all water resource projects free of charge, the users or beneficiaries do not appreciate the projects and have little sense of ownership. The general feeling is that if it is a government project, then it belongs to the government, so let the government take care of it; people do not feel responsible for the upkeep of such projects (Boon-Long & Christensen 1994; Das Gupta & Babel 2003).

At the same time, the problem of unrealistic water allocation also exists, especially in the dry season when the water supply is limited. Besides, with the exception of small-scale projects in which local people are involved at the inception, the current process of water resources development through projects has proven to be unacceptable to local people and other stakeholders, as they need more information and more participation in decision-making. The implementing agencies need to be responsive, but they have to follow their own procedures, evolved to facilitate operations, as well as to comply with important regulations such as the Private Irrigation Act, BE 2482 (1939), the Groundwater Act, BE 2520 (1977), the Dykes and Ditches Act, BE 2525 (1982), and the State Irrigation Act, BE 2535 (1992) (Boon-Long & Christensen 1994).

To improve efficiency and increase stakeholder participation in water resource development projects, these acts need to be amended. Moreover, the national water law, which will be the key framework for overall water resources management, needs to be approved and promulgated. Under the RID's mandate, ironically, it have very little effective authority to enforce its policy through other government agencies. Instead, the RID must honor the supply (water allocation) requests by other agencies, in accord with the inter-agency informal agreement between RID and PWA, the Metropolitan Waterworks Authority (MWA), and the Electricity Generating Authority of Thailand (EGAT). The RID's water allocation priorities, especially for the central Chao Phraya river basin, are to supply the MWA, to flush out wastewater and saline water and to nurture agriculture, mainly for paddy fields (Boon-Long & Christensen 1994). It is a fact that as the stress of water resources augmented, the supply-oriented and government-subsidized water management policy of the past is no longer acceptable. The government agencies concerned should institute a system of demand-side scrutiny for different stakeholders; these agencies should then implement policies and measures to promote a sense of "water conservation" among all the water users. In this process, demand-side management should become an integral component of water management and an integral part of planning and design phases (Das Gupta & Babel 2003).

3.3.2. Organizational structure of the water sector

It is widely accepted that water resource management is a conflict-ridden exercise, and required effective co-operation among government agencies and other stakeholders (Grigg 2016). In the case of Thailand, there is a habitual lack of effective coordination among the numerous concerned government agencies, and therefore the application of new rules and regulations once they are established becomes extremely difficult. In essence, the relationships among various agencies are ad hoc, episodic, and often erratic, responding to shifts in the water supply (availability), the emergence of bottlenecks and clamor by interest groups seeking access to water (Boon-Long & Christensen 1994).

Overlapping mandates and coordination problems arise from the fact that water-related agencies, including line agencies, are not legally obligated to inform other agencies of their activities. The lack of clearly defined property rights among public agencies themselves leads to competing claims and creates bottlenecks for the government. For instance, the RID is water supplier, EGAT is either water supplier or user, while MWA, PWA and the East Water are water users and water seller organizations (EWB 2016; PWA 2016, 2019).

For example, there is fierce competition for water utilization in the Chao Phraya river basin – among RID, EGAT and the MWA. In addition, Thailand is currently experiencing a significant lack of institutional capacity to address water supply bottlenecks and market failures. The command-and-control philosophy of the public sector is proving to be inadequate for effectively dealing with water allocation problems. Moreover, the current institutional framework is incapable of applying market-based instruments, such as pricing policy (Boon-Long & Christensen 1994), to deal with water allocation problems. There is also currently very little coordination on water allocation decision-making between the RID and other departments either within or outside the Ministry of Agriculture and Cooperatives. The decision-making for water allocation has not taken the form of a formal law which mandates the RID to comply. Instead, the water allocation decisions follow the exigencies associated with the policy proclivity of the government (or political party) in power, the stipulations of NESDPs, and the prevalent situation of water demand. The inter-agency allocation decisions will then, at best, compromises to suit the prevailing situation (also see, Boon-Long & Christensen 1994).

Besides the RID, there are several agencies responsible for implementing small-scale water development projects. For example, the Department of Energy Development and Promotion manages the pumping schemes and the Department of Mineral Resources manages and controls the use of groundwater. Other agencies also take part in small-scale project implementation; they usually have their own work plans and do not coordinate their activities with other concerned agencies (Boon-Long & Christensen 1994). In order to address these problems at the national scale, a coordinating body, namely, the "National Water Resources Committee (NWRC)" was created in 1989, by regulation, by the Office of the Prime Minister – with the intention to serve as an apex body for setting up policies and plans for national water resources development and management. The NWRC was given the task of coordinating concerned agencies in planning and systematizing the information system required for facilitating the effective management of water resources. However, this goal has not been achieved because the NWRC lacked the status of a permanent organization and recognition. In 1996, therefore, the Office of NWRC was legally set up under the Office of the Prime Minister to coordinate water resources management activities among concerned agencies, and support improved information, policy and planning for water management (Biltonen 2003; Das Gupta & Babel 2003).

Over the year, the NWRC has come up with several directives, measures and programs for water resource development and management. These have however not been based on any coherent blue-print for water-resource development and management, and hardly any targets for achievement have been set. Various concerned agencies have therefore continued to carry out their operations, year after year, with little or no change; moreover their plans have been subjected to intense political lobbying. The 25 basin preliminary plans have therefore not been of much use and there has been no follow-up study to formulate a long-term plan and targets of development (Das Gupta & Babel 2003). It is also apparent that there has been no coordinated effort to carry out studies, or to prepare a master plan, as has been the case of the World Bank-funded NESDB study of the Chao Phraya river basin and the Chao Phraya river basin management study of the RID, which had more or less the same objective. With better coordination, some budget could have been saved (WB 2011). However, NWRC, with the support of the Office of NWRC and NESDB, has started to implement water resources management through the basin-level approach. The subcommittee for the establishment of a Chao Phraya river basin authority was set up in 1998. Since then, the pilot implementation of a sub-basin authority was started in three priority sub-basins of the Chao Phraya basin, namely, the upper Ping, lower Ping and Pasak. The corresponding sub-basin committees were established by NWRC at the request of the Cabinet. Each committee consists of all involved parties, such as representatives of the local government, local community, local people's organizations, etc. Its duties are information collection, local project formulation and approval before submission to NWRC, and resolution of local conflicts about water issues (Boon-Long & Christensen 1994).

3.3.3. Policies, rules and practices in the water sector

Water policies, rules and practices since 1961 have primarily been driven by the NESDPs. These NESDPs are therefore reviewed and discussed in this section, from the first NESDP (1961-1966), to the twelfth NESDP (2017-2021). The summary of all twelve NESDPs that are relevant to the water sector is provided below.

The 1st NESDP (1961-1966)

During the early stage of development (during NESDP 1), there was no formal policy and regulation for the water sector. Building new infrastructure was viewed as a prerequisite to developing the economy. Natural resources, particularly water, forests and land, were exploited for all aspects of development. Water management practices did not follow any specific plan, rather they were embedded in the NESDP in an ad hoc manner, primarily in terms of budget allocations (of approximately $140 million) for large irrigation construction projects, particularly Mae Klong, Chao Phraya and Bhumibol dams in Central Thailand (Sethaputra et al. 2000). Since the purpose was to expand water access, there were no criteria to develop these projects.

The 2nd NESDP (1967-1971)

Water resource development and management continued to be emphasized in this plan, in order to meet increasing demand for water be several end-uses. As the arable area expanded rapidly to fulfil domestic and foreign demand for agricultural products, investment in irrigation projects grew rapidly and some projects were started to expand the newly irrigated areas, such as the Nan and Nam Un projects in the upper Chi and upper Mun watersheds, the large Mekong development project and the Sirikit dam. The overall target was to expand the irrigated area to 2.4 million hectare by the end of this plan. The investment budget of this Plan was significantly higher (nearly $400 million) than for the 1st plan (Sethaputra et al. 2000). Again, there were no specific criteria to develop these projects.

The 3rd NESDP (1972-1976)

Water management policy was still not a cohesive policy during this plan-period; it was, as in the case of first two plan-periods, subsumed in broader NESDP. During this plan, irrigation was given priority and further expanded to facilitate the development of agriculture. Water resources were developed through a project-based approach, with emphasis on bringing ongoing projects to completion and fully utilizing existing irrigation systems. However, new projects had to be meticulously considered to meet anticipated a significantly higher demand for water for development in the future. In the irrigation sector, the Upper Chao Phraya project, for instance, was prepared for optimal use of the irrigated area. Budgetary allocations for irrigation development amounted to about $330 million (Sethaputra et al. 2000).

The 4th NESDP (1977-1981)

During the 4th NESDP, water resource deterioration had emerged as a pressing issue that urgently needed a serious consideration. The NESDP therefore placed emphasis not only on supply management (with a $800 million budget), but also on rehabilitation. In addition, the necessity for a single master plan for water resource development and management was obviously realized during this period (Sethaputra et al. 2000). Notwithstanding this realization, no concrete measures were taken to formalize water policy and regulation during this plan-period.

The 5th NESDP (1982-1986)

The 5th NESDP took seriously the problem of water shortages and need for proper management of water allocation and for more efficient use of water resources. Besides large-scale and medium-sized irrigation projects, small-scale projects were undertaken to supply water for domestic consumption, especially in villages, in order to raise the standard of living of poor rural people. During this period, water resources development was implemented by several agencies, including, RID, EGAT, PWA, MWA, the Community Development Department (CDD) and the Land Development Department (LDD), which had responsibilities to provide water for household consumption, industry and farming. While there was no master plan for water resource development and management (Sethaputra et al. 2000), the widespread deforestation triggered the development of a system of watershed classification for the entire country. This classification system aimed at formulating land use plan for the conservation of natural resources, in particular sustainable use of water resources.

The 6th NESDP (1987-1991)

It was in this NESDP period that the first policy guidelines for all concerned agencies, to prepare a water resources development plan at the basin level, were developed. These guidelines were intended to spread small-scale water resources development throughout the rural areas; encourage people-based organizations to play a greater role in water management; maintain existing water development projects and develop the information system that could be shared by the relevant agencies. However, the guidelines were not implemented completely and most agencies continued with the project-based approaches, without any effective coordination between various aspects (Sethaputra et al. 2000).

The 7th NESDP (1992-1996)

At the beginning of this NESDP, the National Research Council of Thailand (NRCT) produced a draft of its own version of the new Water Act. Shortly after, the Pollution Control Department (PCD) commissioned the Faculty of Law of Thammasat University (TU Law) to draft an alternative "Water Resources Act". Under the NRCT draft, water remained an "open access" resource, and it treated Thailand's water problem primarily as an administrative problem, which should be addressed with a more practical coordination of bureaucracy. The TU Law draft, on the other hand, proposed a market-based permit system for both water consumption and disposal. Its requirement was a permit for all water users, except for domestic consumers serviced by public piped utilities, and for discharging effluent. Under this proposal, water users may transfer or sell their water rights to other users, and wastewater rights may also be traded freely in the market. The TU Law draft also proposed the creation of the "Ministry of Water Resources". None of these recommendations were however submitted to the parliament for further deliberation (Boon-Long & Christensen 1994).

Since the 6th NESDP period, Thailand's government had formulated several water management policies and plans. Due to the complexity of water-related problems, such policies and plans however proved to be ineffective in terms of responding to new conditions and limitations of government agencies dealing with water issues. It is also evident that no single decision-making mechanism for water policy development and planning emerged during this period, at the national, sectoral, or sub-sector levels (Boon-Long & Christensen 1994).

The 8th NESDP (1997-2001)

At the beginning of the 8th NESDP, the 1997 Constitution was enacted. Under this constitution, the right of citizens to information and participation in regional and local development programs was stipulated. This meant that all stakeholders should participate in the development and management of public projects. Further, the "Water Act" had been drafted where roles of the river basin and sub-basin management authorities are clearly defined. A key role of these authorities was to participate in the identification of water-related problems in the basin, and to formulate solutions, supported by appropriate projects or programs, for the agencies and government to consider and act upon.

As this idea was new and has never been put into practice in the country, the Chao Phraya river basin (comprising eight sub-basins) was selected as a test case to provide policy makers with a comprehensive water management strategy. The study resulted in developing strategy in six areas, namely, institutional management by establishing a Chao Phraya River Basin Organization, supply-side management, demand-side management, water quality management, flood management, and legal management to support the implementation of all strategic orientations. The aim of these strategies is, in essence, to establish a systemic management of water resources at a basin level with participation of all relevant stakeholders.

The outcome of this test-case was however not as expected. The implementation of the six-pronged strategy in the Chao Phraya river basin was hampered by the combination of inefficient enforcement of public regulations, and the continuation of a top-down, centralized, approach in water resource development and management. Except for the small-scale projects, where there are participation from stakeholders at the local-level, all medium- and large-scale projects are driven by the central planning authorities. For these latter type of projects, the inputs from the locals are considered only at the project initiation stage. After this stage, the development and management of water resources are based purely on hydrological and technical information, without consideration of the social side. Moreover, there is little coordination among related agencies, resulted in overlapping of projects in the same areas. These phenomena occurred because there was no comprehensive plan of water management of the national river basins (Das Gupta & Babel 2003).

The 9th NESDP (2002-2006)

It became evident, halfway through the implementation of the 8th NESDP, that the application of the basin approach to water resource management and the establishment of a river basin authority were still in nascent stages and the water resource management problems are worsening rapidly. Therefore, in the 9th NESDP, priority were given to the following issues (Sethaputra et al. 2000): shifting from supply-side approach to demand-side approach; a basin-wide water management strategy to substitute the project-by-project approach, by integrating institutional, policy, legal and technical domains to provide guidance for the systematic development and management of basin water resources; water to be traded as a commodity by using incentives, regulations, permit restrictions, and penalties to guide people to use water efficiently; use economic instruments (particularly cost-recovery mechanisms) to alleviate protracted water crises; establishment of institutional framework for water administration, underscored by user participation in water resource management; and to encourage the private sector to play a more important role in water resource management.

During this period, government organizations were restructured, at both department and ministry levels, following the issuance and enforcement of the Reorganization of Ministry, Sub-Ministry, and Department Act, BE 2545 in 2002 (OCST 2017). The Ministry of Natural Resources and Environment was established, under which two new departments responsible for water resources were attached, namely, the Department of Water Resources (DWR) and the Department of Groundwater Resources (DGWR). The DWR was responsible for all water resource planning and management decisions in coordination with all agencies formerly involved in the water sector (DWR 2018). This role was previously undertaken by the RID, who would now assume the responsibility for the operation of water projects under the Ministry of Agriculture and Cooperatives.

In spite of these changes, it was observed that a large number of agencies continued to be involved in the implementation of various projects; and data and information on water resource development was scattered and disorganized (Das Gupta & Babel 2003). Additionally, information on water resources was not adequately shared between agencies and with water users. There was little involvement of water resource stakeholders in the management decision process (Biltonen 2003). This made it difficult to establish plans for efficient water resource development and management. These conditions reflected deeper management problems, than just coordination problem alone (Das Gupta & Babel 2003). It was also evident that the primary problem of the water sector in Thailand was sectorial conflicts between agricultural, urban and industrial consumption; in the recent past, problems and conflicts between urban and industrial sectors became heightened too. These conflicts were faced primarily in the Central Plain's main river basins (mainly, the Chao Phraya, Mae Klong, Bang Pakong and Thachin), which is the major agricultural production area, and home to several large urban centers and industrial complexes (Biltonen 2003). In addition, large and medium scale water resource development projects were planned and implemented by line agencies in various ministries, and the process started and ended mostly with the direct involvement of civil servants. Public hearing sessions were almost always arranged at the end of the project feasibility study, to inform the general public and affected stakeholders of the objectives and scope of the projects, and the benefits envisaged from the implementation of the projects. This top-down approach proved to be largely unacceptable as local communities and other stakeholders were not involved in the decision-making process at different phases of the project (Das Gupta & Babel 2003).

The 10th NESDP (2007-2011)

Since the early 2000s, several attempts had been made to formulate the draft Water Resources Act. However there was no appreciable progress on this front. The major flood in 2011, that caused severe impact on all sectors (and a damage of about $42 billion, according to the WB (2011) and GISTDA (2012)), appeared to have changed this stance. The reformulation of Water Resources Act and an immediate restructuring of government agencies overseeing the water issues was recommended. After the severity of the great flood had receded, the momentum for reforms faded and phased out of public interest.

The 11th NESDP (2012- 2016)

The government responded to the 2011 floods with measures to strengthen flood management and recognized that flood management must be closely linked with broader issues of water resource management. The Master Plan on Water Resources Management (approved in January 2012) called for an integrated approach to investment in water management related projects so that each investment project is prepared, appraised, implemented, monitored and evaluated on the basis of Integrated Water Resources and Flood Management principles, following a standard set of project guidelines (ADB 2016).

The country experienced severe drought in 2013, with more than 10% of total villages in the country lacking water for household consumption (LDD 2013). The RID had to introduce stringent quotas on water use for agriculture (DRI 2015; DWR 2015). In 2014, the Cabinet approved guidelines and mitigation measures to mitigate drought impacts, with a budget of $75 million (DWR 2015). Despite the presence of large water storage infrastructure, relative to the world standards, and the existence of irrigation scheme that is ranked number eight in the world, the country experienced drought. This, it is argued, was due to ineffective management of agricultural water usage, and production and marketing of agricultural products, also resulting in high cost of production and low yields (Piampajjai & Tancho 2015).

The National Council for Peace and Order (NCPO) assumed political control in May 2014. It (i.e., NCPO) initiated a review of all water management schemes of the previous civilian governments (Funatsu 2014). It also started serious discussions on the need for reforms in water management and administration system of the country. However, with the exception of the very broad and general NESDP, there was no other policy framework for physical and budgetary planning in Thailand. Each government department and agency had its own plans and programs which they implemented with relatively little coordination with other departments and agencies. The then current policy and planning, with top-down approach, had proven to be ineffective as local communities and other stakeholders were not involved in the decision-making processes at different phases of the projects (Das Gupta & Babel 2003). The DWR soon revoked and refined the draft Water Resources Act, based to some degree upon the two previous drafts of the NRCT and TU Law proposed in the 1990s. The other two drafts that were proposed in parallel with DWR's are those of the "National Reform Assembly" and the "Office of Law Reform Commission of Thailand" or the so called "people choice". In the meantime, the Prime Minister, in his capacity as chief of the NCPO announced that the National Water Resources Board will soon be established for a better management and administration of water issues (Nanuam & Theparat 2017).

In July 2014 however the NCPO issued an order to appoint the Water Resource Management and Policy Development Committee to frame the national water management policy. This Committee developed the "Water Resources Management Strategic Plan 2015-2026" which aimed to unify, integrate and resolve all aspects of water resources, including water shortages or droughts, floods and water quality (DWR 2015). This strategic plan, however, has not yet been endorsed by the Cabinet due to the incompatibility of its implementation period with the 20-year National Strategy 2018-2037, developed by the Cabinet. The DWR is currently refining all details of the Water Resources Management Strategic Plan 2015-2026, as well as extending its timeframe of implementation to 20 years in order to fit with the 20-year National Strategy.

The 12th NESDP (2017-2021)

In August 2017, the Prime Minister and Chairman of the National Water Board announced that the Office of the National Water Resources (ONWR) will be established under the Office of the Prime Minister (OPM 2018). This will enable a more efficient coordination between various water-related agencies responsible for storing, diverting and draining water – the three core functions of water management (Nanuam & Theparat 2017).

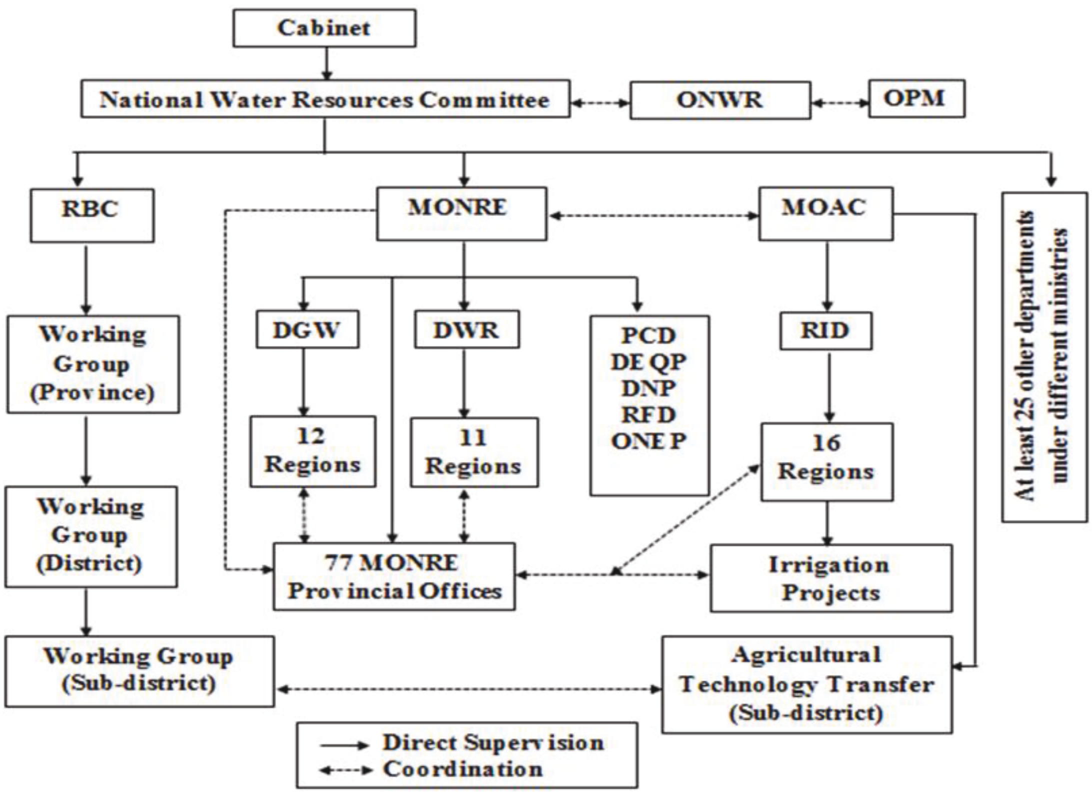
This will also – it was argued – improve the efficiency of water services, reduce operational costs, and facilitate policy implementation. Negotiations to incorporate other water-related agencies into the Department of Water Resources (to become ONWR) have been underway for some time now. The key constraints of water management therefore still remain unresolved, and multiple government agencies, with overlapping legal mandates, still exist (Nanuam & Theparat 2017).

Currently, all relevant personnel and projects (from RID and DWR) are being mobilized and transferred to ONWR to facilitate the logistic and administrative process of ONWR. At the same time, the institutional mechanisms and the line of command of about 38 water-related agencies have been reformulated in consultation with ONWR and its committees at national, regional, provincial and local levels (Figure 3-1). It implies that several committees, agencies and stakeholders will be involved in IWRM and their effective cooperation will be critical. The institutional structure of IWRM comprises ministries and agencies responsible for policy, planning, and implementation at the national level and local agencies responsible for local operations. National and sectoral committees have also been established for policy decisions (WB 2011). The 25 River

Basin Committees (RBCs) are the key decision makers while the ONWR is the leading agency overall (Figure 3-1).

This development (i.e., establishment of ONWR) could indeed be an effective mechanism to improve the water management and administration in Thailand. Its success will however require high level policy perspectives and a thorough understanding of water issues, and the will to resolve conflicts and disagreements about financial (budget) and human resources. It is doubtful that such perspectives, understanding and the will (to resolve) will actually be realized. Although the functions of the new agency are clear and consistent with the latest draft of Water Resources Act, BE 2561 (2018), they are however not amenable to a smooth transition into desired action. It might also be too ambitious to expect that the ONWR, which will be the national focal agency for an overall water policy, will be able to effectively manage and administer the policy implementation, action and operation of all water-related agencies.

Figure 3-1 Institutional structure of water-related agencies



Source: Krairapanond (2018)

The NWRC is responsible for providing policy direction regarding water resource management in Thailand. The committee is composed of representatives from several agencies, local governments, non-governmental organizations, and experts. The NWRC appoints RBCs responsible for planning and supervision at watershed or basin levels. There also exists other national committees, established by other sectors, the most relevant being the National Environment Board and the NESDB (WB 2011). However, the watershed committees do not specify the decision-making criteria and conditions for their authority; it thus creates the opportunity to incorporate diversity into strategies for water management and administration in each of 25 river basins (DWR 2017). The watershed committee of each basin should also be capable of reflecting on the real needs of stakeholders and communicating with the NWRC. It is expected that the watershed committee will strengthen the participation process and unify water management within its own watershed and adjacent watersheds (DWR 2015). The Master plan on water resources management in watershed area, which needs to be approved by the National Water Resources Board, is formulated for normal and critical conditions. In a critical situation, the watershed committee will make decisions, and take action, according to the guidelines stated in the plan. Water utilization and allocation activities will also be developed, and the priorities, criteria, methodology and conditions of water use within the watershed will be established (DWR 2017). The interaction activities associated with intensive upstream and downstream developments will be effectively dealt with in the unified planning framework (Krairapanond & Atkinson 1998). Therefore, in early 2018, the Watershed Management and Administration Division, under the newly established ONWR, was assigned to facilitate the implementation of watershed classification. This Division is responsible for the administration of all 25 river basins in Thailand (Figure 3-1). It also includes the Command Centre for Water Resources and Geographic Information System for water management, which is responsible for monitoring and evaluating water situation and trends (Prajumwong 2018).

3.3.4. Major challenges

The discussion in the previous subsections (3.3.1-3.3.3) show that water sector institutions have undergone considerable change over the past 50 years (that is, since the beginning of the NESDP period). However, the management and administration of water resources in the country remains beset by a number of challenges. The key such challenges are discussed as follows.

1) *Lack of a prevailing philosophy for water allocation*

Apart from the requirement of equitable and fair distribution of water among the stakeholders, governance, economic performance and environmental quality are crucial challenges confronting water resource management (Lautze et al. 2011). Water resource management must inevitably engage multi-objective trade-offs in multi-disciplinary decision-making processes. However, the traditional institutional framework for water resource development in Thailand involve several government agencies. The different state of water supply and demand, and different potential, across the 25 river basins and watersheds inevitably imply different objectives and targets to fulfil people's needs. Therefore, the national water vision has to consider, in the Strategic Plan on Thailand's Water Resource Management 2015-2016, people's needs in every watershed. It is indeed fortunate for the country that the formulation of the national water vision is coinciding with the implementation of the 2017 Constitution aimed at shaping the country's future. The Constitution calls for public participation and partnership in all national development endeavors. The lack of adequate data and information-based decisions and trained personnel may however preclude the development of acceptable universal water allocation principle. This can further aggravate the decision-making processes for water management.

The establishment of the ONWR, under the Prime Minister office, to oversee the overall national water policy should contribute to effective water governance, into its management and administration. The government agencies, especially ONWR, should therefore seriously promote the expansion of a small-scale development programs launched in the 1980s with the aims of improving the living conditions of the people in poor rural areas and of reducing income disparity. Increased emphasis should be placed on the issue of equitable water allocation for all water-using sectors – to fulfil basic water requirements for agriculture and domestic purposes. This will involve establishing efficient and sustainable water usage priorities for each river basin supported by clear water allocation criteria, incorporating cost sharing by the beneficiaries, based on their ability to pay and level of services. Water resources for agriculture and rural development should be a strategic priority, first for promoting economic growth, by efficiently using the existing irrigated areas and developing new areas wherever possible; and, second, for rural development in rain-fed agricultural areas – by promoting more small-scale projects and appropriate technology such as rainwater harvesting, including the royally initiated 'New Theory' projects.

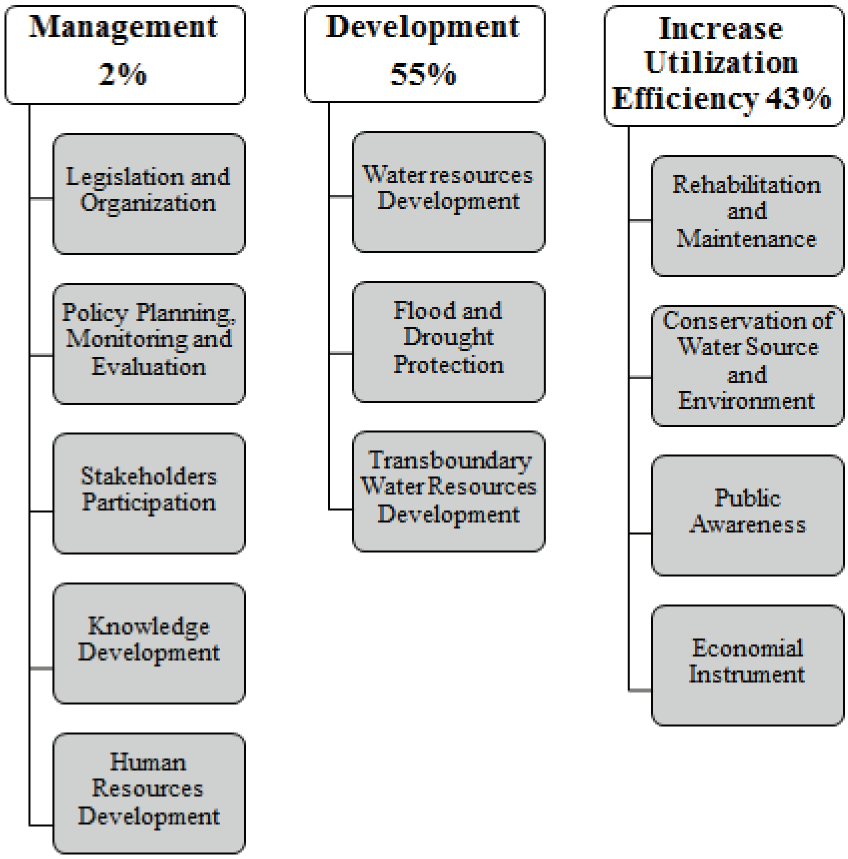
2) Existence of too many water-related agencies

There are more than 38 department-level agencies (including the newly established water leading agency – ONWR) that are involved in water policy making and implementation in Thailand. This has resulted in overlapping mandates and responsibilities, with each agency operating under its own legal framework. The Field Dyke and Ditch Act, BE 2505 (1962) and the Land Consolidation for Agriculture Act, BE 2558 (2015), for instance, authorize the RID to impose charges on land owners and other farmers for operation and maintenance, and for capital costs for land improvements. According to the Groundwater Act, BE 2520 (1977), the groundwater use fees must not be higher than that of tap (piped) water applied in its locality or in the vicinity of its province. However, the groundwater charge is waived for household consumption (OCST 2004). Further, it is argued that the newly established Department of Groundwater Resources (DGR), which oversees groundwater development, utilization and conservation, lacks the administrative capacity to issue licenses or permits to all users and to enforce the charge on the industrial sector. In practice, the actual subsidy paid to farmers in the form of charges waived or deferred has depended on farmer's ability or willingness-to-pay. It is designated in the Groundwater Act, BE 2520 (1977) and Groundwater Act (No. 2), BE 2535 (1992) that person who wants to drill a groundwater well, to use groundwater, and to release water into a groundwater well, has to submit the application for a license costing approximately $30 (OCST 2004). It should be evident that the enforcement and collection of groundwater fee for such activities pose no serious challenge, especially when compared to what given in the Royal Irrigation Act, BE 2485 (1942). One reason why the groundwater may not be readily available resource for use is that the lack of technical expertise and experience with high cost-equipment and its operation.

3) Unbalanced budget allocation in the water sector

Historically, budgets have favored infrastructure development rather than efficiency improvement, although there is widespread recognition of the need for funds for improving the efficiency of irrigation schemes. Most large-scale water resource development projects in the country were constructed between the 1950s and 1970s, and the area served by these projects was only about one-fifth of the total cultivated area. A large number of farmers still do not have access to irrigation water. As also noted above, overwhelmingly large proportion of government budgets went for the development and provision of water, and significantly less on increasing efficiency of the existing water use, and an even smaller amount allocated for management activities. In 2001, for instance, the percentages for development activities, increasing efficiency of the existing water use and management activities were 64, 35.9, and 0.1 percent, respectively, and in 2002, they were 70.9, 28.9, and 0.2 percent, respectively (Das Gupta & Babel 2003). In the last 10 years, average allocation of budget for development activities decreased by 55 percent, while that for increasing efficiency and management activities, by 43 and 2 percent, respectively (Figure 3-2).

Figure 3-2 Water sector budgeting and allocation



Source: Krairapanond (2018)

The Secretariat of the House of Representatives reported that this particular budget approved by the Cabinet was allocated every year to manage the flood and drought situation in Thailand (PBO 2016). For example, urgent budget for flood and drought relief in fiscal year of 2012-2013, and in 2014-2015, was about $1,570 million. This kind of approval of the Cabinet budget (under the Prime Minister's authority) reflects that the government has not yet been able to efficiently manage and administer water resources. There is an opportunity however that, under the newly created agency (ONWR), all implementation activities of water-related policy and planning, including budget allocation, would be efficiently integrated and executed within a single national umbrella (ONWR).

4) Disintegration in the development and management of water sources

Large quantities of water is needed to support economic growth and population increase. Several people are involved in water resource management, leading to conflicts, especially during the dry season. In recent years, many socio-economic activities have faced water shortages, especially agriculture, and domestic consumption during the dry season. In the case of agriculture, which consumes about 80 percent of total water supply, the demand for irrigation is estimated to increase at least about 6 percent per year due to the need for augmenting irrigated area. Overall, however, the share of water available for irrigation is declining due to the competition for water from other sectors. This point to more serious future water shortages in agriculture. It is well-known that the Chao Phraya river basin, which is the largest and the most important basin of the country, faces most serious water shortage problems. The high population density and intense economic activity in the basin has contributed to high water demand. The Lower Chao Phraya project, in the Chao Phraya river basin, is a good example of a wrong decision: it has resulted in water shortages preventing cultivation of the irrigated areas during the dry season.

At the same time, the adverse impact of large dam projects on the environment is widely acknowledged in the country these days, putting a damper on new, large water development projects. All the more reason, then, for people from all sectors coming together to draw the national water vision in order to avoid conflicts of water usage in the future. A study by NESDB (2012) found that there is no more potential for large dam construction in the main river basin such as the four watersheds of northern region, and the Chao Phraya river basin or in the adjacent Tha Chin river basin. Also, new water development projects now have to address environmental issues, and many are unable to do so, seemingly for failure of considering these issues at the planning stages. The setup of ONWR and the promulgation of Water Resources Act, BE 2561 (2018) should, to some extent, provide the government an opportunity to improve water management and administration, through effective decision-making. For instance, clear directions for the provision and development of raw water of suitable quality, compatible with the potential and demands of each river basin, should be identified, while ensuring conservation of natural resources and maintenance of the environment. In order to respond to water demand for sustainable agriculture, and for domestic consumption, raw water sources for farmers should be provided extensively and equitably, similar to the delivery of other basic infrastructure services provided by the government.

5) Sensitive to political intervention

It has been observed in the recent years that the water sector has increasingly being interfered by politics, especially in flood and drought mitigation. Such political intervention, according to the party interests, have detrimentally affected the people and economy of the country. It is evident that Thailand faces a major challenge of containing damages caused by droughts and floods; such damages have reached serious levels in the last 10 years and efforts are being made to mitigate them (WB 2011). In the 30-year period, 1972-2011, almost all (77) provinces of Thailand experienced 13 events of floods, including the great flood of 2011 (DWR 2015). During the last quarter of 2011, Thailand experienced its worst flooding since 1942, which caused drastic damage to life, assets and economy, amounting to approximately $42 billion (DWR 2015). The floods affected more than 3.95 million households (Dhebpunya 2017), and almost 14 million people in 65 of 77 provinces with widespread damages and loss to homes, factories, businesses, transport and energy infrastructure, social service facilities, and crops and livestock (ASEAN Secretariat 2017). The contrasting concepts over "who" and "how" to manage water resources were, and remain, the main conflicting points between the bureaucrats and politicians. There is emerging concern that newly elected government may not support unified water management planning and decision making processes led by a single-command agency lacking in transparency. Therefore, a strong consensual government, and a reliable data and information system, are crucial for dealing with political conflicts, and to effectively implement the new water resources Act BE 2560 (2018) and the Strategic Plan on Thailand's Water Resources Management 2015-2026.

3.4. Water sector institutions: some further observations

Analysis of the institutional and legislative framework for water management and administration in Thailand (as discussed earlier in this chapter) indicates that legislative and institutional reforms in government agency system overseeing the water infrastructure and enforcing water policy and law are absolutely essential for developing effective water policy. Developing policies that put equal emphasis on demand- and supply-sides, rather than solely on supply-side, like in the past, can be powerful in getting the government agencies to focus on the inefficiencies in public water services, particularly agricultural water management (irrigation), which have encouraged waste and loss in water allocation and consumption. Water pricing, permit and license for both consumption and wastewater, for example, will require that the government to clearly specify and enforce water-use rights. This task would require, in turn, a conducive institutional and administrative framework to effectively apply alternative policy approaches.

Immediate attention is also needed to be paid in the institutional aspects of the operation and maintenance of the existing and new irrigation and wastewater treatment systems. Poor operation and maintenance system can affect the large volumes of unaccounted-for-water in many urban areas and low water use efficiency in irrigation projects. It is absolutely essential to adapt technically sound, affordable, simple, cost-effective and sustainable technologies in water supply, sanitation, irrigation and wastewater management sectors. Well-trained personnel in all disciplines are also needed for effective water resource and wastewater management. There are a number of institutional problems largely related to poor capacity of government agencies and poor quality of the government services; this is likely to constrain the effectiveness of applying water pricing, permits and licenses as tools to change user behavior. New laws and policies are designed to enable watershed committee and water user groups to gain more authority over water allocation (to be discussed later). Seldom have these efforts focused on improving the efficiency of the water infrastructure.

The contemporary water sector management practices overemphasize the role of formal institutions (organizational structures and legal underpinnings) in decision-making in the water sector, and ignore the role of informal institutions (social and cultural underpinnings). The pace of change in water sector management practices is rapid and abrupt, and is not compatible with changes in informal institutions. This research contends that informal institutions play a key role in a society, particularly in the water sector, and thus should be recognized in shaping water policies.

If the new legislation, the Water Resources Act, BE 2560 (2018), is to have any perceptible impact on the behavior of water users, reform measures aiming to improve information-based decision making and enforcement capacities of public sector institutions would have to be implemented. Legal reform along these lines is necessary to address the demand-side inefficiencies which ultimately give rise to overuse of water and environmental damage. Amendments to the legislation on water resource management and administration are urgently needed. Since the 1990s, there have been at least six officially recognized versions of the Water Resources Act. The latest, Water Resources Act, BE 2560 (2018), once fully implemented, may have yet-not-understood impacts on water resource management and administration. A more coherent bureaucracy, and more effective policy and legislation enforcement, are necessary to facilitate the management and administration of ONWR. In particular, the implementation of new Water Resources Act during floods and droughts, by the watershed committee, is essential, not only to enable the government to gain more effective control over water allocation and consumption, but also to impart a degree of permanency, transcend changes in governments.

Further, reform of the Artesian Water (Groundwater) Act, BE 2520 (1977) is currently underway in order to extend its coverage in terms of the actual functionalities and responsibilities of DGR, including management, planning, allocation, conservation, control and command, registration, penalty and control measures for recharge areas. The capacity and responsibility of regional groundwater offices should be improved to provide better public services, based on stakeholders' participation. With so many different organizations having a stake in water resource development and planning, regardless of where the planning and decision-making power lies, the challenge is to find a balance in meeting the needs of all in a way that invites least public resistance and attracts most financial support from the government. There might be, however, only a weak connection between legal and policy instruments and the behavior of the responsible agencies.

3.5. Summary and conclusions

This chapter reviews the historical evolution of the water sector in Thailand, with a view to gain insights into the nature of changes that have taken place in its institutional settings, both formal and informal institutions. Review includes consideration of laws, regulations, policies, and organizations responsible for policy development, policy implementation, and management of water resources in Thailand. The focus of this review is to identify changes in key institutional factors that influenced water resource management practices over the last several years.

The major findings of this chapter are as follows:

- Before the establishment of NESDP, water sector institutions were entirely the purview of the King (through RID), and they focusing on the development of canals as a means for public transport, navigation and trade for national economic development. The institutions for supporting this development philosophy depended on the prevailing governance system, which was primarily shaped by the perceptions of the King and a high-level government officials.

- As water was provided as a free and open service, the supply and allocation of water created certain cultural and political constraints for effectively managing and administering water usage, especially for public access. Competing uses for water among the concerned parties, to conduct socioeconomic activities, was only possible in the large river basin areas.

- There was no unified framework for physical and budgetary planning for water provision. The entire focus of development of water resources were on large-scale project development, to support national-level policies and agendas. No specific criteria were followed to assess the viability of these projects.

- During the first three-and-a-half decades of NESDPs (Plans 1-7), several water-related government agencies were established. However, these agencies neither had a clear mandate nor legal obligations to other agencies in relation to their activities. This resulted in overlapping mandates and created coordination problems among the agencies. The RID (main water resource development agency at the time) had very little authority to enforce its (informal) policies and practices over other governmental agencies.

- Similar to the period prior to NESDP, during this period, water continued to be provided for free, creating certain cultural and political constraints for managing and administering water usage. Unlike the previous period, however, the apparent shortages of water supply, especially for agricultural activities, induced some social and political tensions among the users. Further, there was no scope for local water users to participate in decision-making process for developing water resource projects. Hence, the supply-oriented, large-scale water infrastructure continued to be developed. But this still did not prevent social unrest and political turmoil.

- At the beginning of NESDP 8 (in 1996), the NWRC was established, with clear directives about measures and programs for water resource development. The purpose of the NWRC was to resolve the issues of fragmented institutions and conflicting decision-making structures that were created by several water-related management agencies in the earlier period. In addition, the enactment of the 1997 Constitution allowed citizens to stipulate their rights and participate in water resource development and management processes. While these developments partly resolved social and political conflicts within the local settings, they however heightened conflicts across watershed (basin) areas, as water resources were increasingly diverted from one basin to another, resulting from increased occurrence of floods and droughts events. It is observed that the main reason behind such conflicts is the lack of coherent national water policy framework to manage water resources across the spatial and temporal scales. In addition, the decision-making process for managing water, especially during periods of flood and drought, have remained largely unsystematic.

- The analysis also suggests that legislative and institutional reforms in the government agency system overseeing the water infrastructure, and enforcing water policy and law, are urgently needed to support the effectiveness of water policy. Policies that put equal emphasis on demand and supply sides, for example, could be powerful in getting the government agencies to focus on inefficiencies in public water services, particularly agricultural water management to reduce waste and loss in water allocation and consumption.

- Further, the introduction of alternative policy measures (for example, water pricing, permits and licenses) will require that the government clearly specify and enforce water-use rights. There are a number of institutional problems, e.g., poor capacity of government agencies and poor quality of the government services, which may constrain the effectiveness of applying water policies effectively.

CHAPTER 4 PERFORMANCE OF WATER SECTOR IN THAILAND

4.1. Introduction

Chapter 3 notes that the water sector in Thailand has been undergoing restructuring since the 1980s, especially a move away from traditional water management practices, towards Integrated Water Resource Management. The main argument of restructuring has been that it would improve the effectiveness (i.e., performance) of the water sector in terms of meeting its primary role, i.e., to enhance the livelihood of rural population where most of the household income is obtained from water-dependent farming activities. However, this argument has remained essentially anecdotal, devoid of any substantiation through ex-ante or ex-post analyses.

This chapter aims to provide a comprehensive analysis of the performance of the water sector in Thailand, specifically in terms of assessing whether past investments in the water sector have indeed led to beneficial outcomes for the rural population. In particular, this chapter analyses the performance of the water sector (in terms of benefits for the rural people) in Thailand for the period 1987-2017, at both national and basin levels. To the best of the knowledge of this author, such analysis has never been developed before in the Thai context. Further, it is contended that, such analysis will provide a firmer basis to ascertaining the veracity of the argument that the restructuring of the water sector contributes to improve its performance and, by implication, enhance the livelihood of people whose socio-economic condition is very much dependent on water. In addition, such analysis could be used to identify specific aspects of restructuring which could contribute to improved performance.

This chapter is organized as follows. Section 4.2 reviews various methods for performance assessment; literature on the assessment of water sector performance are used as a basis for review. Section 4.3 provides the methodological framework adopted in this research to examine the performance of water sector in Thailand. Section 4.4 describes data and software considerations. Section 4.5 analyses the empirical results. Finally, Section 4.6 presents the summary and conclusions of this chapter.

4.2. Performance assessment: A review of methods

According to Neely et al. (1995), performance assessment is a "process of quantifying the effectiveness and efficiency of actions". It is regarded as one of the key tools to support decision making, state priority and actions, verify the effectiveness of policies and measures, and to aid benchmarking processes in order to improve the quality of provided services (Andersen & Fagerhaug 2002).

Performance assessment has been undertaken at various institutional levels where decisions are made. The decision-making unit (DMU) can be designated according to operational, collective or constitutional levels (Wieriks 2011). The operational level refers to the assessment of the day-to-day operations of business or government entities (such as, water and sewerage companies) within a set framework of rules. The collective level focuses on the assessment of DMU (such as, regions, provinces) involved in the formulation of policies and rules that structure behavior at the operational level. The constitutional level focuses on the overarching decisions regarding the formulation of policies and rules that guide decisions at the collective level; the national government is a prime example of a DMU at this level.

Several issues gave rise to the assessment of water sector's performance, such as structural reform of the sector, regulatory reform of the sector, and monopoly control of water utilities (Abbott & Cohen 2009). There are numerous studies that have analyzed performance at the level of water utilities (see, for example, Anwandter & Ozuna 2002; Aubert & Reynaud 2005; Corton 2011; Erbetta & Cave 2007; Faust & Baranzini 2014; Filippini, Hrovatin & Zorić 2008; Maziotis et al. 2016; Sauer & Frohberg 2007; Thanassoulis 2002; Tupper & Resende 2004; Zschille 2015). In the context of water management, decisions generally take place at the macro level, such as nation, basin, and region. Studies that have assessed performance of the water sector at this level are however uncommon, because of the difficulty in defining and collecting macro-level input-output data (Abbott & Cohen 2009).

A wide range of indicators can be used to measure performance of the water sector. Broadly, the two commonly used indicators are Partial Factor Productivity (PFP) and Total Factor Productivity (TFP) (Abbott & Cohen 2009). The PFP is a simple ratio measure that relates output of a DMU to a single input factor. For example, a labor productivity can be simply calculated as the ratio of water supplied (cubic meters) and number of employees (person). This type of indicator has an advantage of being easy to construct, requiring limited data, and being intuitively easy to interpret (Abbott & Cohen 2009). However, it could provide misleading indication of an overall performance of DMU when considered in isolation. For example, a DMU may raise its performance with regard to the use of labor input (i.e., labor productivity) at the expense of other inputs (e.g., capital productivity) without improving its overall performance. For this reason, the use of PFP measure in relation to the water sector is uncommon in literature.

The TFP, on the other hand, is a composite measure; it is a ratio that relates multiple outputs of a DMU to multiple inputs. When all inputs and outputs of a DMU are used to calculate the TFP measure, it is considered as a complete measure of the overall performance. However, in reality, only selected inputs and outputs can be considered at a time. Further, the TFP measure is obtained through relatively complex methodologies.

There are two approaches to obtain the TFP measure – Index and Frontier. In the Index approach, the TFP is measured by dividing an aggregate output index with an aggregate input index, where information on input-output prices are used to determine weighted average indices to enable aggregation of multiple inputs and outputs. A variety of methods can be used to obtain TFP index, such as Laspeyres, Paasche, Fisher and Törnqvist, which can lead to slightly different empirical results. The use of index approach to obtain TFP of the water sector is however rare because it relies on the use of input and output price data, which is difficult to obtain in practice. There are just a few studies, to the author's knowledge, that have derived TFP indices for the water sector. For example, Kendrick & Grossman (1980) estimated the TFP of the water sector in the United States, over the period 1957-1973, using the Laspeyres index method. No specific results of the water sector were however reported in this study as the main focus was to analyze productivity trends of the United States as a whole. Another limitation of the index approach is that it does not allow one to develop understanding of the underlying reasons for changes in industry performance. As the use of index approach only provides the measure of TFP (i.e., performance) of the water sector and, hence, changes in sector's performance over time, it limits the possibility to develop further understanding of the relative contributions of various factors to changes in performance of the water sector (Coelli et al. 2005).

The Frontier approach, on the other hand, allows the decomposition of changes in TFP into two factors: efficiency and technology. This is possible through the application of the concept of Production Possibility Frontier (PPF), which is used to define the relationship between inputs and outputs in a production process, under the best available technology. In other words, the PPF represents the maximum output attainable from each input level, or, conversely, the minimum input that can be used to produce a particular amount of output. Efficiency refers to the extent to which a DMU might be away from a frontier (Coelli et al. 2005). It shows the effectiveness of a DMU in converting inputs into outputs relative to the best practice frontier; the most efficient DMU operates on a frontier. In this context, productivity change of a DMU that results from changes in the use of inputs, or the level of outputs, under a fixed technology, is called efficiency change. Technological change, in turn, refers to an advancement in technology that may be represented by a shift in the PPF (Coelli et al. 2005). In this context, a change in the ratio of outputs to inputs (productivity change) that results from a shift in frontier is called technology change.

The TFP measurement from the frontier approach can be obtained using Malmquist Productivity Index method, which measures the TFP change between two data points by calculating the ratio of distances of each data point relative to a common technology (i.e., frontier). This method also allows the decomposition of TFP changes into efficiency and technology changes. In essence, the application of Malmquist Productivity Index method provides a measure of relative efficiency and productivity among different DMUs without the need of input-output price data, thus making it a widely-used approach for performance assessment, particularly in the case of water sector (Abbott & Cohen 2009).

The application of frontier approach involves the estimation of PPF by using sample data of various DMUs. There are two methods to do this – Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). The SFA method involves the use of parametric (econometric) function to fit the sample of input-output data of all DMUs; the fitted curve is the PPF. Efficiency of any DMU is then estimated by comparing the observed input-output data of a given DMU relative to the PPF. While this method accounts for the effect of errors and noise in a sample data, it requires the assumption of functional form that captures a specific relationship between input and output in constructing PPF. Further, in this method, it is difficult to accommodate multiple outputs, which are typically a feature of any water sector. Some studies have overcome this limitation by constructing frontier from cost functions, where costs of multiple inputs are combined into a total cost, rather than a direct estimate of PPF. For example, Fraquelli & Moiso (2005) estimated a cost frontier for the Italian water sector by using sample data from 18 Italian water regions over the period 1975-2005, to assess the efficiency score and the impact of network characteristics on inefficiency. In such a study that use cost frontiers to estimate performance, total cost (as an independent variable) is regressed against a number for dependent variables comprising prices and quantities of inputs and prices of outputs. However, the use of input or output prices to develop a frontier in the case of water sector is not appropriate as prices, if available, are often distorted by a lack of competitive forces or influenced by political decisions (Abbott & Cohen 2009). Further, the information on input and output prices to enable analyses of the water sector for Thailand are rarely available, hence this method is not feasible for this research.

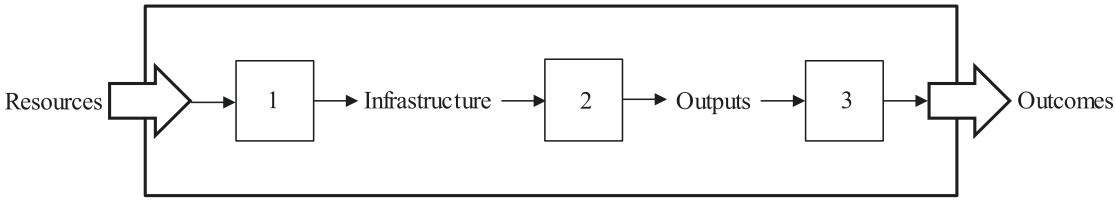
DEA, on the other hand, is a method that directly constructs PPF by enveloping all observed input-output data within a nonparametric-piecewise frontier. It does not require behavioral assumptions such as cost minimization or profit maximization, and accordingly do not need a-priori assumption on the type of functional form (Coelli et al. 2005). Further, this method can accommodate multiple inputs and multiple outputs without the need for input or output prices. Once a frontier is constructed, this method employs a mathematical programming technique to measure efficiency of a DMU relative to other DMUs that produce the same services. This method has been extensively used to assess performance of water sector at the micro level (e.g., individual companies), and at the level of various segments of the sector (e.g., water distribution, wastewater treatment, sewerage services). Some macro-level studies have also used this method to assess the performance of the entire water sector at the levels of municipalities, towns and states (see, for example, Garcia-Sanchez 2006; Garcia-Valinas & Muniz 2007; Sawkins & Accam 1994; Woodbury & Dollery 2004). No study however exists that has analyzed performance at the watershed or basin levels.

4.3. Methodological framework

Considering the centrality of the role of the water sector in wider socio-economic context of Thailand, this research adopts a multi-stage Malmquist-based DEA method to assess the performance of water sector in enhancing the livelihoods of rural Thai population.

Following the method developed by Färe, Grosskopf & Whittaker (2007), the Thai water sector is assumed to operate in three stages as shown in Figure 4-1.

Figure 4-1 Representation of a three-stage water sector



Source: Adapted from Färe, Grosskopf & Whittaker (2007)

In the first stage, resources (in the form of investments) are used to develop water infrastructure. This infrastructure is then available for producing agricultural outputs in the second stage, which are then transformed into outcomes, or benefits (in the form of rural household income) in the third stage. Performance assessment of such a multi-stage system has the advantage over the assessment carried out for a single-stage system (where resources are converted directly into outcomes) in that it enables identification of any ineffectiveness that may occur at different stages across the water sector.

The Malmquist-based DEA method can be used to quantify changes in performance at each stage of the sector, and to decompose these changes into two components: efficiency and technology (Caves, Christensen & Diewert 1982; Färe, Grosskopf & Lovell 1994). Essentially, it provides a measurement of changes in the ability of a sector (at any stage) to convert inputs (x) into outputs (y) in more than one period relative to the best-practice technology of each period. Following Coelli et al. (2005), an input-oriented[5] Malmquist productivity change index between two periods (t and t+1) can be represented in a mathematical form as:

$$m_i(y^t, x^t, y^{t+1}, x^{t+1}) = \left[\frac{d_i^t(y^{t+1}, x^{t+1})}{d_i^t(y^t, x^t)} \times \frac{d_i^{t+1}(y^{t+1}, x^{t+1})}{d_i^{t+1}(y^t, x^t)}\right]^{0.5} \quad (4\text{-}1).$$

This equation is basically the geometric mean of two productivity change indices measured in relation to the best-practice technology of each period. A value of m_i greater

[5] The input-orientation focuses on the minimization of inputs for producing observed output; whereas the output-orientation focuses on the maximum level of outputs that could be produced using a given input. Input-orientation and output-orientation produce the same outcomes under the assumption of constant-return-to-scale technology.

than one shows an improvement in productivity, whereas a value less than one suggests decline in productivity. Equation 4-1 can also be rearranged to show both components of change in productivity, as:

$$m_i(y^t, x^t, y^{t+1}, x^{t+1}) = \frac{d_i^{t+1}(y^{t+1},x^{t+1})}{d_i^t(y^t,x^t)} \times \left[\frac{d_i^t(y^{t+1},x^{t+1})}{d_i^{t+1}(y^{t+1},x^{t+1})} \times \frac{d_i^t(y^t,x^t)}{d_i^{t+1}(y^t,x^t)}\right]^{0.5} \quad (4\text{-}2).$$

The first term on the right-hand-side of equation 4-2 represents an efficiency change index, which measures how efficiency of a system evolves. In other words, it measures the change in productivity (between the periods under consideration) that arise solely due to the ability of water basins to convert inputs into outputs, isolating the influence of changes in best-practice technology frontier. It relates to the extent to which various water basins have performed in relation to the water basin that is considered to be on the best-practice frontier, and measures the movement of the water basins towards the frontier over time. This component compares the distances of the two observations over two time-period (x_t, y_t and x_{t+1}, y_{t+1}) against the frontiers of the corresponding years. An efficiency change index of greater than 1 means that the basin is operating closer to the frontier than in the previous period, while the value of less than 1 means that the basin is operating farther from the frontier.

The second term on the right-hand-side of equation 4-2 refers to the index of technological change. That is, it provides the measure of productivity change that arise solely due to improvement in technology frontier. It refers to a shift of the best-practice frontier, which captures changes in technology (i.e., innovation), management practices, policies or regulations concerning a system in question. Similar to the efficiency change index, technology change index of greater than 1 means that there is a progress in the frontier over time, while the value of less than 1 means that the frontier regresses over time.

The four d_i's in above equations represent distance functions, which measure the observed input-output relationship of the water system against the best-practice technology, represented in the form of production frontier, of each year. As noted in the previous section, the production frontiers are estimated using the nonparametric-based DEA method. This method was first developed by Charnes, Cooper & Rhodes (1978), using mathematical programming approach to construct a production frontier from a set of comparable input-output data. Unlike parametric-based frontier analysis methods, DEA does not require a-priori assumptions on the underlying functional relationships between inputs and outputs (Seiford & Thrall 1990). It is clear that either equation 4-1 or 4-2 will involve solving four mathematical programming problems, for each distance function.

In this research, each of the 25 water basins in Thailand is assumed to represent a unique water sector. Each stage within this sector to assumed to convert various inputs into several desirable outputs. The inputs and outputs of the three stage water sector are summarized in Table 4-1.

Table 4-1 Input-output in a three-stage water sector

	Inputs	**Outputs**
Stage 1	Total investment	Irrigated area Water storage capacity
Stage 2	Irrigated area Water storage capacity	Crops output, including: – Rice – Tapioca – Rubber – Sugarcane – Palm oil
Stage 3	Crops output (five major crops)	Rural household income

x_b and ${y_b}^d$, in the context of this discussion, represent vectors of inputs and desirable outputs, respectively, of the water sector from water basin b. Then, $X \in R^{x \times b}$ and $Y^d \in R^{y \times b}$ are the corresponding input and output matrices. Assume that the production frontier exhibits constant returns-to-scale technology and has a strong disposable relationship between inputs and desirable outputs. According to Färe, Grosskopf & Lovell (1994), the corresponding reference technology can be represented as:

$$T = \{(x, y^d): x \geq X\lambda, y^d \leq Y^d\lambda, \lambda \geq 0\} \quad (4\text{-}3).$$

The generalized mathematical programming problem for input-oriented distance measure of inefficiency, under constraints identified in equation 4-3, is defined by:

$$\begin{aligned} d_i\left(x_b, y_b^d\right) &= min_{\theta,\lambda}\, \theta \\ \text{s.t.} \quad -y_b^d + Y^d\lambda &\geq 0, \\ \theta x_b - X\lambda &\geq 0, \\ \lambda &\geq 0 \end{aligned} \quad (4\text{-}4)$$

where λ is a $b\times1$ vector of constants, and θ is the efficiency score of each water basin. Equation 4-4 is solved 25 times to acquire efficiency scores for all 25 water basins. The values of θ derived from this equation are less than or equal to one, with the value of one means that the water sector of that basin is located on the frontier, or is said to be efficient. This is equivalent to Farrell (1957) measure of efficiency.

4.4. Data and software considerations

This research has developed a panel dataset for 25 water basins in Thailand, over the period of 31 years, between 1987 and 2017. Using the panel data at the basin level has more advantages compared with using either time-series data at the national level or cross-section data of basins. In such panel data, each yearly data point for each basin is treated as a separate decision-making-unit (DMU), making a total of 775 DMUs (i.e., 25×31; 25 basins × 31 years). Such a dataset enables analyses to be made of any basin in comparison with itself over the years as well as with other basins for a particular year, and thus can provide richer insights into the relationship between performance and characteristics of basins.

Developing such a dataset is however a difficult task. This is because no such dataset exists in a form that enable analyses to be made directly. Data for the past many years are scattered in various published and unpublished records, at various government ministries. Therefore, significant effort has been made in this research to compile historical data from various sources. The variables used in the analysis, along with data sources and availability, are summarized in Table 4-2. These (input-output) variables are directly associated with the performance of water sector in various stages, as shown in Figure 4-1.

Table 4-2 Variables used and data availability

Variables	Measurement units	Data sources[#]	Levels of data availability
Total investments	Million Baht	BB & RID	Basin
Irrigated area	Rai[*]	RID & DWR	Province
Water storage capacity	Million Cubic meters	RID & DWR	Province
Rice production	Tons	OAE	Province
Tapioca production	Tons	OAE	Province
Rubber production	Tons	OAE	Province
Sugarcane production	Tons	OAE	Province
Palm oil production	Tons	OAE	Province
Rural household income	Million Baht	NESDB & NSO	Province

Notes: [*] A *rai* is a unit of land area, commonly used in Thailand
[#] BB – Budget Bureau; RID – Royal Irrigation Department; DWR – Department of Water Resources; OAE – Office of Agricultural Economics; NESDB – Office of the National Economic and Social Development Board; NSO – National Statistical Office

As data for most variables are available at the provincial level (Table 4-2), a major effort was required to convert the provincial level data into basin level data. This conversion is based on the application of the apportioning method, as proposed by Palanisami & Ranganathan (2012); key features of this method are as follows.

Let x_{ij} be the proportion of land area occupied by the water basin i in province j. The value of x_{ij} is estimated in this research by mapping GIS data of land area in Thailand over the boundary of two layers – provinces and basins. Further, let b_i and p_j be the value of the (input or output) variable for basin i and province j, respectively. The value of a variable for a particular year (say, irrigated area in 2015) for basin b is estimated by:

$$\begin{bmatrix} b_1 \\ \vdots \\ b_i \end{bmatrix} = \begin{bmatrix} x_{1,1} & \cdots & x_{1,j} \\ \vdots & \ddots & \vdots \\ x_{i,1} & \cdots & x_{i,j} \end{bmatrix} \times \begin{bmatrix} p_1 \\ \vdots \\ p_j \end{bmatrix} \tag{4-5}$$

where i has 25 elements for basins, and j has 77 elements for provinces.

This formulation can also be written in a matrix form as:

$$\underset{(25\times1)}{B} = \underset{(25\times77)}{X} \times \underset{(77\times1)}{P} \tag{4-6}$$.

The application of equations 4-5 or 4-6 provides a consistent and reliable method for converting province-level data to basin-level data.

A panel dataset of variables in Table 4-2, in the form used in this research (i.e., for 25 water basins over the period 1987-2017, are presented in Tables C-1 to C-9, Appendix C.

In this research, the Data Envelopment Analysis Program (DEAP) Version 2.1 is applied to construct frontiers and to calculate efficiency, as well as the Malmquist productivity change indices. The DEAP program is a DOS based computer software that can easily run on Windows operating systems. The program has been widely used because of its capacity to handle unlimited number of DMUs, inputs and outputs, the use of variety of returns to scale assumption (i.e., constant or variable), the capacity of the method orientation (i.e., input-orientation or output-orientation), and in particular, the application of Malmquist-based DEA method to calculate indices of productivity change, and to decomposes such a change into two components: efficiency and technology. The description of DEAP computer program is provided in Coelli (1996).

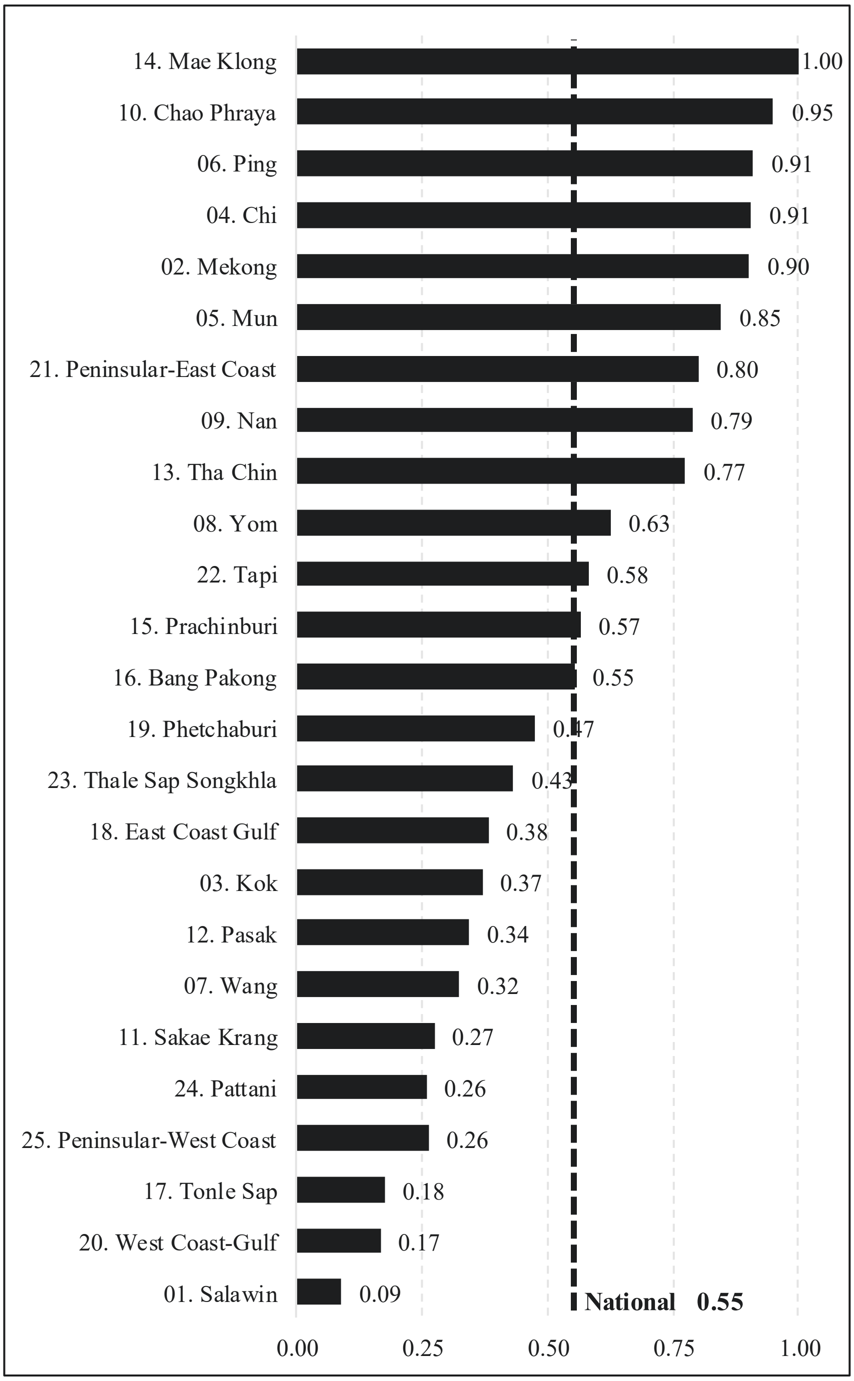
4.5. Empirical results and discussion

This section presents the empirical results of the performance of water sector in Thailand. The results are discussed at both national and basin levels. The results at the national level represent the averages of all basins. The results are first discussed for each of three stages of the water sector, in sections 4.5.1-4.5.3. The summary of the overall performance of the entire water sector, which represent combined outcomes of all three stages, are then presented and discussed in Section 4.5.4.

4.5.1. Performance of water supply (Stage 1)

The relative efficiency score of the water supply (in terms of water infrastructure development) for 25 water basins in Thailand are presented in Figure 4-2.

Figure 4-2 Efficiency Scores: water supply (Stage 1)



Notes: - The efficiency scores are the geometric averages over the period 1987-2017. A score of ‘one’ is assigned to the most efficient basin, and ‘zero’, to the least efficient basin.
- This figure is developed from detailed results presented in Table D-1, Appendix D.

The key observations from Figure 4-2 are as follows.

- The average efficiency of water infrastructure development in Thailand is 0.55, which means that just a little more than half of the potential water infrastructure has been developed from the amount of investments that were made over the past 30 years.

- Mae Klong, Chao Phraya, Ping, Chi, Mekong and Mun have been the most efficient basins in terms of the efficacy with which investments have contributed to the establishment of infrastructure, with their efficiency scores ranging between 0.85 (Mun) and 1 (Mae Klong). Further, these are the major basins, with large land area and relatively significant amount of annual water availability. These six basins collectively have 51 percent of total land area and 49 percent of total water available in the country. Therefore, these basins are suitable to develop large-scale water infrastructure, such as dams and canals.

- In contrast, developing water infrastructure in smaller basins, with relatively less natural water flow, tend to be inefficient. For example, the six least efficient basins (with scores of less than 0.3) have a combined land area of 12 percent, and 19 percent of total water available. Further, the rugged mountainous region in the smaller basins make it difficult to develop large-scale water infrastructure, thus contributing to the inefficiency to convert investments into tangible infrastructure. The Salawin basin, which is located in a mountainous forest complex in the North of Thailand, is a prime example; it is the most inefficient basin with the average efficiency score of 0.09.

- The above noted observations across the basins imply that the efficiency of water infrastructure development system is likely to be correlated with the geographical and physical/natural conditions of the basins. For example, the Northern-most part of the country is mostly mountainous, where most river streams originates. The four major river streams in this region form the three major basins that are relatively efficient, such as Ping, Nan and Yom (a relatively smaller, inefficient, Wang basin is also part of these complex river streams). These river streams converge downstream to form one of the major and most efficient basins in the Central Thailand, namely, Chao Phraya.

The changes in the performance of stage 1 of the water sector in Thailand (national average), for all 25 basins, are presented in Table 4-3. Further, these changes are presented as ten-year averages for the three time-periods: 1987-1997, 1997-2007 and 2007-2017.

Table 4-3 Change in performance: water supply (percent per year)

	Productivity			Efficiency			Technology		
	1987-1997	1997-2007	2007-2017	1987-1997	1997-2007	2007-2017	1987-1997	1997-2007	2007-2017
01. Salawin	3.1	-1.5	0.1	23.2	2.8	2.9	-16.3	-4.3	-2.7
02. Mekong	-17.5	-4.4	-3.1	-0.6	-0.2	-0.4	-16.9	-4.2	-2.7
03. Kok	-6.4	-2.9	-2.4	12.4	1.4	0.3	-16.7	-4.2	-2.7
04. Chi	-12.4	-4.4	-3.3	4.3	0.0	-0.4	-16.0	-4.4	-2.9
05. Mun	-8.6	-4.1	-3.3	8.8	0.3	-0.4	-16.0	-4.4	-2.9
06. Ping	-14.7	-4.8	-3.2	-0.6	0.1	0.0	-14.1	-4.9	-3.2
07. Wang	4.6	-0.1	-0.0	25.9	4.3	2.8	-16.9	-4.2	-2.8
08. Yom	-4.2	-3.4	-2.3	15.1	0.9	0.4	-16.8	-4.2	-2.7
09. Nan	-4.4	-4.2	-1.8	15.1	0.1	1.0	-16.9	-4.4	-2.7
10. Chao Phraya	-10.7	-4.2	-2.7	7.5	0.0	0.0	-16.9	-4.2	-2.7
11. Sakae Krang	-1.0	0.1	1.7	19.2	4.6	4.6	-16.9	-4.3	-2.7
12. Pasak	11.6	1.2	1.5	33.8	5.7	4.4	-16.6	-4.3	-2.8
13. Tha Chin	15.0	-4.2	-3.5	33.3	0.0	-0.8	-13.8	-4.2	-2.7
14. Mae Klong	-14.2	-4.6	-3.2	0.0	0.0	0.0	-14.2	-4.6	-3.2
15. Prachinburi	-10.7	-3.1	-2.7	7.5	1.2	0.1	-16.9	-4.2	-2.7
16. Bang Pakong	19.4	8.3	-3.6	43.3	13.1	-0.9	-16.7	-4.3	-2.7
17. Tonle Sap	-18.2	-1.2	-2.2	-1.6	3.2	0.7	-16.8	-4.3	-2.8
18. East Coast Gulf	-16.9	1.5	-3.0	-0.2	6.2	-0.1	-16.8	-4.4	-2.9
19. Phetchaburi	5.9	-4.8	-0.6	27.0	-0.6	2.4	-16.6	-4.3	-2.9
20. West Coast-Gulf	8.5	1.0	-1.4	26.5	6.2	1.7	-14.3	-4.9	-3.1
21. Peninsular-East Coast	2.1	-3.9	-3.2	22.9	0.4	-0.5	-16.9	-4.2	-2.7
22. Tapi	0.8	-1.5	-3.4	17.6	2.8	-0.3	-14.3	-4.2	-3.1
23. Thale Sap Songkhla	-10.4	-3.0	0.4	7.8	1.3	3.2	-16.9	-4.2	-2.7
24. Pattani	24.6	-0.6	1.5	49.8	3.9	4.7	-16.9	-4.4	-3.0
25. Peninsular-West Coast	-5.5	0.9	-0.7	13.7	5.3	2.1	-16.9	-4.2	-2.7
National average	**-3.1**	**-2.0**	**-1.8**	**15.7**	**2.5**	**1.1**	**-16.2**	**-4.3**	**-2.8**

Notes: - Productivity change refers to the change in overall performance. It comprises of changes due to efficiency (movement of the basins towards the frontier over time) and technology (movement of the frontier over time).
- This table is developed from detailed results presented in Tables D-4, D-7 and D-10, Appendix D.

The main observations from Table 4-3 are as follows.

- The overall performance (i.e., productivity) of water infrastructure development in Thailand has deteriorated over the study period, although the rate of deterioration has slowed down over time. For example, productivity change indices for the national average of all basins decreased by 3.1, 2 and 1.8 percent per year over the three time-period (i.e., 1987-1997, 1997-2007 and 2007-2017), respectively. The main driver for deteriorated overall performance at this stage has been the regress in technology frontier despite continuous improvement in efficiency; technology change indices decreased at an annual rates of 16.2, 4.3 and 2.8 percent over the three time-periods, while efficiency change indices for the same periods increased by 15.7, 2.5 and 1.1 percent per year.

- Most basins have experienced similar trends to the national average – declines in overall performance, driven mainly by deterioration of technology frontier. This is particularly true for major basins that operates very close to the frontier. For example, Mae Klong's (the most efficient basin) performance declined by 14.2, 4.6 and 3.2 percent per year over the three time periods, driven solely by regression in the frontier[6]. Smaller and inefficient basins, on the other hand, have experienced significant improvements in efficiency (i.e., they are moving closer to the frontier each year). However this has not always lead to improved overall performance because of technology change. For example, the operational efficiency of Salawin (the most inefficient basin) increased throughout the study period, but productivity increased (by 3.1 percent per year) during 1987-1997, decreased (by 1.5 percent per year) during 1997-2007, and remained constant during 2007-2017.

- Technology change indices for all basins declined at very similar rates to the national average; approximately 16 percent per year during 1987-1997, 4 percent per year during 1997-2007, and 3 percent per year during 2007-2017. This implies that there could be factors that affect technology and management practices in the development of water infrastructure across all basins in the same way. Such factors could be driven by national directives (such as national development plans, policies, and regulations that locked-in certain type of development pathways which contradict the

[6] Since the Mae Klong basin has always been on the frontier, there is no further room for improvement in efficiency, and thus productivity is only driven by technology change.

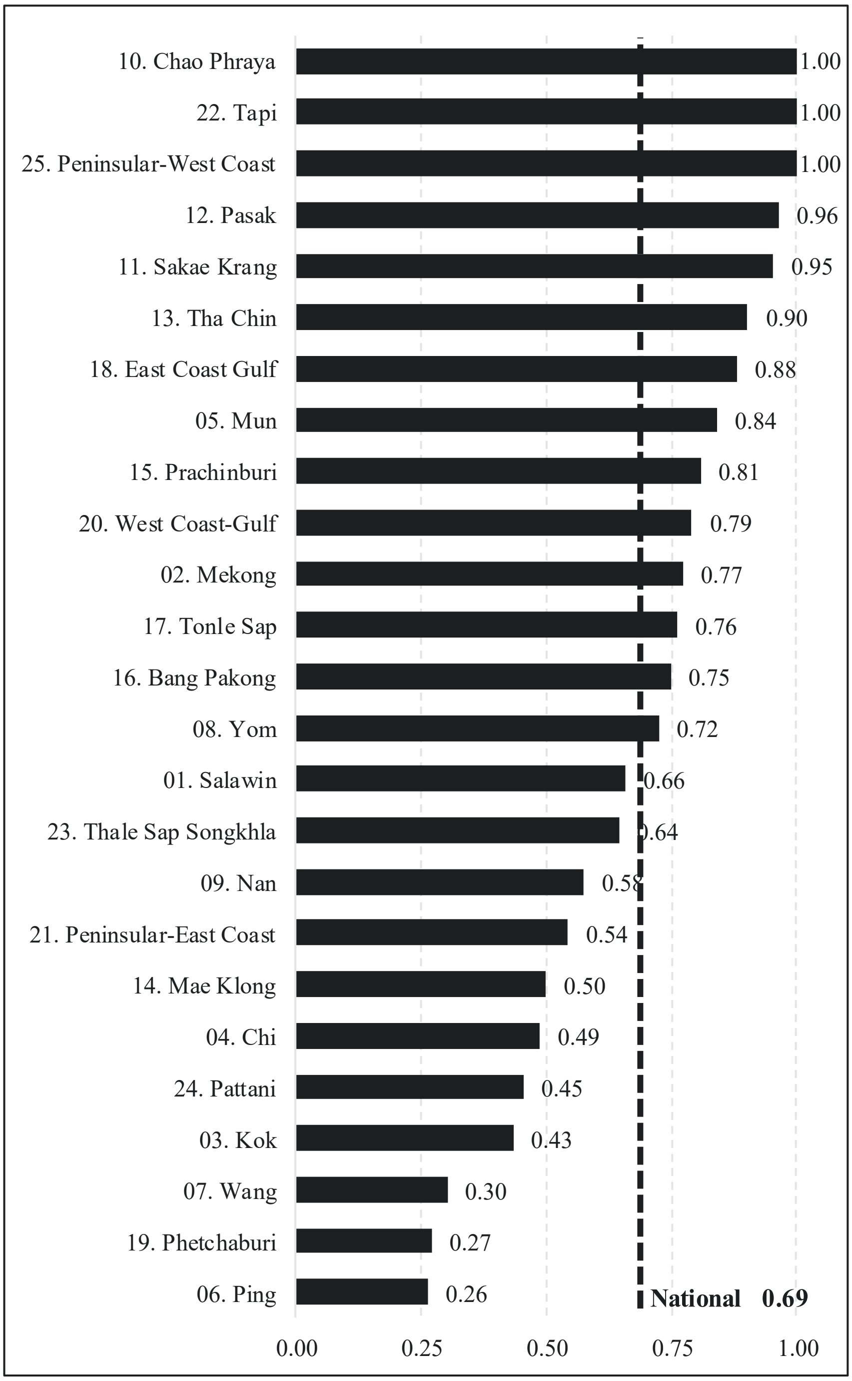
geographical and physical/natural conditions of the basins) or influenced by wider socio-economic-political landscape of the country (such as politics and political instability that may have resulted in misguided investments in infrastructure, which do not reflect the need of the local settings). It should also be noted that the emphasis of investments has always been on the development and provision of large-scale water infrastructure, which may be incompatible with the nature of basins, and significantly less attention (hence, less funds) may have been paid to the operation and maintenance of water infrastructure, and even less on improving management practices (Christensen & Boon-Long 1994).

- Unlike technology change indices, efficiency change indices have however varied across the basins. That is, while efficiency change at the national level is positive throughout the study period, efficiency change are both negative and positive across the basins with varying directional patterns. For example, some basins that have experienced reduction in efficiency are located closer to the frontier (such as Mekong, Chi, Mun, Ping), while others, farther from the frontier (such as Tonle Sap, East Coast Gulf, Petchaburi). Similarly, some basins that have experienced improvement in efficiency are located closer to the frontier (such as Chao Phraya, Nan); others, farther from the frontier (such as Salawin, Sakae Krang). This implies that factors affecting the operational efficiency of basins in developing water infrastructure are more diverse than factors affecting technology and management practices. Such factors could be those that are directly associated with characteristics of the basins (such as basin area, water availability, extent of tributary within basins), or driven by national directives (such as national development plans, policies, and regulations), or influenced by a wider socio-economic-political landscape of the country (such as, competition for budget between provinces in the same basin to develop infrastructure in their constituencies, or tensions among political parties between constituencies and national level, or conflict that may arise between industrial development and rural needs, and so on).

4.5.2. Performance of water usage (Stage 2)

The relative efficiency score of the water usage management, or water productivity, for 25 basins in Thailand are presented in Figure 4-3.

Figure 4-3 Efficiency Scores: water usage (Stage 2)



Notes: - The efficiency scores are the geometric averages over the period 1987-2017. A score of 'one' is assigned to the most efficient basin, and 'zero', to the least efficient basin.
- This figure is developed from detailed results presented in Table D-2, Appendix D.

The key observations from Figure 4-3 are as follows.

- The average efficiency of water usage in Thailand is 0.69, which means that approximately two-third of potential amount of crops have been produced over the past 30 years given the availability of water infrastructure in the country.

- Chao Phraya, Tapi and Peninsular-West Coast basins have operated on the frontier (efficiency scores of 1) during the period 1987-2017. These basins cover prime agricultural land where strategic crops are produced: rice in Chao Phraya basin (almost 20 percent of total production in the country); rubber and palm oil in Tapi and Peninsular-West Coast (34 and 58 percent of total production). Basins in the Central plain area, that surround Chao Phraya basin (including Pasak, Sakae Krang and Tha Chin), are also relatively efficient (with a score exceeding 0.9).

- Not all basins where strategic crop production occurs are however efficient. For example, more than 20 percent of total sugarcane, 16 percent of rice, and 15 percent of tapioca are produced in Chi basin. Its efficiency (0.49) is however below the national average (0.69). In fact, Ping is the most inefficient basin (0.26) despite being the basin where significant proportion of several strategic crops are produced (approximately 5 percent of the nation's output for rice, tapioca and sugarcane). This is perhaps due to the incompatibility between the type of water infrastructure and the type of strategic crop production, or insufficient rainfall in these basins, or perhaps severe flooding that may have ruined crops. Other inefficient basins (including Petchaburi, Wang, Kok and Pattani) are not located on prime agricultural land.

Changes in performance of stage 2 of the water sector in Thailand (national average) for all 25 basins are presented in Table 4-4. These changes are presented in terms of averages for three time periods: 1987-1997, 1997-2007 and 2007-2017.

Table 4-4 Change in performance: water usage (percent per year)

	Productivity			Efficiency			Technology		
	1987-1997	1997-2007	2007-2017	1987-1997	1997-2007	2007-2017	1987-1997	1997-2007	2007-2017
01. Salawin	-25.9	-2.2	-3.0	19.8	6.3	-0.4	-38.1	-8.0	-2.6
02. Mekong	-18.9	-0.9	-0.2	47.1	4.7	0.0	-44.9	-5.4	-0.2
03. Kok	-21.3	0.6	-6.2	29.1	7.0	2.1	-39.1	-5.9	-8.1
04. Chi	-18.7	-1.2	1.8	32.0	2.1	4.4	-38.4	-3.3	-2.5
05. Mun	-22.8	-3.0	-1.3	26.6	2.2	0.0	-39.0	-5.1	-1.3
06. Ping	-22.9	-1.9	-2.1	28.1	3.6	4.9	-39.8	-5.3	-6.7
07. Wang	-25.9	-6.6	-6.6	21.5	-1.9	-4.4	-39.0	-4.8	-2.3
08. Yom	-17.6	-1.0	-4.4	28.3	3.8	1.6	-35.7	-4.6	-5.9
09. Nan	-23.7	-5.9	-5.8	26.0	4.6	-0.1	-39.4	-10.0	-5.8
10. Chao Phraya	-26.5	-6.6	-14.7	0.0	0.0	0.0	-26.5	-6.6	-14.7
11. Sakae Krang	-9.1	-5.3	-5.3	30.0	0.0	0.0	-30.0	-5.3	-5.3
12. Pasak	-31.4	-4.1	-2.5	5.7	0.0	-0.0	-35.1	-4.2	-2.5
13. Tha Chin	-40.3	-3.0	-1.8	-3.1	0.9	2.3	-38.4	-3.9	-4.1
14. Mae Klong	-35.1	-2.4	3.6	22.7	-1.9	5.6	-47.1	-0.5	-1.9
15. Prachinburi	-17.1	-5.1	-6.8	51.8	2.7	-4.2	-45.4	-7.6	-2.8
16. Bang Pakong	-45.3	-19.9	-3.2	0.0	-7.2	4.2	-45.3	-13.6	-7.1
17. Tonle Sap	2.5	-4.4	-0.7	64.5	-0.0	0.0	-37.7	-4.4	-0.7
18. East Coast Gulf	-25.0	-6.7	-5.6	32.9	-1.1	-4.1	-43.5	-5.7	-1.5
19. Phetchaburi	-29.8	4.9	-1.8	9.9	12.6	-1.1	-36.1	-6.8	-0.7
20. West Coast-Gulf	-33.1	-8.7	2.0	3.8	-5.9	3.0	-35.5	-3.0	-1.0
21. Peninsular-East Coast	-37.5	-4.9	1.6	1.7	0.4	3.2	-38.5	-5.3	-1.6
22. Tapi	-14.9	-6.4	0.3	0.0	0.0	0.0	-14.9	-6.4	0.3
23. Thale Sap Songkhla	-39.0	-2.4	-9.2	-2.0	3.4	-3.2	-37.7	-5.6	-6.2
24. Pattani	-37.9	0.4	-1.8	-12.4	5.4	-0.6	-29.1	-4.8	-1.2
25. Peninsular-West Coast	-31.0	-3.5	-0.8	0.0	0.0	0.0	-31.0	-3.5	-0.8
National average	**-26.7**	**-4.1**	**-3.1**	**17.1**	**1.6**	**0.5**	**-37.4**	**-5.6**	**-3.5**

Notes: - Productivity change refers to the change in overall performance. It comprises of changes due to efficiency (movement of the basins towards the frontier over time) and technology (movement of the frontier over time).
- This table is developed from detailed results presented in Tables D-5, D-8 and D-11, Appendix D.

The main observations from Table 4-4 are as follows.

- The overall performance (i.e., productivity) of water usage in Thailand has deteriorated over the study period, with the rate of deterioration however slowing over time. For example, productivity change indices, for the national average of all basins, decreased significantly – by 26.7 percent per year over the period 1987-1997, with the rate of decline reducing to 4.1 percent during 1997-2007, and 3.1 percent during 2007-2017. The main driver for deteriorated overall performance in this stage has been the regress in technology frontier despite continuous improvement in efficiency; technology change indices decreased at annual rates of 37.4, 5.6 and 3.5 percent over the three time-period, while efficiency change indices for the same periods increased by 17.1, 1.6 and 0.5 percent per year.

- Most basins have experienced trends that are similar to the national average, i.e., decline in overall performance, driven mainly by deterioration in technology frontier. These trends are also very similar to those experienced in stage 1, with the following exceptions.

  – The reduction in technology frontier in stage 2 is relatively more severe during 1987-1997. For example, the technology change indices of the national average in stage 2 declined by 37.4 percent per year over the period 1987-1997, compared with 16.2 percent per year in stage 1. This is perhaps due to the incompatibility between the type of water infrastructure (dams and irrigation canals) that has been developed during the 1960s and 1970s and the type of crops that has been promoted during the 1970s and 1980s. Increased production of strategic crops between 1982 and 1996 have also resulted in a degradation and misuse of natural resources and water infrastructure, and thus in turn led to production problems (Chainuvati & Athipanan 2000).

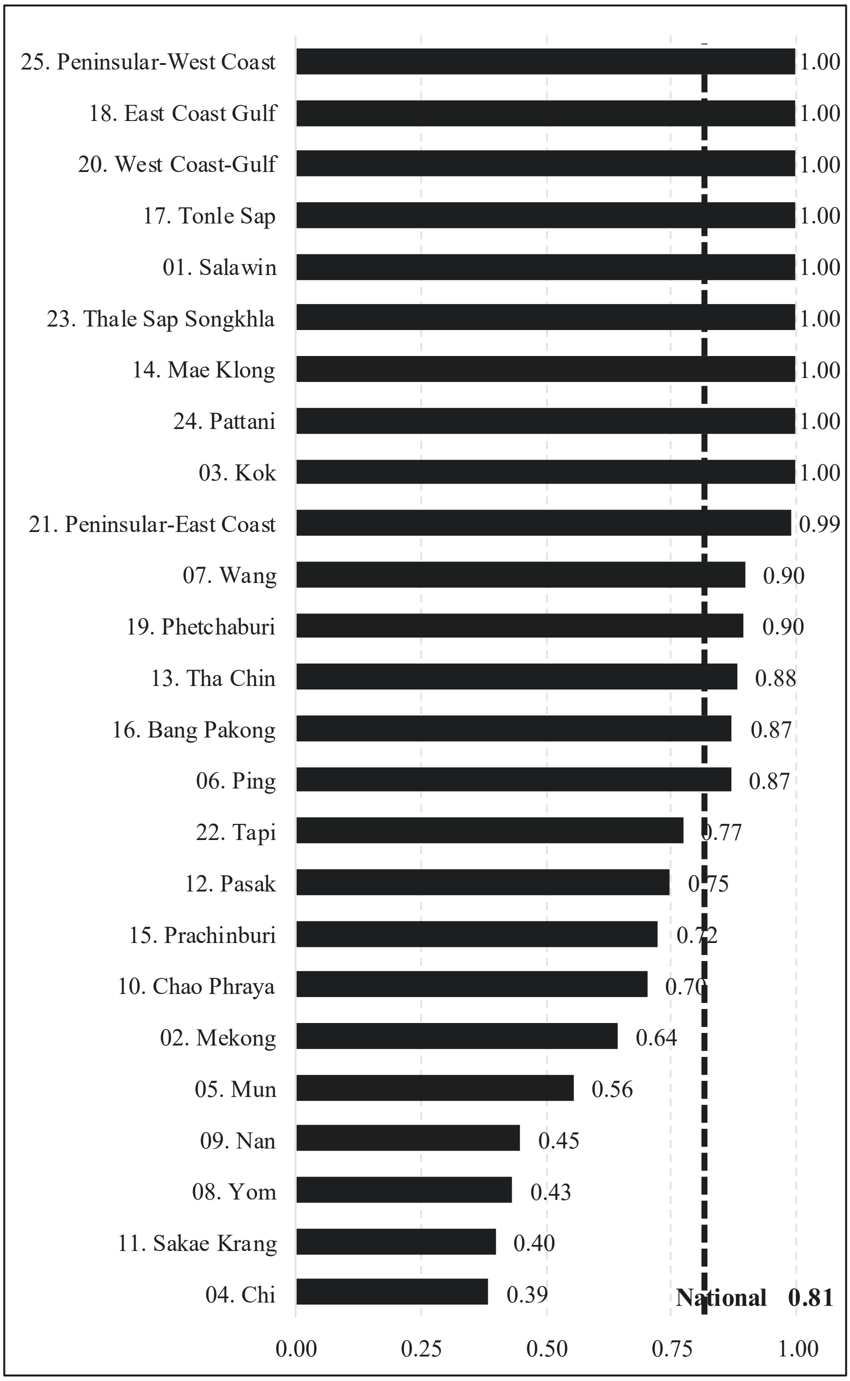
  – The magnitude of reduction in technology frontier is not uniform across basins. For example, technology change indices of most basins (16, out of 25) decreased at higher rates than the national average of 37.4 percent per year during 1987-1997. Most of these basins are located in the north and northeast part of the country. Since 1997, however, only 9 basins have lower technology change indices compared with the national average. Further, Kok, Nan and Bank Pakong basins are the only ones that have consistently experienced regression in the frontier throughout the study period.

- Most basins had experienced improvement in efficiency over the study period, i.e., they moved closer to the frontier over time. Most of these improvements occurred during 1987-1997 however where efficiency change indices of most basins increased at higher rates than the national average (of 17.1 percent per year). Just three basins (Pattani, Tha Chin and Thale Sap Songkhla) experienced deterioration in efficiency during 1987-1997. The number of basins that experienced deterioration in efficiency however increased over time, from 3 basins during 1987-1997, to 6 basins during 1997-2007, to 9 basins during 2007-2017. There are several factors that could affect the efficiency of water-dependent agriculture production by reducing the availability of water in the basins. These are, for example, a long-term decline in annual rainfall mainly in the Central region (Christensen & Boon-Long 1994); increased deforestation due to land-use changes that affected the side-flow of water into tributaries, dams and irrigation canals (Kaosa-ard 1997); rapid development in Northern Thailand that has tripled its per-capita water consumption and thus reduced water availability in the lower basins (Poapongsakorn, Ruhs & Tangjitwisuth 1998); and country's rapid industrial development that has changed water allocation in favor of urban and industrial areas (Krongkaew 1995). Factors that affect the growth in agricultural production could also lead to changes in efficiency. These factors are, for example, the use of fertilizers and the occurrence of major floods, particularly in Southern Thailand.

4.5.3. Earning performance of water-dependent farming (Stage 3)

The relative efficiency scores of agricultural earnings, for 25 basins in Thailand, are presented in Figure 4-4.

Figure 4-4 Efficiency Scores: Water-benefits (Stage 3)



Notes: - The efficiency scores are the geometric averages over the period 1987-2017. A score of 'one' is assigned to the most efficient basin, and 'zero', to the least efficient basin.
- This figure is developed from detailed results presented in Table D-3, Appendix D.

The key observations from Figure 4-4 are as follows.

- The average efficiency of earnings generated from agricultural production (i.e., increase in household earning from agricultural activities) in Thailand is 0.81, which means that 81 percent of potential household income have been generated over the past 30 years from the sale of strategic crops.

- There are a number of basins that have been very efficient in converting increased agricultural production into increased household income; ten of these basins operate on the frontier (efficiency score equals 1). Most of these basins are located in the southern part of the country where a relatively high-value, less-water-intensive crops, such as rubber and palm oil, are grown. While Tapi is the only basin in South Thailand that has the average efficiency score over the study period (1987-2017) of less than 1 (0.77), its efficiency improved significantly to reach the frontier from 2011 onwards.

- Basins that are relatively inefficient in stage 3 are mostly large basins, located in the Northeast (Chi, Mun and Mekong) and North (Yom and Nan) of Thailand. Chi, Mun and Mekong basins are famous for the production of in-season rice on flat plains. While this type of rice is of a higher quality, and hence higher economic value, than off-season rice, its production is less frequent (only once a year), and it relies mainly on rainfall. Coincidentally, these basins are among the driest basins in the country. A large proportion of farmers in Yom and Nan basins are also involved in the production of low-yield, in-season rice in the upland areas where irrigation is limited. Sakae Krang is the only inefficient basin that is relatively small, and just marginally contributed to the production of strategic crops.

- The above noted observations imply that the efficiency to convert agricultural production into earnings is likely to dependent upon several factors, such as the quality of arable land that are suitable for certain type of crops and the extent of irrigation development. Forssell (2009) notes that the production of low-yield, high-quality, water-intensive rice, and a low percentage of irrigated areas means that farmers are not able to diversify their production into more profitable crops, and hence remain poor. Further, most farmers in these inefficient basins operate on small and scattered pieces of land, which leads to high production costs. The ownership of small and widely scattered land prevents these small farmers to benefit from economies-of-scale (OECD 2013).

Changes in performance of the water sector in Thailand (national average), during stage 3, for all 25 basins are presented in Table 4-5. These changes are presented in terms of averages for the three time periods: 1987-1997, 1997-2007 and 2007-2017.

Table 4-5 Change in performance: water-benefits (percent per year)

	Productivity			Efficiency			Technology		
	1987-1997	1997-2007	2007-2017	1987-1997	1997-2007	2007-2017	1987-1997	1997-2007	2007-2017
01. Salawin	-25.3	-3.9	-23.6	0.0	0.0	0.0	-25.3	-3.9	-23.6
02. Mekong	-4.5	-7.5	-5.3	-2.0	-0.1	-1.8	-2.5	-7.5	-3.6
03. Kok	2.0	-12.3	-18.5	0.0	0.0	0.0	2.0	-12.3	-18.5
04. Chi	0.4	-0.5	-2.8	1.0	-1.2	3.1	-0.7	0.7	-5.7
05. Mun	-9.4	-6.8	-2.7	1.3	2.1	-0.4	-10.5	-8.7	-2.3
06. Ping	2.1	2.3	-10.8	6.0	-0.4	0.4	-3.6	2.7	-11.2
07. Wang	-4.4	-8.4	-26.5	0.9	-0.1	0.1	-5.3	-8.3	-26.6
08. Yom	-1.0	0.7	-15.0	2.6	-2.0	3.5	-3.6	2.8	-17.8
09. Nan	-1.2	0.7	-10.9	2.2	-1.9	2.1	-3.3	2.7	-12.7
10. Chao Phraya	-4.0	-8.8	-30.0	-0.5	5.0	1.5	-3.5	-13.2	-31.1
11. Sakae Krang	-0.1	-0.8	-5.9	3.9	-3.4	0.4	-3.8	2.8	-6.2
12. Pasak	6.6	1.2	-1.1	6.1	-1.1	0.5	0.5	2.4	-1.6
13. Tha Chin	-3.1	2.5	-3.5	1.2	0.1	1.4	-4.2	2.4	-4.9
14. Mae Klong	-6.6	-2.7	-3.5	0.0	0.0	0.0	-6.6	-2.7	-3.5
15. Prachinburi	-3.4	-0.1	-0.9	-1.3	-1.5	0.8	-2.1	1.4	-1.7
16. Bang Pakong	-5.3	-1.8	-2.2	0.0	-2.8	-0.2	-5.3	1.0	-2.0
17. Tonle Sap	-25.7	-28.3	-4.3	0.0	0.0	0.0	-25.7	-28.3	-4.3
18. East Coast Gulf	-1.6	-8.2	10.7	0.0	0.0	0.0	-1.6	-8.2	10.7
19. Phetchaburi	1.5	1.1	-0.4	3.8	-0.2	0.2	-2.2	1.3	-0.6
20. West Coast-Gulf	-8.3	4.2	4.5	0.0	0.0	0.0	-8.3	4.2	4.5
21. Peninsular-East Coast	-4.1	-2.7	-2.7	-0.0	-0.1	0.1	-4.1	-2.6	-2.8
22. Tapi	-5.6	-2.4	26.1	0.1	-1.5	5.5	-5.6	-1.0	19.5
23. Thale Sap Songkhla	-8.0	-0.5	-3.2	0.0	0.0	0.0	-8.0	-0.5	-3.2
24. Pattani	-1.3	-7.8	10.1	0.0	0.0	0.0	-1.3	-7.8	10.1
25. Peninsular-West Coast	3.0	-1.0	3.2	0.0	0.0	0.0	3.0	-1.0	3.2
National average	**-5.5**	**-3.7**	**-6.4**	**1.0**	**-0.4**	**0.7**	**-6.5**	**-3.3**	**-7.1**

Notes: - Productivity change refers to the change in overall performance. It comprises of changes due to efficiency (movement of the basins towards the frontier over time) and technology (movement of the frontier over time).
- This table is developed from detailed results presented in Tables D-6, D-9 and D-12, Appendix D.

The main observations from Table 4-5 are as follows.

- The overall performance (i.e., productivity) of agricultural earnings in Thailand deteriorated over the study period. Unlike in stages 1 and 2, the rate of decline in stage 3 has not been uniform throughout the study period. For example, productivity change indices decreased at the highest rate in the recent years; 6.4 percent per year during 2007-2017, compared with 5.5 and 3.7 percent during 1987-1997 and 1997-2007, respectively.

- The main driver for the deterioration of overall performance in this stage is the regress of technology frontier. For example, the rate at which technology change indices decreased (6.5, 3.3 and 7.1 percent per year, over the three time periods) correlates strongly with the rate at which productivity change indices decreased (5.5, 3.7 and 6.4 percent per year over the same time-period).

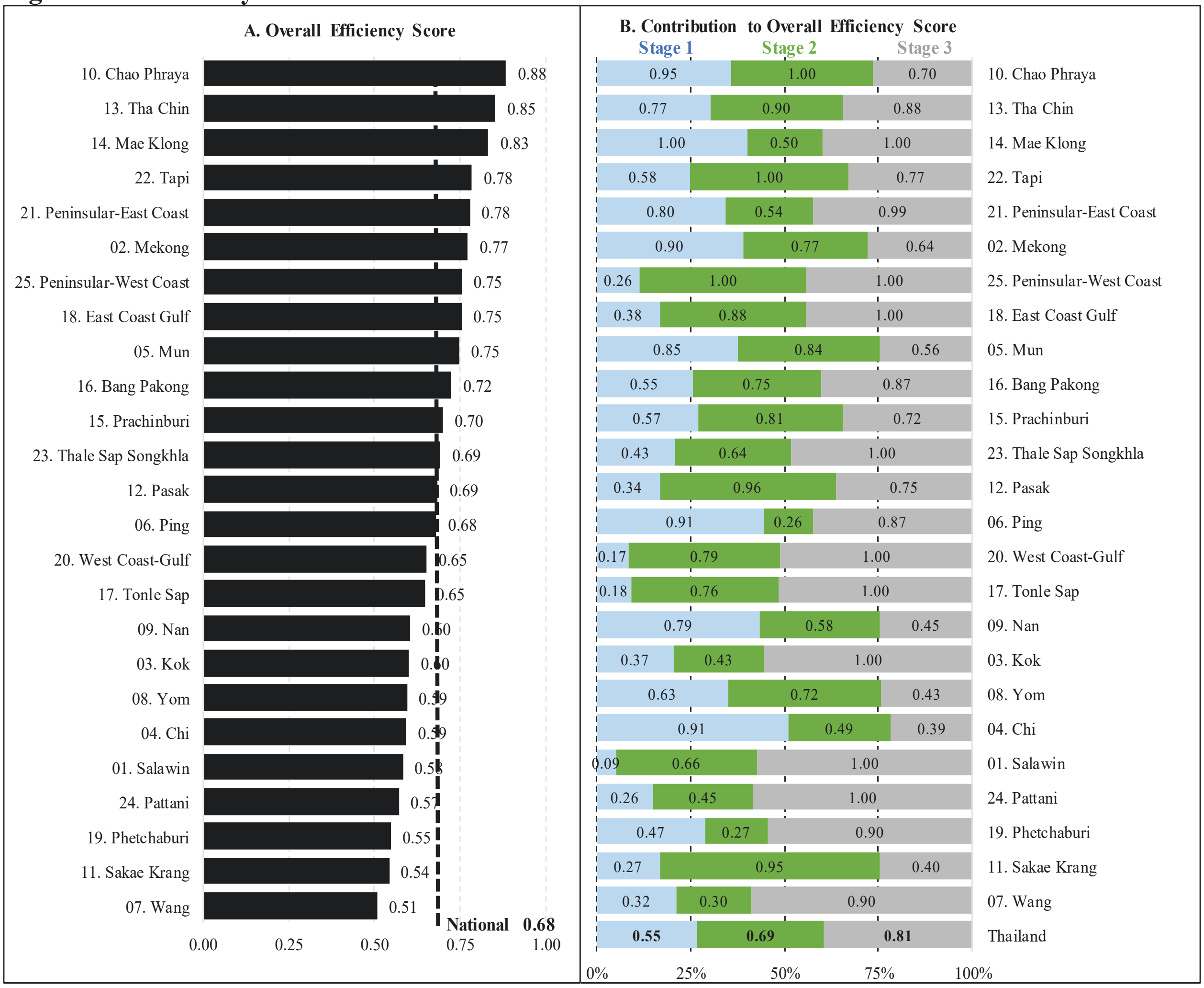
- Most basins have experienced deterioration in technology, with a few exceptions. For example, during 1987-1997, three basins in different part of the country experienced improvement in productivity through technology improvement, namely, Kok in the north, Pasak near the central plain, and Peninsular-West Coast in the south. During 1997-2007, eleven basins showed technology improvement. All these basins are scattered throughout the country except in the south. During 2007-2017, the majority of basins that experienced technological improvement (3 out of 5) are in South Thailand, the remaining in the east. There do not appear to be any definitive patterns of technological improvement except that all three basins in the northeast, which happen to be the most inefficient, did not experience improvement in technology throughout the study period.

- The rate of change in efficiency has not always been positive, in this stage, during the entire study period, unlike in stages 1 and 2. For example, most improvement in efficiency in this stage occurred during 1987-1997 (1 percent per year), followed by a marginal deterioration during 1997-2007 (0.4 percent per year), and a slight improvement again during 2007-2017 (0.7 percent per year). The period during which efficiency deteriorated (i.e., most basins moved farther away from the frontier) coincides with the beginning of Asian Financial Crisis in 1997-98, when industrial production was heavily affected. Unemployment rose as a result, prices of commodities dropped, which led to reduced earnings from agricultural production. In fact, most basins experienced reduced efficiency during this period. Other possible factors that could have affected efficiency include: changes in agricultural pricing policies; changes in insurance program, particularly for rice; inability of farmers to diversify crop production in favor of higher value crops; lack of land ownership, confining farming to small rental lands, thus preventing farmers to gain from economies-of-scale.

4.5.4. Performance of the entire water sector

This subsection presents the summary of overall outcomes of the three stages of the water sector, as discussed in sections 4.5.1-4.5.3. Figure 4-5 presents the overall efficiency scores of the entire water sector, across 25 basins in Thailand. These scores are obtained by taking the geometric averages of efficiencies for all three stages of the sector. The contributions of each of the three stages to overall efficiency scores are also provided in this figure.

Figure 4-5 Efficiency Scores: Entire Water Sector



Notes: - The overall efficiency scores in figure on the left-hand-side (A) are the geometric averages of all three stages of the water sector over the period 1987-2017. That is, it is the average of values contained in Figures 4-2, 4-3 and 4-4. A score of 'one' demotes the most efficient basin and, 'zero' – the least efficient basin.
- The figure on right-hand-side (B) shows the contribution of each stage to the overall efficiency score; specific values of efficiency scores of these stages are also provided in the figure.

The results from Figure 4-5 show that:

- At the national level, the average efficiency of the entire water sector during the time period 1987-2017 was 0.68. This means that approximately only two-third of the potential for increased income was in reality realized by the rural households engaged in farming activities. In other word, the increase in investment, by the government, in the water infrastructure, over the past 30 years, produced lower than expected returns for the rural households (mostly farmers). In a quantitative sense, every baht invested in water infrastructure produced only 0.68 baht of increase in rural household income. In simpler words still, rural household income should have been

32 percent higher, than the prevailing levels of income, if the water sector was managed more efficiently.

- Of the three stages of the water sector, stage 1 has been the least efficient (0.55), and stage 3 – the most efficient (0.81). This suggests that efforts to improve the efficiency of water infrastructure development in Thailand, even without any efforts to improve the efficiency of other two stages, could significantly improve overall sectoral performance, thus significantly raising farmers' incomes beyond the prevailing levels.

- This may, however, prove difficult for some basins that have relatively low efficiency score in stage 1. This is because these basins tend to be small and have limited water availability (as discussed in Section 4.5.1), which may make the development of large-scale infrastructure a challenging feat. Salawin, Tonle Sap, West-Coast Gulf and Pattani are such cases in point. Unless different types of water infrastructure systems are developed in these basins (such as small-scale wells, boreholes, rainwater catchment, and piping systems), and management practices that suit these types of infrastructure are put in place, the only other alternative to further enhance overall performance in these basins is to increase agricultural productivity (stage 2); the potential for such increase is limited though because stage 2 efficiency is relatively high already (with efficiency scores in the range of approximately 0.7 and 0.8), except for the Pattani basin.

- The potential options to further increase overall efficiency is considerably diverse across basins. For example, the top three most efficient basins have overall efficiency scores exceeding 0.8. Improving overall efficiency further in the Chao Phraya basin would require increased emphasis on improving efficiency of stage 3 (i.e., by incentivizing the farmers to change crop-mix – to improve farm incomes). For the Tha Chin basin, however, the overall efficiency gains are likely to come from improving the efficiency of developing water infrastructure (i.e., stage 1); and for the Mae Klong basin, by increasing agricultural productivity (i.e., stage 2).

4.6. Summary and conclusions

This chapter has examined the performance of the water sector in Thailand, comprising 25 major water basins, for the period 1987-2017. The performance is measured in terms of the ultimate goal of the water sector, namely, to improve the livelihood of rural population (essentially, farmers) whose main income comes from water-dependent agricultural activities. For the purpose of this examination, this research has divided the entire water sector into three ‘functional’ stages, namely: 1) water supply (i.e., use of investments to develop water infrastructure), 2) water usage (i.e., use of water infrastructure to produce agricultural outputs), and 3) earnings of water-dependent farming (i.e., conversion of agricultural outputs into incomes). For each stage, the Malmquist-based DEA method is used to quantify changes in productivity (i.e., performance) of the sector, and to decompose these changes into two components – efficiency (effectiveness of a water basin in converting inputs into outputs relative to the best practice frontier) and technology (advancement in the frontier). To enable the quantifications, significant efforts has been made in this research to develop a panel dataset, at individual basin level, as no such datasets exist for Thailand.

The major findings of this chapter are as follows:

- There was a decline in overall performance (i.e., productivity) of the water sector over the period 1987-2017 (4.6 percent per year). This decline was largely driven by deterioration of technology frontier (7.8 percent per year). This suggests that the substantial investments made in water infrastructure over the past 30 years did not lead to a commensurate rise in farmers’ incomes and hence their well-being.
- Further, the performance deteriorated in all three stages of the water sector. The productivity of water usage (stage 2) declined the most (12 percent per year), again driven by technology change. This was followed by the ineffectiveness in stage 3 (5.2 percent per year), where agricultural production did not proportionally convert into increase in income. While the performance of water infrastructure development (stage 1) declined the least (of the three stages), the rate of reduction was nonetheless appreciable (2.3 percent per year).
- Most of the reductions in productivity indices occurred during the period 1987-1997, with the rates of decline slowing thereafter. This is particularly true for stages 1 and 2 of the water sector. For example, for stage 1, productivity change indices for the national average of all basins decreased by 3.1 percent per year over the period 1987-2017, with the rate of decline reducing to 2 percent during 1997-2007, and 1.8 percent

during 2007-2017. For stage 2, the corresponding rates of reduction are 26.7, 4.1 and 3.1 percent per year over the three time periods. The main likely reasons for such trends are: incompatibility between the geographical/natural conditions of river basins, the type of water infrastructure that has been developed during the First and Second national development plans during the 1960s and 1970s (mostly large-scale dams and irrigation canals), and the type of crops that have been promoted (mainly for exports, including rice, tapioca, rubber and sugarcane) during the Third and Fourth national development plans during the 1970s and 1980s. In the subsequent periods, increased production of these so-called strategic crops resulted in a degradation and misuse of natural resources and water infrastructure.

- Contrary to the above, the performance of the stage 3 of water sector has deteriorated significantly in the recent years (6.4 percent per year during 2007-2017, compared with 5.5 and 3.7 percent per year during 1987-1997 and 1997-2007, respectively), driven by appreciable negative performance changes in basins located in the north and northeast of the country (in particular, Salawin, Wang, Kok, Yom, Ping and Nan basins). Most farmers in these basins operate on small and scattered pieces of land, and extensively engage in the production of low-yield, water-intensive agricultural products, mainly rice. This prevents them to benefit from economies-of-scale. Further, they are strongly influenced by political interference and business interests as Thailand is a major exporter of rice in the world market. This means that these farmers are not able to diversify their production into alternative, more profitable, crops. Since 2006, the country has been experiencing political instability, leading to considerable shifts in agricultural pricing and insurance schemes, particularly for rice. This could have been a significant reason for the deteriorating performance, in this stage, in the recent years.

- In addition to uneven growth in performance across the three stages of the water sector over different time periods, there has also been a disparity in performance across different stages of the water sector. For example, the average efficiency of the entire water sector, at the national level, was 0.68. Of the three stages of the water sector, stage 1 has been the least efficient (0.55) and stage 3 has been the most efficient (0.81); the efficiency level of stage 2 is similar to the national average (0.69). Further, there is disparity in efficiency levels across the 25 basins. For example, most large basins in the central plain area (e.g., Chao Phraya, Tha Chin and Mae Klong) have efficiency scores of more than 0.8, while others, relatively small basins in other part of the country (e.g., Wang, Sakae Krang and Petchaburi), have efficiency scores of approximately 0.5. This implies that there could be several factors that affect performance across basins. Such factors could be those that are directly associated with physical/natural characteristics of the basins, or driven by national and sectoral directives, or influenced by a wider socio-economic-political landscape of the country.

Based on these findings, one can infer that the ongoing restructuring of the water sector since the 1980s did not contribute to improved performance of the sector. In other words, past investments in the water sector did not lead to sufficiently beneficial outcomes for the rural population whose socio-economic condition is very much dependent on water. This inference calls into questions the main argument of restructuring, namely, that the restructuring of water sector will improve its performance and, by implication, enhance the livelihood of rural population.

While the analysis in this chapter has provided a better understanding of the performance (in a quantitative sense) of each stage of the water sector in Thailand over the past three decades, it did not provide any definitive understanding of the underlying causes of performance. A comprehensive understanding of such causes could be very useful for policy makers, as it would augment their capacity to design more focused policies specifically targeted to improve water sector performance. Investigation of these underlying causes (factors) is the subject matter of discussion in the next chapter.

CHAPTER 5 INSTITUTION-PERFORMANCE LINKAGES IN THE THAI WATER SECTOR

5.1. Introduction

This chapter aims to analyze the relationship between institutional factors and performance of the water sector. Particularly, it aims to empirically investigate the influence of specific institutional factors that have historically affected the performance of the water sector in Thailand (the performance of the Thai water sector was analyzed in Chapter 4). The main motivation of this investigation is to ascertain the veracity of a key premise of this research, namely, socio-political institutions do affect the performance of the water sector. The case for this investigation gets further strengthened if one takes note of the fact that past efforts to improve water sector performance – by focusing solely on water-specific institutions (e.g., water regulation, administrative and organizational arrangements for water) – have failed to improve water sector performance (as discussed in Chapter 3), suggesting that factors beyond water-specific institutions could hold the 'key' to improving water sector performance. An early observation of this claim was also made in Chapter 2.

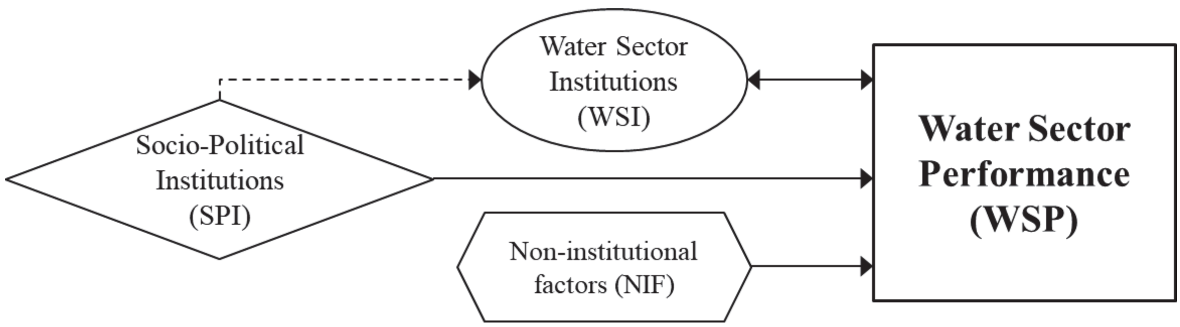
This chapter is organized as follows. Section 5.2 describes the framework for assessing institution-performance linkages in the water sector. Section 5.3 provides the analytical framework adopted in this research to assess the institution-performance linkages of water sector in Thailand. Section 5.4 provides description of variables, their definitions, and data considerations. Section 5.5 discusses the empirical results. Finally, Section 5.6 provides some broad conclusions of this chapter.

5.2. Assessment framework

This section presents the framework adopted in this research to empirically investigate the relationship between institutions and performance of the water sector. This framework draws on a number of previous studies, for example, Bonacina et al. (2014), Krause (2009), Massarutto & Ermano (2013), Saleth & Dinar (2004). These studies broadly evaluate the relationship between the reform of water sector and its performance, from institutional-economics and political-economy perspectives.

Based on the review of previous studies, in particular Krause (2009) and Saleth & Dinar (2004), Figure 5-1 presents the relationship between water sector performance (WSP), water sector institutions (WSI), and wider socio-political institutions (SPI). The relationships are of two types. First, there is a direct relationship between WSP and WSI. It is a well-developed theory that performance of a sector (water sector, in this instance) depends on the institutional arrangements of the sector (Lowndes & Roberts 2013; North 1990). The belief in this relationship has been well-recognized in the context of the water sector of Thailand. For example, Chapter 3 discussed how Thai policy makers aimed to bring about improvements in the performance of the water sector through changes in regulation and organizational arrangements of the water sector. This research however posits that such a relationship may not be straightforward as there could be a bidirectional linkages between institutions and performance of the water sector (also see, Saleth & Dinar 2004). That is, not only do the water sector institutions influence its performance, changed performance of the water sector can also affect water sector institutions. Saleth & Dinar (2000) provides ample evidence of how institutions of the water sector have been affected by water-related challenges.

Figure 5-1 Framework for assessing institution-performance linkages of a water sector



Notes: Bold line represents a direct relationship; dashed line represents an indirect relationship, and an arrow represents direction of relationship.
Sources: Adapted from Krause (2009) and Saleth & Dinar (2004)

The second part of the relationship in Figure 5-1 is between WSP and SPI. Although the water sector institutions are directly responsible for enhancing the effectiveness of the water sector, these institutions operate within an environment characterized by several other wider factors, including social, economic and political. The 'conventional' and 'narrowly-defined' institution→performance linkages (i.e., between WSI and WSP) are thus subject to these wider influences. For example, some water basins may lack political representation in the government, which could result in a lack of sufficient public funds to improve water infrastructure in those basins. As noted by Noll (2002), "… extensive government intervention in the [water] industry is inevitable … [these] interventions are likely to be distorted by distributive politics because of … the competition for the enormous rents that are available from the system in an environment in which many of the social costs of inefficient policies … are likely to be delayed and difficult to observe". Another example: the existence of business interests over farmer interests may affect the implementation of desirable policies in allocating water rights, which could result in worsening water productivity (in agricultural production) despite having sufficient water infrastructure.

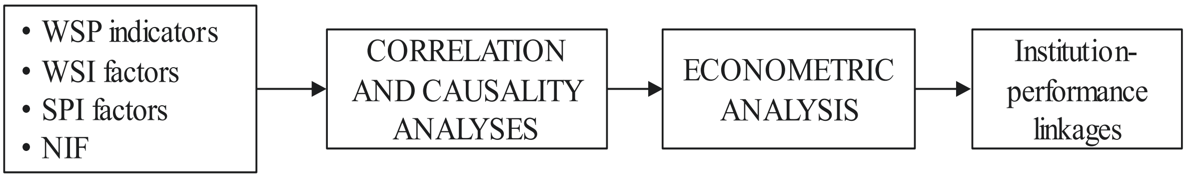
The framework presented in Figure 5-1 not only reflects the relationship between institutions and performance within the water sector, but also explicitly takes into account of the wider socio-political institutional factors that systematically influence, directly or indirectly, water sector performance. That is, changing SPI may affect WSP directly, as shown in bold line in Figure 5-1. Alternatively, or concurrently, the SPI may shape WSI (dotted line), which in turn affect WSP. The exact shape and direction of the institution-performance linkages of the water sector in Thailand (as postulated in Figure 5-1) is the subject of empirical analysis in this chapter.

In addition to the institutional factors (i.e., WSI and SPI), some other non-institutional factors (NIF) may also affect performance of the water sector. These factors are, for example, the availability of freshwater resources, amount of rainfall, average income levels of the population, spatial population patters. In order to reliably and accurately assess the institution-performance linkages, these plausible variables affecting performance need to be controlled for – such factors are typically called 'control variables' in literature; this research used the term NIF.

5.3. Analytical framework

Figure 5-2 shows the overall analytical procedure for assessing institution-performance linkages. It has two analytical components: correlation and causality analyses, and econometric analysis. These are discussed in the following sub-sections.

Figure 5-2 Analytical procedure



5.3.1. Correlation and causality analyses

Correlation analysis, as a method, can statistically evaluate he existence, and the strength, of relationship (linkage, correlation) between two variables. The evidence of linkage (i.e., correlation) between two variables would imply that a change in one variable will systematically change the other variable. Further, such linkage can be either positive or negative. A positive linkage means that an increase in one variable will lead to an increase in the other variable. Conversely, a negative linkage means that an increase in one variable will result in a decrease in the other variable.

In this research, the Spearman's rank correlation coefficient (ρ) is used to establish any possible linkages between various variables that reflect WSP, WSI, SPI, and NIF (the description of variables are shown in Section 5.4). This is a widely-used method in statistical literature to establish possible relationships between multiple variables. Unlike other statistical methods, the Spearman's rank correlation coefficient allows the relationship to be established even if the relationship is non-linear (Corder & Foreman 2014). The value of ρ ranges between -1 and +1: a positive value indicates that the two variables move in the same direction (either increase or decrease), whereas a negative value indicates that the two variables move in the opposite direction. Further, the strength of linkages is determined from the absolute value of ρ as follows: strong when $|\rho|\geq 0.5$; moderate when $0.2<|\rho|<0.5$; and weak when $|\rho|\leq 0.2$.

The existence of a relationship between variables from the correlation analysis does not prove causation. When a change in one variable in the past causes another variable to change at a future point in time, it is said that there is causal (or cause and effect) relationship between the two variables. This is the idea behind the Granger causality analysis, i.e., to see whether causes happen before consequences and not vice versa (Granger 1969).

The simplified Granger causality analysis in this research is presented as:

$$WSP_t = \sum_{n=1}^{p} \alpha_{11} WSP_{t-n} + \sum_{n=1}^{p} \beta_{11} WSI_{t-n} + \varepsilon_{11,t} \quad (5\text{-}1);$$

$$WSI_t = \sum_{n=1}^{p} \alpha_{12} WSP_{t-n} + \sum_{n=1}^{p} \beta_{12} WSI_{t-n} + \varepsilon_{12,t} \quad (5\text{-}2);$$

$$WSP_t = \sum_{n=1}^{p} \alpha_{21} WSP_{t-n} + \sum_{n=1}^{p} \beta_{21} SPI_{t-n} + \varepsilon_{21,t} \quad (5\text{-}3);$$

$$SPI_t = \sum_{n=1}^{p} \alpha_{22} WSP_{t-n} + \sum_{n=1}^{p} \beta_{22} SPI_{t-n} + \varepsilon_{22,t} \quad (5\text{-}4);$$

$$WSI_t = \sum_{n=1}^{p} \alpha_{31} WSI_{t-n} + \sum_{n=1}^{p} \beta_{31} SPI_{t-n} + \varepsilon_{31,t} \quad (5\text{-}5);$$

$$SPI_t = \sum_{n=1}^{p} \alpha_{32} WSI_{t-n} + \sum_{n=1}^{p} \beta_{32} SPI_{t-n} + \varepsilon_{32,t} \quad (5\text{-}6).$$

Equations 5-1 and 5-2 aim to analyze the existence of a causal relationship between WSP and WSI. Each of these two variables is specified in each equation as a function of time-lag of both variables. α_s and β_s are the parameters that determine the extent of causal relationship, ε_s are the random error terms, *t* represents the year, *n* and *p* is the number of time-lag. The causal relationship between WSP and WSI is determined based on the following principles:

- WSI causes WSP if the estimated β_{11} is statistically different from zero, and the estimated β_{12} is statistically close to zero;
- WSP causes WSI if the estimated β_{11} is statistically close to zero, and the estimated β_{12} is statistically different from zero;
- There is a two-way causal relationship between WSP and WSI if the estimated β_{11} and β_{12} are statistically different from zero;
- There is no causal relationship between WSP and WSI if the estimated β_{11} and β_{12} are statistically close to zero.

Equations 5-3 and 5-4 are used to determine the existence of a causal relationship between WSP and SPI, based on the same principles outlined above. Similarly, the existence of a causal relationship between WSI and SPI is determined from equations 5-5 and 5-6.

5.3.2. Econometric analysis

The relationships between WSP, WSI and SPI (as presented in Figure 5-1) are transformed into a set of functional models to enable empirical estimation using an econometric method. The formalization of the model, in terms of how each variable in the model interacts, is informed by the correlation and causality analyses presented in Section 5.3.1. Once the model is formalized, an econometric approach is used, in this research, to empirically estimate the relationships between variables. Only limited studies exist that employed econometric methods to estimate the relationship between institutions and water sector performance. These studies are summarized as follows.

Saleth & Dinar (2004) developed one of the most comprehensive quantitative model to assess the relationship between performance and institutions in the context of water. The model is developed based on a multi-equation econometric approach where 10 equations are structured with sequential linkages.[7] Several variables are considered in this study, including 4 performance indicators, 21 indicators of water sector institutions (7 indicators for each of the three aspects of institutions, including water law, water policy, and water administration), and 12 control variables. Other wider institutional factors are however not included in this study. Data for water sector performance and institutions are collected through an international survey of 127 water experts from 43 countries, and are inherently qualitative where values for such indicators are assigned within the range of 0 to 10 by the experts. Based on this model set-up and survey-based data, the authors used a three-stage least square regression technique to demonstrate several institution-performance linkages. One such linkage is as follows: the overall performance of the water sector (average of the four performance indicators) depends on the overall effectiveness of water law (average of the seven water law indicators), which in turn depends on the effectiveness of the bureaucratic systems that are responsible to develop and enforce water laws, which in turn depends on water policy that promote water users' participation.

While the study by Saleth & Dinar (2004) provides an extremely useful basis for the method used in this research, it has several weaknesses. Some of these weaknesses are: lack of analysis of a 'wider' institutional factors (including social, economic and political) on water sector performance; arbitrary assumption about the (sequential) linkages rather than model specifications based on objective analysis; all variables, particularly performance indicators, are based on subjective valuation rather than quantifiable proxies. Some of these weaknesses have been overcome by the following studies.

Estache & Kouassi (2002) employed a censored tobit regression model to analyze the effects of water sector institution (type of ownership) and wider institutional factors

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[7] A multi-equation modelling approach typically assumes that the equations can be structurally nested either with sequential linkages or simultaneous linkages. The decision upon which type of linkages is used can be either subjective (i.e., based on the modeller's judgment), or objective (e.g., based on correlation and causality analyses).

(including the extent of corruption in the government, and the governance structure) on the efficiency of the water sector (in terms of an efficiency score based on DEA). The analysis is based on data of 21 African water service providers for the period between 1995 and 1997. The results show that corruption has had a significantly negative impact on the efficiency of water provision. On the other hand, the involvement of private sector and suitable governance structures resulted in improved efficiency of the water sector. The authors however did not specify which aspects of the governance structure are considered in the study.

Krause (2009) employed a multivariate regression model to investigate the influence of political governance on the performance of water services in developing countries. The analysis is based on a cross-sectional data of 69 countries. The results suggest that increased democratic participation and more checks-and-balances in political processes have a statistically significant positive effect on access to water services. It also shows that increased private participation in the water sector does not have statistically significant effect on water access.

Gizelis & Wooden (2010) employed a multivariate regression model to analyze the relationship between the availability of water resources and different political regimes (institutions). The study incorporates pooled data of 98 countries over the period 1981-2001; the selected countries are typified by a wide ranges of political institutions, from the military-based regimes to democratic states. A number of control variables are also included in the model, such as, precipitation, total population, level of urbanization, per-capita income. A key result of the study is that democratic political institutions are likely to prevail in countries with greater availability of water resources.

Bonacina et al. (2014) employed two analytical methods (censored tobit regression and ordinary least square regression) to analyze the effects of governance (including, type of ownership and local political parties) and managerial (including, concentration of customers and frequency of water interruptions) factors on DEA-based efficiency score of the Italian water utilities. The analysis is based on data of 51 urban water companies/utilities for the period between 2007 and 2010. The overall results show that the effects of ownership structure and politics on the efficiency of water utilities is insignificant.

The methodology adopted in this research is based on insights gained from a review of above noted studies, supplemented by the water-institutional context in Thailand. Firstly, the methodology adopted in this research follows Saleth & Dinar (2004) in using a multi-equation econometric approach to estimate relationships between institutions and performance, rather than using a single-equation multivariate econometric as adopted in other studies noted above. This is because, as discussed in Section 5.2 and presented in Figure 5-1, the relationship between institutions and performance is not likely to be simple and direct. Accordingly, this research employs a three-stage least square regression technique for the estimation of parameters as this technique is suitable to capture the relationships between variables that are complicated and indirect.

Further, this research also employs a simpler ordinary least square regression technique, such as that used by Krause (2009) and Gizelis & Wooden (2010), in order to examine the robustness of the estimated parameters. This research also examines the robustness of the estimation by employing a censored tobit regression technique, following Estache & Kouassi (2002) and Bonacina et al. (2014). These two studies note that there is no consensus as to which regression techniques should be used when the dependent variable has values that cluster within a limited range, such as between 0 and 1 as in the case of efficiency score. Hoff (2007), for example, argues that the DEA efficiency score introduces a censoring problem as values are not distributed evenly, but clustered around a limiting value. In this case, tobit regression would be superior to ordinary least square, as it is likely to produce unbiased estimates of parameters. McDonald (2009), on the other hand, contends that using a tobit model, when DEA efficiency score is a dependent variable, will result in an error term being heteroscedastic, thus resulting in inconsistent estimates of parameters. This study (i.e., McDonald 2009) then recommends the use of ordinary least square regression, over tobit regression. Given such a stark disagreement in literature as to the selection of suitable estimation technique, this research adopts both ordinary least square and tobit regressions.

The simplified multi-equation model adopted in this research is formulated as:

$$\mathrm{WSP}_{\mathrm{it}} = \beta_0 + \beta_1 \mathrm{WSI}_{\mathrm{it}} + \beta_2 \mathrm{SPI}_{\mathrm{it}} + \beta_3 \mathrm{NIF}_{\mathrm{it}} + \varepsilon_{\mathrm{it}} \quad (5\text{-}7);$$

$$\mathrm{WSI}_{\mathrm{it}} = \alpha_0 + \alpha_1 \mathrm{SPI}_{\mathrm{it}} + \alpha_2 \mathrm{WSI}_{\mathrm{it}} + \alpha_3 \mathrm{WSP}_{\mathrm{it}} + \upsilon_{\mathrm{it}} \quad (5\text{-}8).$$

Equation 5-7 aims to assess the effects of WSI on WSP. However, as noted in Section 5.2, SPI may also directly affect WSP, and hence included in this equation. Other non-institutional factors (NIF) that may affect WSP are included as control variables. This equation therefore specifies $\mathrm{WSP_{it}}$ as a function of $\mathrm{WSI_{it}}$, $\mathrm{SPI_{it}}$ and $\mathrm{NIF_{it}}$ for basin *i* and year *t*. β_s are the estimated parameters, and ε is the random error term.

Similarly, equation 5.8 aims to assess the effects of SPI on WSI. Again, as noted in Section 5.2, WSI may also be affected by WSP. This equation specifies $\mathrm{WSI_{it}}$ as a function of $\mathrm{SPI_{it}}$, $\mathrm{WSI_{it}}$ and $\mathrm{WSP_{it}}$ for basin *i* and year *t*. α_s are the estimated parameters, and υ is the random error term.

Both equations are estimated as linear functions. The adoption of such a simple functional form is justified on the basis of the argument that the main purpose of this estimation (in this research) is to demonstrate the existence of linkages among variables (institutions and performance). Using a more complicated functional form, such as quadratic or logarithmic, has the potential to present serious technical constraints in the estimation, and thus defeat a key purpose of this research. Also, a constant term is introduced in both equations (β_0 and α_0) to account for the effects of factors that are not explicitly included in the model (i.e., factors other than WSI, SPI and NIF).

In a three-stage least square regression (model), equations 5-7 and 5-8 are estimated as a system of simultaneous equations. The estimated parameters in this model thus account for the linkages between both equations. In ordinary least square and censored tobit regressions (models), on the other hand, both equations 5-7 and 5-8 are estimated separately as a single equation. Thus the estimated parameters (β_s and α_s) ignore the linkages between both equations.

5.4. Description of variables and data

5.4.1. Variable selection and definition

In order to implement the methods discussed above, four groups of variables need to be identified. These are WSP, WSI, SPI, and NIF. The selection of variables for each group is based on their ability to reflect the key attributes of their respective group, and also their amenability to quantification for empirical analysis. Further, while some of these variables are quantitative and directly available or quantifiable using proxy data, others are inherently qualitative and thus requires some subjective considerations. These subjective variables are mainly related to WSI, and are obtained from consultations with water sector experts in the country. Table 5-1 presents the summary of these variables for the three-stage water sector.

Table 5-1 Summary of variables used for econometric analysis

	Water Sector		
	Water supply (Stage 1)	**Water usage (Stage 2)**	**Water-benefits (Stage 3)**
WSP	- Efficiency score (ES_1)	- Efficiency score (ES_2)	- Efficiency score (ES_3)
WSI	- Project selection criteria (PRO) - Ownership (OWN) - Organizational structure (ORG) - Accountability (ACC)	- Water "rights" (RIGHTS) - Independent regulation (REG_2) - Organizational structure (ORG) - Policy integration (INT)	- Degree of competition in agricultural products (COMP) - Independent regulation (REG_3)
SPI	- Political power (POL) - Checks and balances (CHK) - Level of democracy (DEM) - Bargaining power of key water user (BAR) - Geographic-political boundaries (BOUND)		
NIF	- Water resources (WAT) - Land area (LAND)	- Rainfall (RAIN) - Tributary (RIV) - Land area (LAND) - Income (INC) - Population density (DEN)	- Income level (INC) - Population density (DEN)

Notes: WSP – Water Sector Performance; WSI – Water Sector Institutions; SPI – Socio-Political Institutions; NIF – Non-institutional factors.

The description of variables for each of the four groups is provided as follows.

First, the efficiency score (ES) is selected as an indicator of water sector performance (WSP), similar to that adopted by Estache & Kouassi (2002) and Bonacina et al. (2014). The selection of this variable in this research is justified on the basis that it reflects overall performance of the water sector, and it is developed by using a Malmquist-based Data Envelopment Analysis method (see Chapter 4).

For the second group (WSI), there is no standard definition of water sector institutions. Hence, there is no reliable and consistent data on this aspect. Because of these limitations, some major studies (for example, Krause 2009) completely ignored this component in their analysis, and concentrated only on analyzing the macro-level relationships (i.e., between political institutions and water sector performance). This research however follows Saleth & Dinar (2004) in using subjective proxies to define institutional factors of the water sector. Data for these proxies are obtained from a survey of 49 water experts across the public and private organizations in Thailand; the list of these experts are provided in Appendix A. These proxy variables and their definitions are as follows.

- Project selection criteria (PRO): a criteria used for making decisions on investments in water infrastructure projects; this variable has a value range of 0-3, with 0 representing no criteria (i.e., no specific criteria was followed to make investment decisions); 1 for financial/economic (i.e., the criteria for investments focused on financial and economic considerations); 2 for social and environmental (i.e., social and environmental considerations were the primary factors influencing investment decisions); and 3 for political dictates (i.e., investments were predominantly driven by political considerations).

- Ownership (OWN): type of ownership in the provision of water supply; this variable has a value range of 0-2, with 0 representing exclusively public supply; 1 for public-private partnership; and 2 for sole private ownership.

- Organizational structure (ORG): whether the water sector organization is arranged according to administrative functions (value of 0), or according to geographic location, i.e., by basin (value of 1).

- Accountability (ACC): the effectiveness of accountability (e.g., administrative oversight, financial auditing, etc.) in water organizational arrangements; values expressed on a 0-5 scale; a value of zero denoting extreme unaccountability and 5 – high level of accountability.

- Water 'rights' (RIGHTS): the format of rights to use water resources; unclear or unauthorized (value of 0); proportional-sharing system (value of 1); and license or permit system (value of 2).

- Independent regulation (REG): the existence of independent body for regulating water usage (stage 2) and agricultural sector (stage 3); a dummy variable with a value of 1 if there is independent regulation, but 0 otherwise.

- Policy integration (INT): the extent to which agricultural policies are considered while formulating water policy; value expressed on a 0-5 scale, where 0 means that water policies are developed in complete isolation, and 5 means that water and agricultural policies are developed conjointly.

- Degree of competition (COMP) in the agriculture sector; value expressed on a 0-5 scale, where 0 means no competition.

For the third group (SPI), several variables are used to measure the wider institutional factors that have shaped the water sector institutions in Thailand. Further, unlike other factors, the wider institutional factors are common for all three stages of the water sector. The selection of variables in this group (SPI) follow existing literature reviewed in Section 5.3.2, particularly Estache & Kouassi (2002), Krause (2009), Gizelis & Wooden (2010) and Bonacina et al. (2014). These variables and their definitions are as follows.

- Political power (POL): whether the major political party in the basin area is in the national-level government; a dummy variable with a value of 1 if the major political party in the basin area is in the government, but 0 if the major political party is from the opposition. This variable postulates that a basin has more political power compared to other basins if the major political party in that basin is in the national-level government. Data on this variable is compiled from various databases of the Election Commission of Thailand and the Secretariat of the Cabinet.

- Checks and balances (CHK) in political system: determined by the degree of distribution of political power in the basin-based electorate; value expressed on a 0-1 scale, with a value of 0 means an equal distribution of all political parties in the electorate (hence, more checks and balances), and 1 means that just one political party in the electorate (hence, no checks and balances). Data from the above variable (POL) is used to determine CHK by employing a widely-used Herfindahl–Hirschman Index method, by squaring the percentage share of each political party in the basin-based electorate and then summing the resulting values.

- Level of democracy (DEM): determined by the basis used for the formation of constitutional legislatures, that is, whether their members are appointed by a particular interests group (a value of 0), or elected through an open voting system (a value of 1). Data for this variable is common for all basins, and is obtained directly from the Office of the Council of State, Royal Thai Government.

- Bargaining power (BAR) of key water users: represents bargaining power of farmers and industrialists; this variable is calculated by dividing the value-added of the agriculture sector with value-added of the manufacturing sector – a relatively high value in any basin means that farmers in that basin have more bargaining power than industrialists. Data on value-added is compiled from databases published by the Office of the National Economic and Social Development Council.

- Compatibility of geographic-political boundaries (BOUND): refers to the number of provinces in each basin, which is used to determine the extent of competition for budget, for example, among provinces in a basin area as budget is allocated at the provincial level but management of water sector is undertaken at the basin level. Data for this variable is obtained from the Royal Irrigation Department.

Finally, the analysis is controlled for further independent variables that are likely to have an influence on the performance of water sector; these control variables are called NIF in this research. Similar to variables for SPI, the selection of variables in this group is also based on Estache & Kouassi (2002), Krause (2009), Gizelis & Wooden (2010) and Bonacina et al. (2014). These variables and their definitions are as follows.

- Water resources (WAT): the availability of water resources in a basin area is represented by the total amount of annual water runoff in million cubic meters. Data for this variable is obtained from the Department of Water Resources.

- Land area (LAND): total area in a basin that is suitable for agricultural production, and hence irrigation. Data for this variable is obtained from the Department of Water Resources.

- Rainfall (RAIN): annual rainfall in millimeters, obtained from the Meteorological Department of Thailand. This data is available at the provincial-level; equation 4-5 (in Chapter 4) is used to convert provincial data into basin-level data.

- Tributary (RIV): the number of tributaries within a basin area, obtained from the Department of Water Resources.

- Income (INC): per-capita gross provincial product is used as a proxy for the average income levels. Data on this variable is developed from databases published by the Office of the National Economic and Social Development Council.

- Population density (DEN): total population divided by total land area for each basin. Data on population is obtained from the Office of the National Economic and Social Development Council, and data on land area is obtained from the Department of Water Resources.

5.4.2. Description of data

This research employs panel data for 25 water basins in Thailand, covering the period 1987-2017. The datasets employed in this research (i.e., data for variables listed in Table 5-1) are provided in Appendix C. Some descriptive statistics of the data are presented in Table 5-2.

Table 5-2 Summary of descriptive statistics

Groups	Variables	Obs.	Mean	Min	Max	S.D.	Skewness	Kurtosis
WSP	ES_1	775	0.5	0.0	1.0	0.3	0.0	1.0
	ES_2	775	0.7	0.0	1.0	0.2	-0.4	1.3
	ES_3	775	0.8	0.3	1.0	0.2	-0.8	1.8
WSI	PRO	775	1.8	0.0	3.0	1.1	-0.4	1.9
	OWN	775	0.6	0.0	1.0	0.5	-0.6	1.4
	ORG	775	0.3	0.0	1.0	0.5	0.8	1.6
	ACC	775	2.3	1.0	3.1	0.6	-0.4	2.2
	RIGHTS	775	0.3	0.0	1.0	0.5	0.8	1.6
	INT	775	2.6	1.0	3.5	0.7	-0.5	2.5
	COMP	775	2.8	1.0	3.5	0.7	-1.1	3.7
	REG_2	775	0.3	0.0	1.0	0.5	0.8	1.6
	REG_3	775	0.5	0.0	1.0	0.5	0.1	1.0
SPI	BOUND	775	8.9	3.0	21.0	5.0	0.0	1.0
	POL	775	0.8	0.0	1.0	0.4	-1.6	3.4
	CHK	775	0.6	0.2	1.0	0.3	0.0	1.4
	DEM	775	0.3	0.0	1.0	0.5	0.9	1.9
	BAR	775	1.8	0.1	9.1	1.8	0.3	2.5
NIF	WAT	775	7.9	1.2	34.0	7.8	1.7	5.6
	LAND	775	5.6	0.9	25.7	5.9	2.0	6.6
	RAIN	775	1.4	0.5	3.1	0.5	1.3	4.0
	RIV	775	10.2	2.0	37.0	9.0	1.1	3.2
	INC	775	81.1	12.7	377.6	72.3	1.1	3.4
	DEN	775	127.3	20.0	686.0	119.1	2.5	8.4

Notes:
1. The detailed dataset used to develop this table is provided in Tables C10-C18, Appendix C.
2. Obs. = observations; S.D. = standard deviation; abbreviations under the heading Groups and Variables are described in Table 5-1.
3. Skewness is a measure of the asymmetry of the probability distribution of a variable about its mean; data sets with low value of skewness tend to have symmetric

probability distribution (negative values indicate data that are skewed left and positive values indicate data that are skewed right).

4. Kurtosis is a measure of the 'tailedness' of the probability distribution, or the "sharpness" of the peak of probability distribution, of a variable; data sets with low kurtosis tend to have light tails, or lack of outliers.

A review of the table suggests that the mean value for all three variables of WSP are the same as discussed in Chapter 4; the efficiency scores of stages 1, 2 and 3 of the water sector are approximately 0.5, 0.7 and 0.8, respectively. The standard deviation (S.D.) is highest for ES_1 and lowest for ES_3. This means that there are more significant differences in ES_1 for 25 basins across the sample period as compared with ES_2 and ES_3. Further, these variables are normally distributed as their skewness are in the range of -1 and 1, and kurtosis' are lesser than 3.

For variables that belong to other groups (particularly WSI and SPI), most variables are also normally distributed. There are however some exceptions. For example, sample data for COMP and POL are slightly skewed to the left, while most data for NIF are slightly skewed to the right. In addition, all these data that exhibits some degree of skewness also have value of kurtosis that are slightly larger than 3. This means that these data have a slightly heavier tail (or flatter peak). Despite the existence of slightly non-normal distribution, these data are still suitable to be used with parametric method, such as econometrics, employed in this study.

Some variables, on the other hand, may not be suited to be used with parametric method, and must therefore be interpreted with caution. These variable are mainly for NIF, including LAND, DEN, WAT and RAIN. This is because these four variables have relatively high values of skewness and kurtosis, which means that they are most likely to exhibit a non-normal distribution.

5.5. Empirical results and discussion

This section examines the institution-performance linkages of the Thai water sector. This examination is conducted for each of the three stages of the water sector in the following subsections. In each subsection, the relationship among the selected variables is first established from correlation and causality analyses. This is followed by the examination of the effects of institutional factors on shaping the performance of water sector (based on econometric analysis).

5.5.1. Institution-Performance linkages in water supply (Stage 1)

This subsection provides an assessment of the relationship between institutions and performance in stage 1 of the water sector. The term performance in this stage refers to the effectiveness of investments in creating water infrastructure (see Chapter 4). The relationship among selected variables for the first stage of the water sector is summarized in Table 5-3 in a form of pairwise comparison matrix of correlation and causality.

Table 5-3 Estimation results of correlations and causality: Stage 1

		ES_1	WSI				SPI					NIF
			OWN	PRO	ORG	ACC	BOUND	POL	CHK	DEM	BAR	WAT
WSI	OWN	↔										
	PRO	→	→									
	ORG	↔	←	↔								
	ACC	→	↔	↔	↔							
SPI	BOUND	→	—	—	—	—						
	POL	—	—	→	→	→	—					
	CHK	→	←	—	→	→	—	←				
	DEM	→	→	→	→	—	—	→	↔			
	BAR	—	—	—	—	—	—	—	—	—		
NIF	WAT	—	—	—	—	—	—	—	—	—	—	
	LAND	→	—	—	—	—	—	—	—	—	—	—

Notes: 1. All abbreviations are described in Table 5-1.
2. Bold indicates strong correlation; red indicates weak correlation; shaded area indicates that correlation is significant at 5% level.
3. '→', '↔', '←' indicate the direction of the causal relationship between variables, and '—' indicates no causal relationship between variables.
4. This table is developed from detailed results presented in Tables E-1 and E-2, Appendix E.

A review of this table suggests the following:

- There is evidence of institution-performance linkages in stage 1 of the water sector. Specifically, there is a correlation between most variables of water sector institutions (WSI) and the performance of water supply provision (ES_1). While the extent of correlation is moderate, yet it is statistically significant, which implies that these institutional variables should ideally be included in the statistical model. The evidence of causality between these variables further substantiate this claim. For example, there is a unidirectional causation from the project selection criteria (PRO) and accountability in the water sector (ACC) to ES_1. In addition, there is a bidirectional causation between the type of ownership in the provision of water supply (OWN) and its performance; the same is true for the organizational structure (ORG).

- However, the evidence of strong inter-institutional linkages within the water sector (i.e., correlation among variables of water sector institutions) suggests that the inclusion of water sector institutions as independent variables in the model needs to proceed with caution. For example, the correlation between five out of six pairs of water sector institutions are both strong and statistically significant; only the correlation between ORG and PRO is weak. As noted by Gujarati & Porter (2008), the inclusion of highly-correlated variables as independent variables of the statistical model might cause multi-collinearity problem, resulting in imprecise estimation of coefficients. Since the estimated coefficients reflect the magnitude of impacts that water sector institutions may have on water sector performance, the existence of multi-collinearity among the institutional variables means that the model may not able to precisely estimate their impacts on water sector performance.

- There is also evidence of intra-institutional linkages; there exists correlation between socio-political institutions (SPI) and water sector institutions (WSI), and the direction of causation for most variables running from the former to the latter. For example, increased checks and balances in the political system (CHK) is likely to lead to improvement in organizational structure (ORG) and accountability (ACC) in the water sector. In some cases, the direction of causation may run in the opposite direction. For example, increased private participation in the provision of water supply (OWN) may results in increase in checks and balances in the political system.

- The evidence of intra-institutional linkages and institution-performance linkages within the water sector (above) also suggests that there is likely to be an indirect relationship between socio-political institutions and water sector performance. For example, increased checks and balances in the political system (CHK) is likely to lead to accountability (ACC) in the water sector, which in turn is likely to improve performance of water supply provision (ES_1).

- In fact, the relationship between socio-political institutions and water sector performance can be direct. For example, there is evidence of correlation between three socio-political institutional variables and ES_1. These variables are: BOUND, CHK and DEM. Further, there is a causation running from these socio-political institutions to the performance indicator, which suggests that improvement in these wider institutional factors is likely to directly improve water sector performance.

While the correlation and causality analyses (as above) is extremely useful for providing some insights into institution-performance linkages in water supply provision (stage 1), such linkages are however somewhat arbitrary as the analyses look at linkages between each pair of variables in isolation. Based on the understanding gained from these analyses, however, a statistical model is formalized in this research to estimate coefficients that reflect the institution-performance linkages in a comprehensive manner. In other words, the direction of causation is taken into account in the formalization of the simultaneous equations model. The estimated coefficients of the models for the first stage of the water sector are presented in Table 5-4.

Table 5-4 Estimation results of econometric models: Stage 1

VARIABLES		MODELS		
Dependent	**Independent**	**Tobit**	**OLS**	**3SLS**
ES_1	C	-0.100**	-0.001	0.122**
	OWN	0.154**	0.126**	0.203**
	PRO	0.046**	0.039**	-0.033*
	ORG	0.069**	0.062**	-0.040
	BOUND	0.046**	0.041**	0.040**
	LAND	0.000	0.000	0.000
OWN	C			-1.099**
	ACC			0.704**
	DEM			0.357**
	ES_1			0.013
PRO	C			-2.605**
	ACC			1.410**
	POL			-1.202**
	DEM			0.483**
ORG	C			-3.882**
	ACC			2.351**
	CHK			-1.487**
	DEM			-0.552**
	ES_1			-0.251**
ACC	C			1.777**
	OWN			0.200**
	CHK			-0.646**
R-squared			**0.575**	**0.518**

Notes: 1. C = Constant term; other abbreviations are described in Table 5-1.
2. ** and * means that the estimated coefficients are statistically significant at 5% and 10% levels, respectively.
3. This table is obtained from detailed results presented in Tables E-3 to E-5, Appendix E.

A review of this table suggests that:

- The type of ownership in the provision of water supply (OWN) is one of the most significant factor that affects the performance of the water sector. In particular, if the investment in water infrastructure projects is made by the private sector, the performance of the water sector would be approximately 0.203 index-point (3SLS model) higher relative to investments made by the public sector. That is, the efficiency score of the water supply provision would be 37 percent higher when investment in water infrastructure projects is made by the private sector (0.753, instead of 0.55 as estimated in Chapter 4). Estimates from OLS and tobit models also point to the same conclusion.

- The likelihood of private sector investment however depends on the accountability of the water sector (ACC), which in turn depends on the checks and balances in the political system (CHK). A higher concentration of political parties in the basin-based electorate (i.e., a higher value of CHK, which corresponds with lower checks and balances) is negatively correlated (-0.646) with the accountability in the water sector. Further, the accountability in the water sector is positively correlated with the extent of private sector involvement in water infrastructure investments (0.704), i.e., the higher the accountability, the more willing the private sector will be to make investments.

- Another factor that determines the extent of private sector investments in water infrastructure is the democratic participation of the citizens (DEM). In particular, there is a positive correlation between the level of democracy and the degree of private sector investments (0.357). If the constitutional legislative assembly is formed through an open voting system, for example, this would result in increased level of private sector investments in the water sector, and hence, improved performance of water supply provision.

▪ In addition to the type of ownership, the criteria to select water infrastructure projects (PRO) is also an important determinant of water sector performance (ES_1); the correlation between these two variables has a value of 0.033. For example, if the basis to select water projects is influenced by political reasons, the performance of water sector will be worse than if the projects are selected to support any particular interest based on social or environmental reasons. Similarly, the selection of projects based on this latter criteria will lead to the worse outcome compared with selection that is based on purely financial or economic criteria.

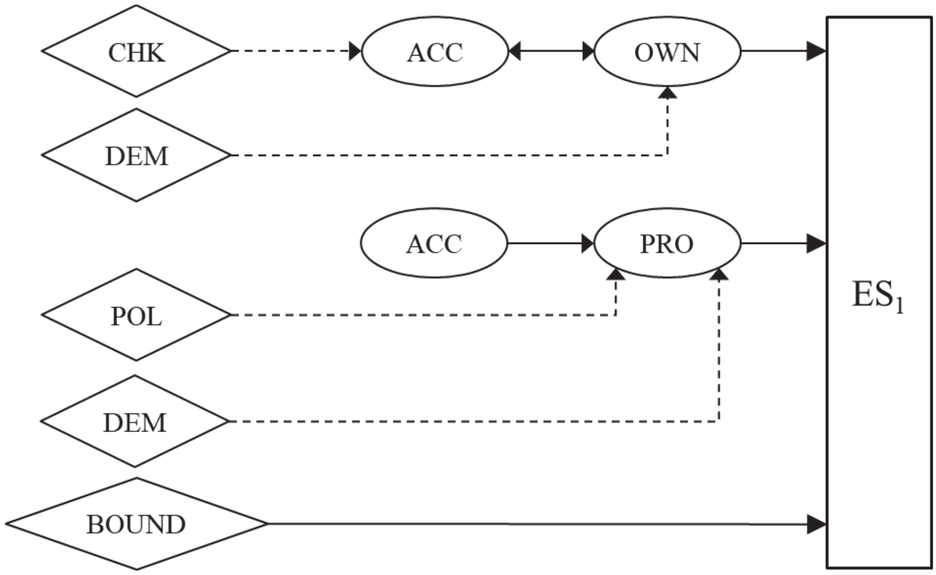
- Such project selection criteria is however dependent on the degree of accountability in the water sector; there is positive correlation between these two variables (1.41). That is, if there is more accountability in decision making process in the water sector, the basis of project selection tends to be driven by financial/economic criteria. In contrast, if there is zero accountability in decision making process within the water sector, the project selection tends to be dictated by politics.

- The project selection criteria is not only influenced by the degree of transparency and accountability within the water sector, but also depends on a wider socio-political institutions. Two such factors could drive project selection outcomes. First is the extent of political power (POL) at the basin level. If the major political party in the basin area is in the government, the project selection criteria tends towards political dictate outcome. In contrast, if the major political party from the basin area is in the opposition, the criteria of project selection tends towards neutrality, for example, focusing on financial/economic criteria. This is shown as the negative correlation between the two variables (-1.202). The second factor is the level of democracy at the level of the national government (DEM). In particular, there is a positive correlation between the level of democracy and the neutrality of project selection criteria (0.483). If the members of the constitutional legislative assembly are selected through an open voting system, for example, this would result in the selection of projects that do not favor any particular interest group (e.g., social, environmental or political).

- While the above noted wider socio-political institutional factors such as CHK, DEM and POL could indirectly affect the performance of water sector, through water sector institutional factors (such as OWN, ACC and PRO), there is one such wider factor that could have a direct impact on improving the performance of water supply provision. The estimated coefficient shows that there is a positive correlation between BOUND and ES_1 (0.04); a basin that has large number of provinces is likely to have a greater performance in terms of water supply provision. This implies that provinces within the basin area need to efficiently utilize the budgets that they receive to develop water infrastructure. If the utilization of budget in a basin is inefficient, this may affect its future budget allocation, where funds may divert to other provinces within the same basin area. In a basin that has lesser number of provinces, in contrast, there is likely to be less competition for budgets, and hence, lower performance.

The results and discussions of institution-performance linkages in the first stage of water sector (i.e., this section) can be summarized in Figure 5-3.

Figure 5-3 Institution-Performance linkages in water supply (Stage 1)



Notes: This figure is developed from discussion in this section, based on the framework presented in Figure 5-1. All abbreviations are described in Table 5-1.

5.5.2. Institution-Performance linkages in water usage (Stage 2)

This subsection provides an assessment of the relationship between institutions and performance in stage 2 of the water sector. The term performance in this stage refers to the effectiveness of utilizing water from the available infrastructure in producing agricultural outputs (see Chapter 4). The relationship among selected variables for the second stage of the water sector is summarized in Table 5-5 in a form of pairwise comparison matrix of correlations and causality.

Table 5-5 Estimation results of correlations and causality: Stage 2

		ES2	WSI				SPI					NIF			
			REG	ORG	INT	RIGHTS	BOUND	POL	CHK	DEM	BAR	RIV	DEN	INC	RAIN
	ES3	↔													
WSI	REG	—													
	ORG	—	x												
	INT	—	→	↔											
	RIGHTS	—	x	x	←										
SPI	BOUND	→	—	—	—	—									
	POL	—	→	→	→	→	—								
	CHK	→	→	→	→	→	—	←							
	DEM	—	→	→	→	→	—	→	↔						
	BAR	↔	—	—	—	—	—	—	—	—					
NIF	RIV	→	—	—	—	—	**—**	—	—	—	—				
	DEN	→	—	—	—	—	—	—	—	—	→	—			
	INC	↔	—	—	—	—	—	—	←	—	↔	—	**—**		
	RAIN	→	→	→	→	→	—	→	→	→	—	—	→	→	
	LAND	→	—	—	—	—	**—**	—	—	—	—	**—**	—	—	—

Notes: 1. All abbreviations are described in Table 5-1.
2. Bold indicates strong correlation; red indicates weak correlation; 'x' indicates perfect collinearity between variables; shaded area indicates that correlation is significant at 5% level.
3. '→', '↔', '←' indicate the direction of the causal relationship between variables, and '—' indicates no causal relationship between variables.
4. This table is developed from detailed results presented in Tables E-6 and E-7, Appendix E

A review of Table 5-5 suggests the following:

- Unlike in the stage 1 (section 5.5.1), there is no evidence of direct institution-performance linkages in stage 2 of the water sector. That is, there is no correlation and/or causation between any variable of water sector institutions (WSI) and the performance of water usage (ES_2). Accordingly, this group of variables is excluded in the statistical model to quantify the extent of relationships. This means that the inter-institutional and intra-institutional linkages are also not present in the analysis at this stage.

- There is however the evidence of linkages between SPI and ES_2. That is, the performance of water usage is dependent on the wider socio-political institutions. In fact, the relationship between the two is direct; changing SPI has a direct impact on ES_2 (as shown by a bold line between the two, in Figure 5-1), instead of indirectly changing ES_2 through WSI (as shown as dotted line in Figure 5-1). For example, there is evidence of correlations between three socio-political institutional variables and ES_2. These variables include: the compatibility of geographic-political boundaries (BOUND), checks and balances in the political system (CHK), and relative bargaining power of key water users (BAR). While the correlations between the two (SPI and ES_2) is weak, yet they are statistically significant.

- Further, there is a causation running from the former (SPI) to the latter (ES_2), which suggests that improvements in these wider institutional factors are likely to have a direct impact on water sector performance. One variable in particular (BAR) has a bidirectional relationship with ES_2.

- The performance of water usage is also influenced by several non-institutional factors (NIF), particularly the extent of tributaries or small rivers that are dispersed across the basin (RIV), population density (DEN), income levels (INC), rainfall (RAIN) and land area (LAND). While the correlation between the two groups (NIF and ES_2) is weak, they are still statistically significant.

While the correlation and causality analyses (as above) is extremely useful for providing some insights into institution-performance linkages in water usage (stage 2), such linkages are however somewhat arbitrary as the analyses looks at linkages between each pair of variables in isolation. Based on the understanding gained from these analyses, however, a statistical model is formalized in this research to estimate coefficients that reflect the institution-performance linkages in a comprehensive manner. In other words, the direction of causation is taken into account in the formalization of the simultaneous equations model. The estimated coefficients of the models for the second stage of the water sector are presented in Table 5-6.

Table 5-6 Estimation results of econometric models: Stage 2

VARIABLES		MODELS		
Dependent	**Independent**	**Tobit**	**OLS**	**3-SLS**
ES_2	C	-3.184**	-2.922**	-2.621**
	BOUND	-0.006	-0.005	-0.007
	CHK	-0.003	-0.003	-0.032
	BAR	0.061**	0.057**	0.047**
	RAIN	0.011	0.009	0.017
	RIV	-0.008**	-0.007**	-0.008**
	DEN	-0.027	-0.024	-0.030
	INC	0.294**	0.276**	0.232**
	LAND	0.075**	0.069**	0.080**
	ES_3	-0.532**	-0.498**	-0.451**
CHK	C			1.000**
	POL			-0.460**
	DEM			0.036*
R-squared			**0.266**	**0.258**

Notes: 1. C = Constant term; other abbreviations are described in Table 5-1.
2. ** and * means that the estimated coefficients are statistically significant at 5% and 10% levels, respectively.
3. This table is obtained from detailed results presented in Tables E-8 to E-10, Appendix E.

A review of this table suggests that:

- One of the most important factors that has significant direct impact on the efficiency of water usage is the bargaining power of farmers relative to other major energy users (BAR). The estimated coefficient (0.047) suggests a positive correlation between BAR and ES_2; a basin where farmers have more bargaining power is likely to utilize water in a more effective way to produce agricultural outputs.

- Additionally, there are two wider socio-political institutional factors that have direct impact on the efficiency of water usage, namely, checks and balances in the political system (CHK), and the compatibility of geographic-political boundaries (BOUND).

Despite being statistically insignificant (at 10% level), the linkages are real, as shown by the statistical significance of pairwise correlations and causation (Table 5-5).

- First, there is a negative correlation (-0.032) between CHK and ES_2, with the causation running from the former to the latter. That is, increased checks and balances in the local electorate at the basin level (i.e., a low value of CHK) could result in a better allocation of water resources across sectors, thus leading to improved performance of water usage. The results further suggest that there are two socio-political institutional factors that determine the degree of checks and balances in the political system. One such factors is the extent of political power at the basin level, where the correlation between POL and CHK is negative (-0.46). That is, if the political party from the basin-level electorate is in the government, there is likely to be more checks and balances in the utilization of political power at the basin level. Another factor is the level of democratic participation at the national-level government; there is a positive correlation between DEM and CHK (0.036). That is, if the members of the constitutional legislative assembly are selected through an open voting system, there is likely to be more checks and balances in political decisions at the basin level.

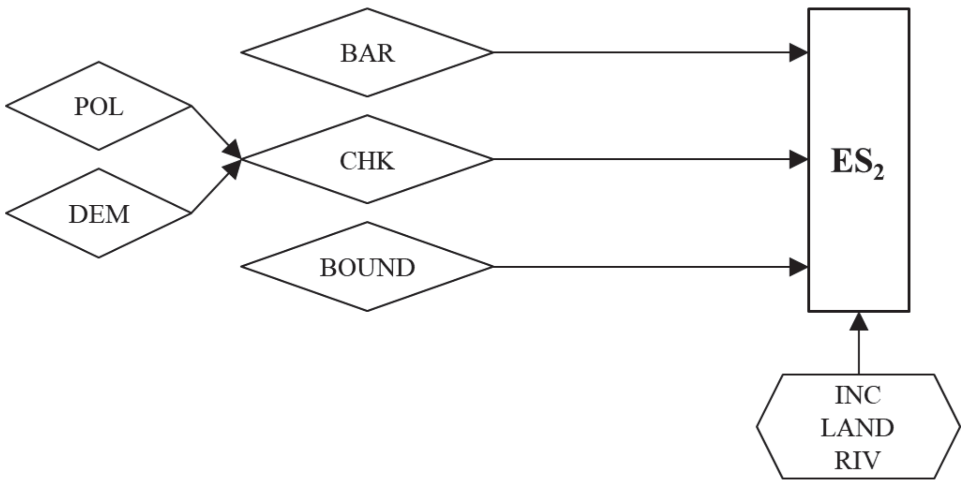
- Second, there is a negative correlation between BOUND and ES_2 (-0.007). That is, a basin that has large number of provinces is likely to be relatively less-efficient in the way water is utilized. This relationship is opposite of the relationship observed in the stage 1 of water sector, between BOUND and ES_1 (Section 5.5.1), where a basin that has large number of provinces is likely to be more efficient in water supply provision. Here, the negative correlation in stage 2 implies that there may be a lack of coordination between different provinces in utilizing water from the same basin. A lack of coordination means that water may not be allocated in a way that reflects the best use of water resources required for agricultural production, and hence worsening performance of water usage.

▪ There are several non-institutional factors (NIF) that could affect the efficiency of water usage. These factors are as follows:

- The levels of average income (INC) is strongly and significantly correlated with ES_2 (0.232). That is, increased income is likely to results in improved performance of using water to produce agricultural products.
- The availability of agricultural land (LAND) is significantly correlated with ES_2 (0.08). This is obvious as less water is typically needed to grow food on fertile land, as compared with growing food on infertile land.
- Basins with large number of tributaries or small rivers (RIV) is negatively correlated with ES_2. As ES_2 explains the efficiency of using water from available infrastructure such as dams or irrigation systems to produce agricultural products (see Chapter 4), the negative correlation between RIV and ES_2 means that farmers are less dependent on water infrastructure to meet their water needs as they have a choice to withdraw water from natural system (i.e., tributaries and small rivers).

The results of institution-performance linkages in the second stage of water sector (this section) can be summarized in Figure 5-4.

Figure 5-4 Institution-Performance linkages in the water usage (Stage 2)



Notes: This figure is developed from discussion in this section, based on the framework presented in Figure 5-1. All abbreviations are described in Table 5-1.

5.5.3. Institution-Performance linkages in water-benefits (Stage 3)

This subsection provides an assessment of the relationship between institutions and performance in stage 3 of the water sector. The term performance in this stage refers to the effectiveness of the system that convert agricultural outputs into farmer income/earnings (see Chapter 4). The relationships among the selected variables for the third stage of the water sector is summarized in Table 5-7, in a form of pairwise comparison matrix of correlations and causality.

Table 5-7 Estimation results of correlations and causality: Stage 3

	ES3	COMP	REG_3	BOUND	POL	CHK	DEM	BAR	DEN
ES_1	—								
ES_2	↔								
COMP	—								
REG_3	—	↔							
BOUND	—	—	—						
POL	—	→	←	—					
CHK	—	→	←	—	←				
DEM	—	→	↔	—	→	↔			
BAR	↔	—	—	—	—	—	—		
DEN	↔	—	—	—	—	—	—	→	
INC	↔	—	—	—	—	←	—	↔	**—**

Notes: 1. All abbreviations are described in Table 5-1.
2. Bold indicates strong correlation; red indicates weak correlation; shaded area indicates that correlation is significant at 5% level.
3. '→', '↔', '←' indicate the direction of the causal relationship between variables, and '—' indicates no causal relationship between variables.
4. This table is developed from detailed results presented in Tables E-11 and E-12, Appendix E.

A review of this table suggests that:

- Similar to stage 2 (section 5.5.2), there is no evidence of direct institution-performance linkages in the stage 3 of water sector. That is, there is no correlation and causation between any variable of water sector institution (WSI) and the performance of water sector in stage (ES_3; the ability of farmers to raise their income from agricultural production). Accordingly, this group of variables is excluded in the statistical model to quantify the extent of relationships. This means that the inter-institutional and intra-institutional linkages are also not present in the analysis at this stage.

- There is however the evidence of linkages between SPI and ES_3. In fact, there is one key factor (BAR) that has a direct linkage with ES_3, and the linkage is bidirectional. That is, the ability of farmers to raise their income from agricultural production depends on the relative bargaining power of farmers with respect to other water users.

Conversely, increased farmer earning from agricultural production is also likely to increase their bargaining power.

While the correlation and causality analyses (as above) is extremely useful for providing some insights into institution-performance linkages in stage 3 of the water sector, such linkages are however somewhat arbitrary as the analyses looks at linkages between each pair of variables in isolation. Based on the understanding gained from these analyses, however, a statistical model is formalized in this research to estimate coefficients that reflect the institution-performance linkages in a comprehensive manner. In other words, the direction of causation is taken into account in the formalization of the simultaneous equations model. The estimated coefficients of the models for the third stage of the water sector are presented in Table 5-8.

Table 5-8 Estimation results of econometric models: Stage 3

VARIABLES		MODELS		
Dependent	**Independent**	**Tobit**	**OLS**	**3-SLS**
ES_3	C	-1.725**	-1.716**	-0.932**
	BAR	0.059**	0.059**	0.044**
	DEN	-0.142**	-0.142**	-0.128**
	INC	0.294**	0.293**	0.198**
	ES_2	-0.231**	-0.230**	0.096
R-squared			**0.401**	**0.238**

Notes: 1. C = Constant term; other abbreviations are described in Table 5-1.
2. ** and * means that the estimated coefficients are statistically significant at 5% and 10% levels, respectively.
3. This table is obtained from detailed results presented in Tables E-13 to E-15, Appendix E.

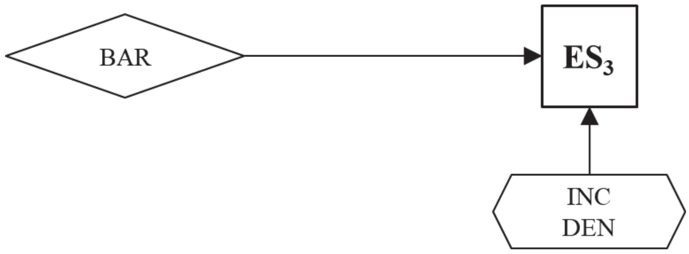
A review of this table suggests that:

- The bargaining power of the farmers the only factor (that is considered and observed in this research) that determines the effectiveness of transforming agricultural products into increased earnings. The estimated coefficient shows that there is a positive correlation (0.044) between BAR and ES_3; a basin where farmers have more bargaining power is likely to have more ability to add more wealth from its agricultural production.

- Some non-institutional factors (NIF) could also affect the performance of the water sector in this stage. One such factor is the average income level; there is a positive correlation (0.198) between INC and ES_3. The basin that has relatively higher average income (living standard) is likely to generate more earnings for farmers from agricultural production. However, if the basin is densely populated, the ability to raise earnings is likely to be relatively less. This is shown as a negative correlation (-0.128) between DEN and ES_3.

The results and discussion of institution-performance linkages in the third stage of water sector (this section) can be summarized in Figure 5-5.

Figure 5-5 Institution-Performance linkages in the water-benefits (Stage 3)



Notes: This figure is developed from discussion in this section, based on the framework presented in Figure 5-1. All abbreviations are described in Table 5-1.

5.6. Summary and conclusions

This chapter has empirically investigated – for 25 basins, for the period 1987-2017 – the influence of institutional factors on the performance of the water sector (WSP) in Thailand. Two types of institutions are included in this investigation: those directly associated with the water sector (water sector institutions, WSI), and those that are outside of the domain of water sector (socio-political institutions, SPI). This investigation is conducted for each of the three stages of water sector: 1) water supply provision (i.e., infrastructure development), 2) water usage (for producing agricultural outputs), and 3) earnings of water-dependent farming.

The major findings of this chapter are as follows:

- The wider socio-political institutions (SPI) have historically exerted significant influence on the performance of the water sector in Thailand. Further, these wider influencing factors have affected water sector performance (WSP) both directly and indirectly, through water sector institutions (WSI).

- The bargaining power of the key water users (BAR) seems to have a direct effect on the performance of water usage (stage 2) and the earnings of water-dependent farming (stage 3). In particular, the results show that a basin where farmers have more bargaining power, relative to water users from the industry sector, is likely to utilize water in a more effective way, to produce agricultural outputs (stage 2), and has better ability to raise their income from agricultural production (stage 3).

- The compatibility of geographic-political boundaries (BOUND) could also directly affect water sector performance. However, the effect of this factor is positive in one area and negative in the other. For example, statistical evidence shows that a basin that has large number of provinces is likely to have a better performance in water supply provision (stage 1), due probably to increased competition for budget allocation to develop water infrastructure. In contrast, a basin that has large number of provinces is likely to be relatively less-efficient in the way water is utilized (stage 2), due perhaps to a lack of coordination between different provinces in utilizing water from the same basin.

- Another factor that has the potential to directly affect water sector performance is the level of checks and balances in the political system (CHK). Higher checks and balances in the local electorate at the basin level could result in a better allocation of water resources across the water users, leading to improvement in performance of water usage (stage 2).

- The checks and balances in the political system (CHK) also seem to have an indirect effect on water sector performance, particularly in water supply provision (stage 1). Evidence suggests that increased checks and balances in the local electorate at the basin level is likely to lead to the establishment of transparent and accountable water sector institutions (ACC), which in turn would result in increased participation of private sector in water infrastructure investments (OWN), thus improving the performance of the water sector.

- There is also strong evidence to suggest that democratic participation by the citizens at the national-level (DEM) affects performance of water supply provision (stage 1), through two water sector institutional channels. In other words, if the members of the constitutional legislative assembly are selected through an open voting system, there will be two channels through which water sector performance will improve. First, there will be increased private sector investments in the water sector (OWN). Second, the criteria for selecting water projects (PRO) will be neutral, that is, not favoring any particular interest groups in society.

- Another factor that could indirectly affect the performance of the water supply provision (stage 1) is the extent of political power at the basin level (POL). If the major political party from the basin-level electorate is in the national-level government, the project selection criteria (PRO) appears to be directly driven by ‘politics’, favoring specific interest group (e.g., social, environmental or political). In contrast, if the major political party from the basin area is in the opposition, the criteria of project selection tends towards neutrality, leading to improvement in performance of the water sector.

In summary, the analysis in this chapter has demonstrated that wider socio-political institutions have indeed affected the performance of the water sector in Thailand, directly, and indirectly through water sector institutions. Such an outcome thus provides a validation to the key premise of this research, namely, socio-political institutions do affect the performance of the water sector. This validation further strengthens the case to revisit the existing water policy framework, that has recently been developed in Thailand, based almost entirely on water-specific considerations. A water policy framework, developed solely by focusing on the consideration of water-specific institutions (e.g., water regulation, administrative and organizational arrangements for water), is unlikely to improve the sector’s performance, as has happened in the past. The ‘key’ to improving water sector performance lies in the appreciation of the influence of these wider socio-political institutions in the design of water policy framework. This appreciation could enable the design of a water policy framework that accords with the country’s economic, social and political realities, and hence contributes to improved performance of the water sector. This is the subject matter of discussion in the next chapter.

CHAPTER 6 A SUITABLE FRAMEWORK FOR WATER RESOURCE MANAGEMENT IN THAILAND

6.1. Introduction

The previous chapters of this thesis developed a comprehensive analysis of various facets of the water sector in Thailand. Chapter 3 provided a detailed discussion on the historical evolution of the water sector in Thailand. It showed that the Thai water sector has been undergoing a restructuring of its institutions since the 1980s, with the expectation that this would improve the sector performance, and contribute to enhancing the livelihoods of rural population. The assessment undertaken in Chapter 4 however showed that this was not the case; the performance of the water sector over the past three decades has remained poor. The analysis in Chapter 5 further revealed that the performance of the water sector in Thailand has essentially been strongly influenced by the underlying socio-political institutions of the country. The institutions designed to directly govern the water sector, which have been the focus of restructuring since the 1980s, have had rather limited effects on the sector's performance. Based on these findings, this chapter aims to develop a framework for water resource management that accords with the country's social and political realities. This framework, this research argues, will lead to effective management of water resources, improve performance of the water sector and, by implication, enhance the livelihood of people whose socio-economic condition is very much dependent on water.

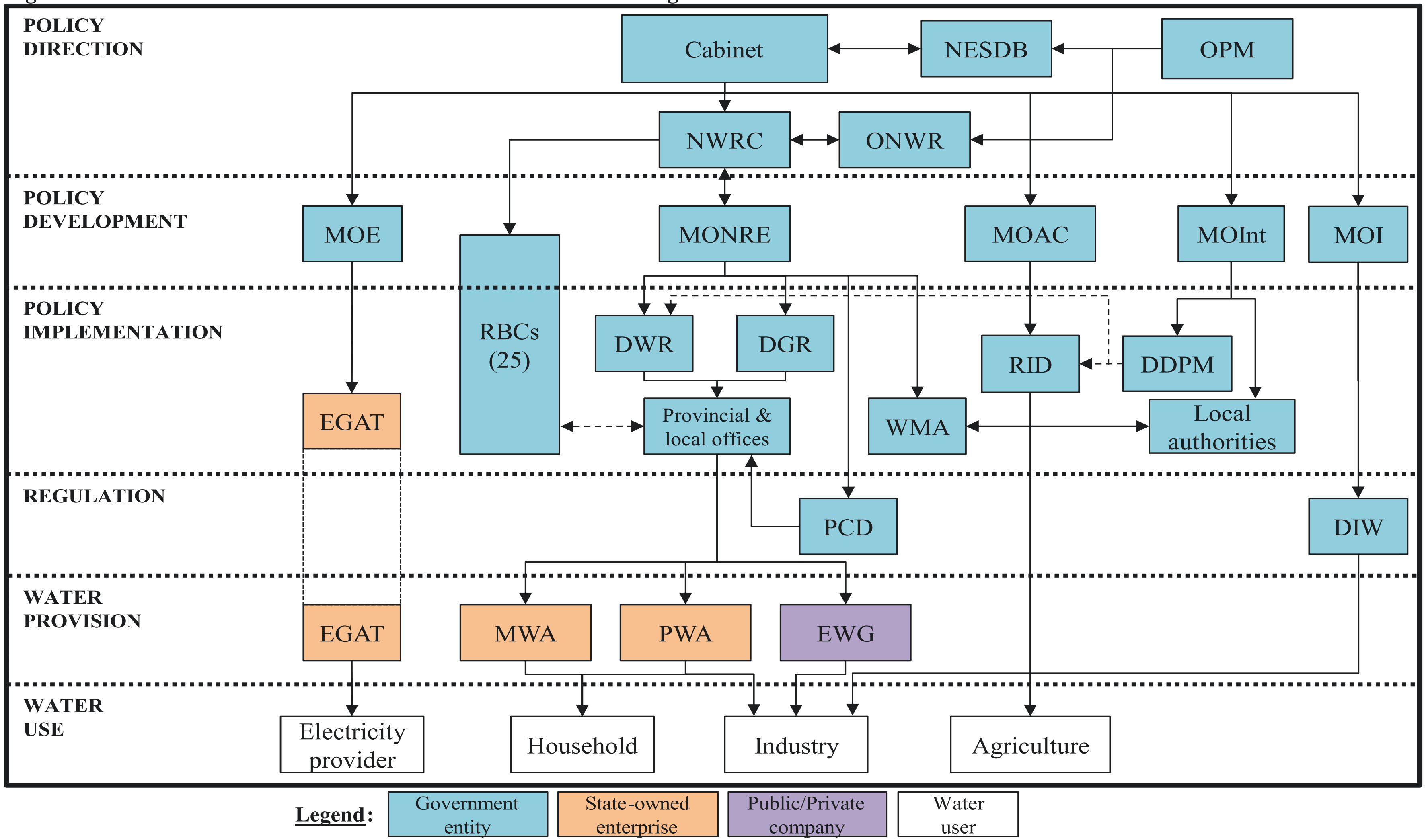
This chapter is organized as follows. Section 6.2 analyzes the existing framework for water resource management in Thailand in terms of its institutional structure for providing policy direction, for developing and implementing water policies, and for regulating the water sector – to meet the water needs of a society. Section 6.3 presents the key features of the proposed framework for water resource management that accord with the country's realities. This section also discusses the key challenges that the country is likely to face in implementing the proposed framework. Section 6.4 summarizes the major findings of this chapter.

6.2. Existing framework for water resource management

This section analyzes the existing framework for water resource management in Thailand. This analysis is specifically drawn from the insights gained from chapters 3 and 5, in terms of identifying institutional weaknesses – in both water-specific and wider socio-political institutions – in existing framework for water resource management in the country.

Based on the review and description of water sector institutions in Section 3.3 (Chapter 3), Figure 6-1 provides a panoramic overview of the current institutional structure of the Thai water sector.

Figure 6-1 Current institutional structure of water resource management in Thailand



Source: Developed by the author from various sources (Biltonen 2003; DRI 2002; DWR 2016; Krairapanond 2018; MFA 2016; WB 2011)

Notes:
- Single arrow – flow of command; double arrow – flow of consultation; dashed line – coordination
- Acronyms – see list of glossary (page xv)

The key observations based on a review of this figure, complemented by the discussion of water sector institutions in Chapter 3, are as follows.

- The current institutional framework for water resource management is highly fragmented, at all levels, for several major facets of the water sector. For example, there are multiple government entities (e.g., NESDB and ONWR) that provide policy direction with no apparent connections between them. Under their directions, several government ministries (e.g., MOE, MONRE, MOAC, MOInt, and MOI) develop water-related policies, guided by their own priorities and understanding of their responsibilities. These priorities are oftentimes in conflict with each other, resulting in a lack of coherence in water policies, to tackle water-related issues in an effective manner. Further, under each government ministry, there are several government-initiated committees, subcommittees and departments to implement policies. There are overlapping responsibilities and insufficient coordination between these implementing agencies. This contributed to an uncoordinated development of projects, inappropriate budget allocations, and other obstacles essential for effectively managing water resources (MFA 2016).

- To overcome the fragmented institutional structure, the NWRC was established to provide overall policy direction for water resource management at the national level. Together with NWRC, the RBCs were established for 25 basins to develop policies and implementation plans at the basin level, and to coordinate these policies and plans with various agencies in the basin area. However, these committees (i.e., NWRC and RBCs) appear to lack authority to exert any influence on overall water policy development, lack formal mechanisms and capability to guide policy implementation, and lack of adequate budget to perform required tasks (MFA 2016; WB 2011). As a result, both committees function on a rather ad-hoc basis and are thus incapable of promoting a shared vision, among national and local levels, for the need for integrated water resource management.

- There is no independent regulatory body responsible for regulating the water sector in a way that balance the interests of various stakeholders. In fact, the overall regulatory remits of various agencies are not clearly defined; they are rather translucently embedded within the remits of agencies that implement water policies. Most of these regulations concerning the water sector appear to have been put in place to govern the operation of government departments and state-owned enterprises. In addition, some regulations about water quality also exist; these regulations are under the authority of government departments (i.e., PCD and DIW) that function according to their own mandates.

- Due to the insufficient capacity of the overarching planning body, and the absence of an independent regulatory body, to oversee water resource management in a holistic manner, regulations were developed mainly for policy implementation at the departmental levels. For example, the operation of EGAT is governed by the *EGAT Act BE 2511 (1968)*; DGR, by the *Groundwater Act BE 2520 (1977)*; RID, by the *People's Irrigation Act BE 2482 (1939)*, *Dykes and Ditches Act BE 2484 (1941)*, and *State Irrigation Act BE 2485 (1942)*; PCD, by the *National Environmental Quality Act BE 2535 (1992)*; DIW, by the *Factory Act BE 2535 (1992)*.[8] This has resulted in the promotion of a planning philosophy that is tied to the operational and budgeting processes, thus, restricting the capacity to forge effective integration of water policies and to coordinate activities of implementing agencies (WB 2011).

In addition to the above observations, the insights gained from the analyses of institution-performance linkages in the water sector (from Chapter 5; and as summarized in Figure 6-2) further suggest the following.

- The process of policy development and implementation in Thailand is susceptible to political interference. As noted above, the development and implementation of water-related policies is undertaken by several government ministries, with limited coordination between them. The responsible ministers of these ministries often come from different political parties, owing to the nature of Thai politics where most of the past governments (and the present one too) have been formed through a coalition of different political parties (SOC 2018). Further, in most ministries, the minister and the deputy minister come from different political parties. As a result, decisions about policy are often driven by the negotiation skills and the bargaining power of these political parties, leading to pork-barrel type of politics. Moreover, both NESDB and ONWR are under office of the OPM, implying that a strong prime minister can exert his/her influence on shaping the policy direction of the country. This mish-mash

[8] There are several amendments to these original *Acts* over the years.

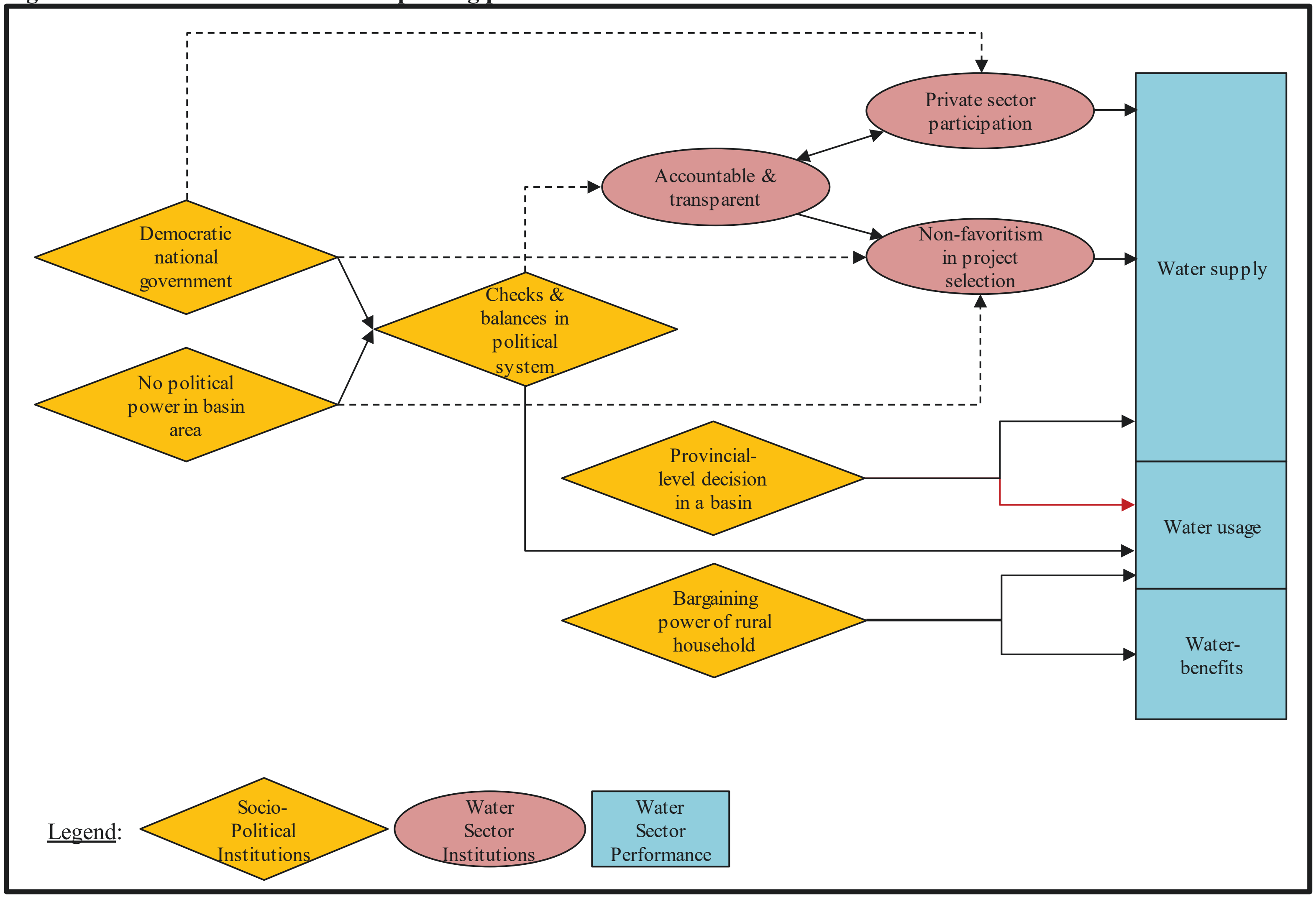
political landscape leads to a lack of political checks and balances, which is one of the key factors contributing to unaccountability and non-transparency of the institutional framework of the Thai water sector (Figure 6-2).

- In the absence of clear policy direction and coherent regulatory framework, various government departments assume the role of self-regulation, in accord with the Acts that govern their respective departmental mandates and responsibilities. This implies that the regulatory decision making can also be highly susceptible to political interference. The lack of independent regulatory body, for example, is a key factor contributing to unaccountability and non-transparency in decision-making process, resulting in project selection criteria that favor specific interest groups (Figure 6-2). Such a bias in project selection may contribute to diverting scarce funds to projects that do not produce net benefits to society.

- A lack of authority of RBCs implies that decisions relating to water policy implementation are often made by the provincial and local authorities. The analyses in this research has shown that decisions at different levels (provincial or basin) will have different effects on performance of the water sector, for both water provision and usage (Figure 6-2). Further, there are multiple authorities at the provincial/local level, each implementing policies under the directives of different ministries. For example, water policies developed by MONRE are implemented by various local offices. Similarly, other local authorities (such as DOPA and DOLA) implement policies of the MOInt. These policies (of MONRE and MOInt) may be in conflict, and may subsequently cause implementation problems.

- The role of private sector, in the current institutional structure, is extremely limited; only one private company (i.e., EWG) is involved in supplying water to the industry sector, through its extensive water-grid system in the eastern coastal area of the country. Increased private sector participation, specifically in water infrastructure development (e.g., water storage facilities and distribution networks), would improve the performance of water provision (Figure 6-2).

Figure 6-2 Institutional factors for improving performance of the Thai water sector



Source: Developed from Figures 5-3 to 5-5

Notes: Bold line represents a direct relationship; dashed line represents an indirect relationship; arrow represent direction of relationship; black line represents a positive effect of institutions on performance; red line represents a negative effect of institutions on performance.

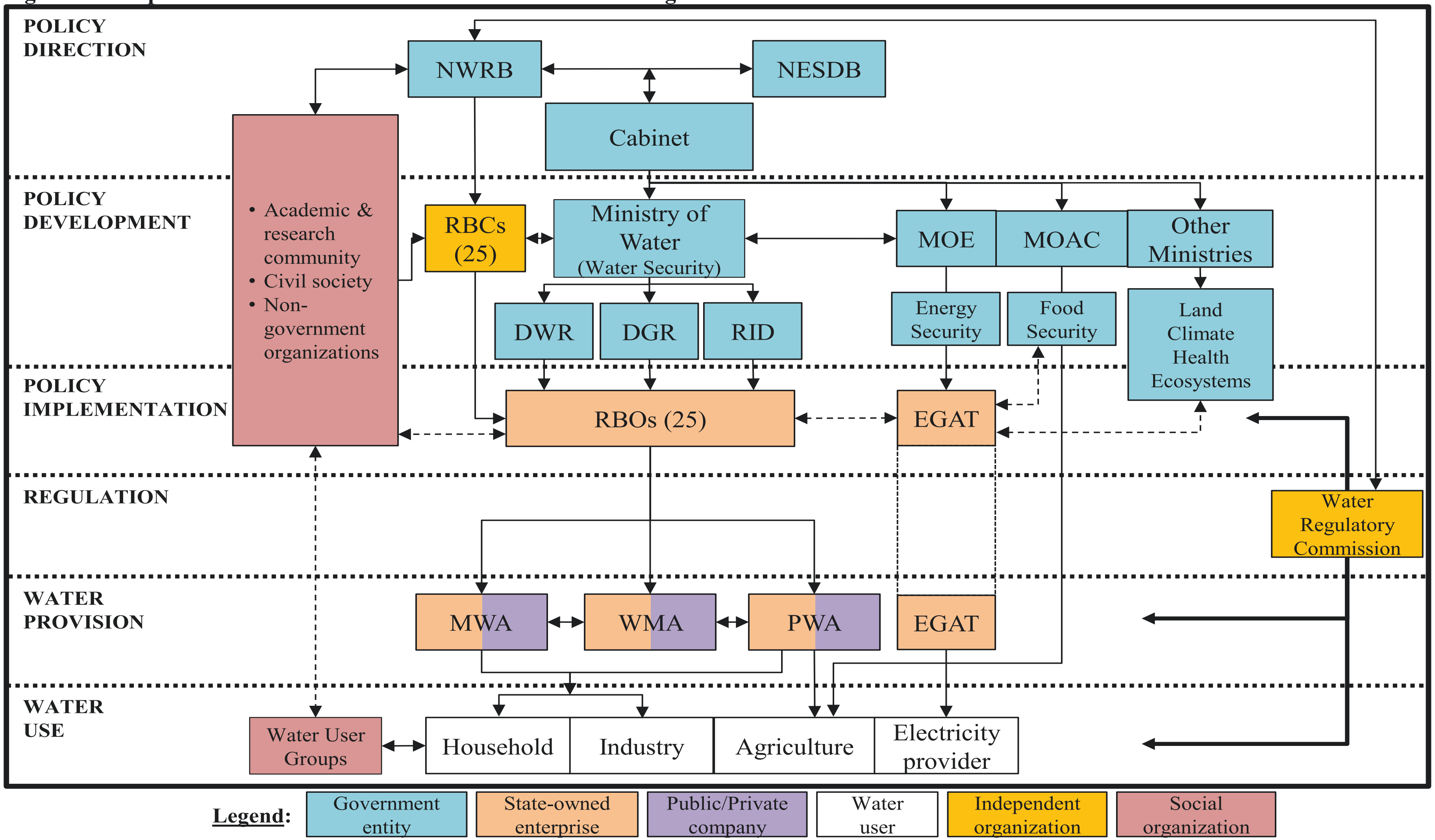
- There is a lack of involvement of citizens in water policy development and implementation stages. Decisions regarding projects and plans are made solely by government ministries, and implemented by the ministerial departments. As a result, many projects and plans are not implemented as they face opposition from the local communities. The analysis in this research has shown that democratic participation by citizens at the national level, and increased bargaining power of citizens at the local level, would improve water sector performance (Figure 6-2).

- There is no apparent support provided to water-dependent rural households (i.e., farmers) in the current institutional arrangements of the water sector. Despite being the largest water users (approximately 90 percent of total water use), they remain relatively poor. The analysis in this research has shown that increased relative bargaining power of rural households, as compared with other water user groups, has the potential to improve the performance of water usage, and enhance their livelihoods, resulting from increased earnings from water-dependent activities (Figure 6-2).

6.3. Proposed framework for water resource management

The weaknesses in the current institutional arrangements, as discussed in the previous section, clearly inhibit improved performance of the water sector. There is therefore a need to modify these arrangements, to enable effective management of water resources and, by implication, improved performance of the overall water sector. This section proposes such a framework. Figure 6-3 provides a panoramic overview of the proposed institutional structure of the Thai water sector.

Figure 6-3 Proposed institutional structure of water resource management in Thailand



Source: Developed by the author based on modification of Figure 6-1

Notes: ▪ Single arrow – flow of command; double arrow – flow of consultation; dashed line – coordination; bold line - regulation

▪ Acronyms – see list of glossary (page xv)

The key ‘elements’ of the proposed framework are presented below.

1) Adopt a broader ‘nexus’ approach in planning philosophy

Chapter 2 demonstrated the criticality of ‘water’ in shaping human history, in terms of its social, cultural, political and economic transformation. ‘Water’ has universally been a key driver for societal dynamism. The call for integrated management of water is captured by the WB (2011): “water is limited, difficult to control, easily to be polluted, and could cause social conflicts and public health, therefore water resources management is everyone business”. The concept of Integrated Water Resources Management (IWRM) enjoys a wide acceptance across the water planning communities around the world. By definition, IWRM is “a process which promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems and the environment” (GWP 2000). The application of IWRM, thus, requires the application of a ‘nexus’ approach, underscored by ‘holism’. That is, the planning and management of water resources need not be confined to the intra-sectoral level (i.e., within the entire water sector), but also the inter-sectoral levels (i.e., between the water sector and other sectors of the economy). This can be achieved, in the context of Thailand, by modifying the institutional structure (Figure 6-3) as follows.

- Water policy should be in accord with the economic and social developmental priorities and aspirations of the nation. Accordingly, the policy direction for the water sector should be determined through a close consultation between NWRB and NESDB. This will ensure that water plans are incorporated into, and aligned with, the NESDPs.
- The ministry responsible for water policy development should have a clear mandate to improve water security of the nation. To achieve this, the ministry should interact with other government ministries responsible for policy development in other areas that have the potential to affect water security, for example, energy, food, land, climate, health and ecosystems. A formal arrangement to allow consultation between various government ministries will

facilitate cross-sectoral dialogue and, hence, effective implementation of IWRM.

2) Develop a unified decision-making processes

Chapter 3 and Section 6.2 of this chapter have shown that the current institutional structure for decision-making in the Thai water sector remains highly fragmented despite some efforts to rectify this problem. This is because past efforts have overlooked structural issue in decision-making processes (Krairapanond 2018; Prajumwong 2018). In particular, the Thai governmental structure is very centralized – several policy-related functions (policy development, implementation and regulations) are the responsibilities of national governmental entities – while the Thai societal structure is rather decentralized. One of the key strategies to overcome this structural problem is to change the role of government entities, from planner, developer and implementer (of policies), to facilitator and regulator. This can be achieved by modifying the institutional structure (Figure 6-3) as follows.

- Establish a separate Ministry of Water (MOW), and task it with the overall responsibility to develop water policies, under the policy direction provided by the Cabinet (as with other ministries). All the relevant ministerial departments, that are currently responsible to implement water-related policies, should be moved to MOW and tasked with the responsibility to ensure a coherence in water policy. For example, DWR and DGR (currently under the MONRE) and RID (currently under the MOAC) should develop policies for surface water, groundwater, and water for irrigation, respectively, in ways that would enhance water security of the country. Further, MOW should develop nation-wide water policy in consultation with RBCs, who should be responsible for providing inputs to MOW in developing policies that are suitable for, and reflect the needs of, local stakeholders for all 25 basins.

- The implementation of water policies should be undertaken primarily by the RBOs, at the basin level. That is, all water-related projects should be undertaken by the 25 RBOs; no provincial and local administrative offices (under the MOInt) should be responsible for these projects. Further, there should be a horizontal coordination for policy implementation between RBOs, EGAT, and other stakeholders to ensure smooth implementation of water policies.

– The responsibility for wastewater treatment and management is currently separated between WMA and local authorities (provincial and local administrative offices). Due to unclear responsibility, just one-fifth of the country's wastewater is being treated (Pongrai & Sarn 2012). To enhance the effectiveness of wastewater treatment, WMA should be restructured, and involvement of local authorities in managing wastewater should be eliminated. This research recommends that the WMA should not function as a government entity, rather it should operate wastewater treatment plants as public/private company, or, at least, as a state-owned enterprise. This would effectively add more water supply to meet water needs of the society. In fact, private participation in the provision of water should also increase; currently MWA is solely responsible for ensuring water provision in the Bangkok metropolitan area, and PWA, for the rest of the country. Additionally, WMA should work closely with these former state-owned enterprises. As shown in Figure 6-2, increase private participation would improve water provision.

3) Limit the influence of politics in policy decisions

One of the main limitations of the current institutional structure for effective water resource management in Thailand, as discussed in Section 6.2, is the influence of politics in policy decisions. It is widely recognized in literature that the way to limit the influence of unhealthy politics is to engage public in policy-decision-making processes, and to strengthen accountability and transparency of these processes (WB 2016). This will increase checks and balances in decision-making processes and, hence, improve performance of the water sector (Figure 6-2). Achieving this aim will need a modification of the institutional structure (Figure 6-3), as follows.

– Establish an independent regulatory body – Water Regulatory Commission – to regulate the water sector, by monitoring and enforcing water legislations, particularly according to the *National Water Resource Act BE 2561 (2018)*. Perhaps there is a need to revise this Act, to account for the proposed change in the institutional structure, and streamline all water-related legislations to be consistent with this Act. To ensure independency, the regulatory commission needs to be clearly separated from the hierarchy of policy-making entities, and be allowed functional autonomy. This will allow more accountability in decision-making processes and, thus, limit the political incentives for rent-seeking behavior.

- The transparency in the water sector can be further strengthened by embedding public opinions in decision-making processes at all levels. For example, the 25 RBCs should be operated independently, with the committees selected by collective action, such as voting, of self-organized local citizens (e.g., academic and research community, civil society, non-governmental organizations) in respective basin areas. Further, various social groups, such as farmer associations, should be formed through coordination with water user groups from different sectors. This will ensure that policy that suits local needs will be developed through consultation between RBCs and the proposed MOW.

4) Reinstitute the role of informal institutions

The discussion in Chapter 2 suggested that water management practices in the past were informed by the local contexts, drawing from customs, norms and religious beliefs (i.e., its informal institutions). The rise of scientific practices for water management, and the design of formal institutional arrangements for water (that follow a top-down planning approach) have lessened the role of informal institutions in the design of water management policies. This is one of the main reasons for the failure of water management policies, specifically when water policies and projects are implemented at the local level. As argued by Saleth & Dinar (2004), "informal institutions play an important role in grass-roots decisions on water use and management". Unlike other sectors, the informal institutions in the water sector tend to change faster than its corresponding formal institutions (Ostrom 1990), implying that the informal institutions are more adaptable to water-related problems, and are in a better position to solve them. Decision-making processes that put too much emphasis on formal institutions are likely to create tensions between altered informal rules and persisting formal rules, thus creating potential for conflicts at the local level.

Water is a public good, thus the framework for developing and implementing water policies must be based on public participation (i.e., a participatory approach). This approach allows the management of water resources through self-organized groups in society (Ostrom 2005). By fostering grassroots/local involvement, and inclusion of self-organized social groups in decision-making processes (as above; Figure 6-3) there is potential to reinstitute the role of informal institutions in water management and practices. This would allow water resource management policies to contextualize water in a local setting, by giving primacy to traditional rituals, cognitive strategies, and mutual belief-systems. It will also ensure the involvement of public and private agencies, that are governed by formal rules and regulations. Collectively, these features should contribute to an effective redress of the nation-wide objective, of ensuring water security for all.

This will however not be sufficient as past emphasis on the development of formal institutions may have undermined the capacity and willingness of local citizens to meaningfully participate in water policy discourse. That is, engagement of the local citizens will not automatically bring back the informal institutions into decision-making processes. There is therefore a need for careful deliberation to reinstituting informal institutions. One of the ways is to create a sense of ownership of 'water' among community stakeholders. As long as water is freely available, and the government provides water-resource projects free-of-charge, the users do not appreciate the projects, and hence have little sense of ownership. There is therefore a need to share the responsibility for the projects, by creating mechanisms whereby the government or private company develops water projects, and the community is responsible for the upkeep of such projects. History from the ancient Lan Na period (13^{th}-18^{th} centuries) provides useful clues about the efficacy of such mechanisms (see, Chapter 2). For example, during that period, the state developed large-scale Muang Fai (water infrastructure), while the locals developed small-scale Muang Fai that suited their needs; the operation of these infrastructure was based on formal and informal rules agreed between the state and locals; water allocation and sharing systems were based on informal institutional arrangements among the locals (Arsvai 1978; DRI 1967, 2002; Ounvichit 2005).

5) Recognition of the role of 'water' as a multidimensional commodity

Water is a public good and a basic need for sustaining life; it therefore has a social value. However, the development throughout human history has witnessed a complete transformation of water, from being considered as a social commodity, to being treated as an economic commodity (Chapter 2). An extreme position, to support the process of commodification of water, is expressed in The Economist (2003): "throughout history … [water] has been ill-governed and … underpriced … leads to overuse of water for the wrong things … The best way to deal with water is to price it more sensibly – to reflect … its marginal utility". This clearly states that the management of water resources should be based on the "application of economic principles, particularly pricing and markets" (The Economist 2003). A contrasting position, against water commodification, is provided by Barlow & Clarke (2002) that, "it is a universal and indivisible truth that … water belongs to the Earth and all species, and therefore must not be treated as a private commodity to be bought, sold, and traded … [it] is a shared legacy, a public trust, and a fundamental human right, and therefore, a collective responsibility".

This research does not take any of the above extreme positions; it rather holds that commodification of water has largely resulted in the neglect of the influence of informal institutions. This has in turn taken the 'ability to make decision' out of the hands of the individual, social-citizen, and placed it into the hands of the 'ideology' (Saul 1995) – market ideology, in this case. Reinstituting the role of informal institutions (as above), specifically bringing the importance of socio-cultural values into the planning culture, will invigorate the process of de-commodification of one of the most important resources in human lives (i.e., water) in the design of institutional arrangements for water resource management. It is anticipated that this will lead to the recognition of the 'original' role of water as a public good, and hence appreciation for the underlying socio-economic-cultural-political values.

In a practical sense, this recognition will be reflected in a relative bargaining powers of various water users, through water user groups, and between water users, water providers, and water decision-makers, through their involvement in RBCs (Figure 6-3). As a result, water for farming activities by rural household, for example, may be treated differently than water for industrial activities by urban elites. Such a change in relative bargaining power will, in turn, lead to improved performance of the water sector (Figure 6-2).

Key challenges to implement the proposed framework

The implementation of the proposed framework discussed above will inevitably pose some challenges. Some of these challenges are as follows.

- The proposed changes in the institutional arrangements are fundamental. It is therefore likely to be seen as confronting, by stakeholders who have vested interests in the current institutional arrangements and administrative practices, which have roots in the early development interests of the water sector. The current institutional arrangements – based on the conventional practices of large-scale engineering project development that was aligned with bureaucratic allocation of funds and management structure – may have served well in the past when the focus was to increase water access. It however no longer serves the purpose in the current environment where frequent floods and droughts has become a norm. Changes must therefore be made. These changes in institutional arrangements must however reflect a balance between the interests of concerned stakeholders, and a consensus among them on this balance.

- The proposed changes would require a strong political will and leadership. This could pose a challenge, as one of the suggestions made in this research is to limit the influence of politics in policy-making processes – to limit the possibility of political rent-seeking. Further, the indecisiveness of political leadership in Thailand is a norm, owing to the fragmented nature of political-party system, resulting in weak coalition governments, and the ensuing instability and ineffectiveness of the cabinet (MacIntyre 1999). A major effort was made in 1997 to reform this political culture, by aiming to remove widespread abuses of the political processes and political power, through the design of "people's power" Constitution (Laird 2000). Ironically, after two decades of major political reform, the recent formation of the government appears to suggest that political deal-making and pork-barrel politics still persist, and the country appears to be faced with the prospects of years of political instability (Murray 2019).

- The proposed institutional arrangements require balancing the roles of formal and informal institutions in water management. There is however an inherent imbalance of power among relevant parties (e.g., between central agencies and grassroot organizations) in these arrangements. While there is need to use formal means to rebalance the distribution of power, ‘trust’ is also an essential element (Fukuyama 1996). However, there is a strong distrust in the Thai society (Ward, Mamerow & Meyer 2014), driven largely by past decades of socio-political instability and social injustice in the country (Hanvongse 2014). To successfully implement the proposed change implies that the socio-political landscape need to be reconstructed, and rebuilding of ‘trust’ should be central in this reconstruction (Bureekul & Thananithichot 2012).

6.4. Summary and conclusions

The major findings of this chapter are as follows:

- The current framework for water resource management in Thailand is deficient; there are inherent weaknesses in, and dichotomies between, water-specific and wider socio-political institutions. Some example of these weaknesses and dichotomies include:

  - The current institutional structure is highly fragmented, at all levels – multiple government entities are involved in providing policy direction; several government ministries are responsible for developing water-related policies; and numerous government-initiated committees, subcommittees, and departments to oversee the implementation of policies. As a result, there is lack of policy coherence, leading to uncoordinated project development, supported by disproportionate budgetary allocations. Efforts have been made in the recent years to overcome this fragmentation, primarily through the creation of two overarching committees. However, the lack of authority of these committees, and lack of formal mechanisms and disproportionate budgets to guide policy processes, has prevented these committees to effectively build a shared vision for integrated water resource management, and hence to engender a sense of ownership for the shared vision at the national and local levels.

  - The regulatory functions are also disjointed; there is no independent regulatory body to regulate the entire water sector; instead multiple regulatory strands are incoherently embedded within the remits of agencies that are responsible for implementing water policies. This has resulted in the emergence of a planning philosophy that is tied to the operational and budgeting processes, with limited capacity to forge effective integration of water policies, and to coordinate disparate activities of implementing agencies.

- The above weaknesses in water sector institutions make the sector susceptible to political interference – in the realms of policy development and implementation, and in regulation. This precludes the institution of a system of appropriate checks and balances in the political system, which in turn contributes to unaccountability and non-transparency in decision-making processes, resulting in policies that favor specific interest groups, thus diverting scarce resources into areas that do not provide net benefits to society.

- There is a lack of involvement of the broader citizenry in water policy development and implementation, and insufficient participation by the private sector in water provision. This contributes to poor performance of the water sector, as many projects and plans are not implemented due to the opposition by the local communities. Projects that are implemented, specifically in water provision, are often undertaken by state-owned entities, which are relatively less-efficient compared with private sector projects.

▪ To overcome some of the inherent dichotomies of the current framework for water resource management, this research proposes the following:

  - Water policy should be consistent with the economic and social developmental priorities of the nation (i.e., in alignment with NESDPs), with the overall objective of improving water security of the country. A new Ministry of Water (MOW) should be established to oversee the overall development of water policies, and it should interact with other government ministries to ensure that there is no conflict between water and other related policies (e.g., energy, food, land, climate, health and ecosystems).

  - The new ministry should develop a nation-wide, overarching, water policy, in consultation with the River Basin Committees (RBCs), who should be responsible for providing inputs to this ministry for developing policies and plans that are suitable for, and reflect the need of, local stakeholders at the basin level. The implementation of water policies should be undertaken primarily by the River Basin Organizations (RBOs), underscored by horizontal coordination with other stakeholders to ensure smooth implementation.

- There should be increased private participation in the provision of water (i.e., supply and distribution of water). This means that the former state-owned enterprises, responsible for supply and distribution, need to be operated as public-private entities. Also, the responsibility for wastewater treatment should be transferred to these entities. This would effectively add more water to meet water needs of the society.

- A new Water Regulatory Commission should be established to regulate the water sector, by monitoring and enforcing water legislations. This Commission needs to be clearly separated from the hierarchy of policy-making entities, and allowed functional autonomy, to ensure accountability in decision-making processes and, thus, limiting the scope for political interference in policy decisions.

- The transparency in the water sector can be further strengthened by integrating public opinions, particularly from self-organized local citizens, in decision-making processes. The 25 RBCs should therefore be operated independently, with its members selected by the public. This will also allow that policies that suit local needs are developed and implemented.

▪ The proposed changes are underpinned by the following principles:

  - adopt a broader ‘nexus’ approach in planning philosophy, where the concept of Integrated Water Resource Management is applied in a holistic manner (i.e., at intra- and inter-sectoral levels);

  - develop unified decision-making processes, where the roles of government entities change, from being the implementer of policies, to being the facilitators and regulators;

  - limit the influence of politics in policy decisions, by engaging the public in policy-decision-making processes, and strengthen accountability and transparency of these processes;

- reinstituting the role of informal institutions, by fostering grassroot/local involvement in decision-making processes, thereby ensuring the ‘immersion’ of traditional rituals, cognitive strategies, and mutual belief-systems in modern water resource management practices; and
- recognition of the role of ‘water’ as a multidimensional commodity, by leveling the ‘playing field’ for various water stakeholders, and hence enabling a meaningful appreciation of the economic, social, cultural and political values associated with water.

The proposed changes in the institutional arrangements are fundamental and significant. The implementation of these changes will inevitably pose some challenges. Firstly, these changes are likely to be seen as confronting the stakeholders who have vested interests in the current institutional arrangements and administrative practices; any changes must reflect a balance between the interests of concerned stakeholders, and a consensus among them on this balance. Secondly, the changes in this magnitude would require a strong political will and leadership. This is unlikely as the country appears to be faced with the prospects of years of political instability. Lastly, the changes require rebalancing of power (between central agencies and grassroot organizations) in the institutional arrangements; ‘trust’ is an essential element in this process. However, the current distrust in the Thai society is high driven largely by past decades of socio-political instability and social injustice in the country. To successfully implement the proposed change implies that the socio-political landscape need to be reconstructed, and rebuilding of ‘trust’ should be central in this reconstruction.

CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

7.1. Conclusions

Motivated by persistent water-related problems in Thailand, this research has developed a comprehensive analysis of its water sector, with specific emphasis on understanding the causes of poor sectoral performance, and for identifying ways to improve performance. This analysis has included: examination of the role of water in shaping human history, both in the global and Thai contexts; review of the evolution of the Thai water sector; assessment of the performance of the Thai water sector; investigation of the nature of relationship between institutional factors and performance; and delineation of the contours of the recommended framework for improving water sector performance.

A summary of the major findings of this research is provided as follows.

History of 'water'

The historical review of 'water' aimed to examine its role in shaping human history, in terms of shaping its social, cultural, economic and political dimensions. The review showed that:

- Water has played a central part in the **social** development of the world (including Thailand). In the earlier times, people across the world developed settlements and communities along the river banks, river islands and canals. This led to the creation of social norms across the world. For example, the practice of public participation in agricultural activities and water management emerged from the need to 'share' or to adopt a 'collective' approach to deal with the challenges of the times. The irrigation and water management practices therefore became embedded in a social contexts of humanity.

- Water has also been critical to the creation of **cultural** heritages of countries around the world. It also helped to create national identities, in the form of its cultural rituals and festivals; water festivals, for example, are famous in several Southeast Asian countries. In addition, water is viewed as a symbol of 'purity' and has been used in holy ceremonies and religious practices around the globe. This became the foundation for a spiritual approach to water. Water resource have therefore been managed as a common-pool, held by mutual belief-systems, in the form of cultural mythologies, worship and ceremonial practices, of various segments in each society.

- From **economic** perspective, water has been a fundamental resource for expanding agricultural production and trade. Moreover, since the ancient times, rivers and canals have been used as a means for transport within and outside the cities around the world (including Thailand). The development of water-related technologies contributed to the success of Industrial revolution of the late 1700s. The expansion of trade was supported by irrigation and water development. The digging of canals, particularly in Thailand, helped to enhance trade in commodities since the period of Ayutthaya Kingdom (beginning in the year 1351).

- In the realm of **politics** too, water has played an important role. For example, as people chose to stay and built their communities near water, states were formed as political units. After the establishment of the states, formal institutional arrangements such as bureaucracy, laws and regulations were developed in order to manage people and natural resources, including water resources. Water can also be a source of political conflicts. For example, constructing dams in trans-boundary area, such as Mekong River that shares boundaries across several countries, or Chao Phraya basin in Thailand that shares the basin area with several provinces, often encountering protests from various groups in society. To deal with such conflicts, several formal institutional arrangements have emerged over the years.

In short, much of water management policies and practices in the earlier times were informed by the social and cultural contexts of water (i.e., its informal institutions). The later years however witnessed a complete transformation, with water being treated as an economic commodity supported by the rise of advanced technology and formal institutions. The rise of formal institutions in water management has resulted in a neglect of the role of informal institutions. Hence – failures in water management, and emerging water resource problems, this research argues.

The Thai water sector

The second part of the historical review looked at the evolution of the water sector in Thailand, with a view to identify changes in key institutional factors that influenced water resource management practices over the last several years. The review showed that:

- Before the establishment of the system of National Economic and Social Development Plans (NESDPs) in 1961, water sector institutions were entirely the purview of the King (through the Royal Irrigation Department), and the primary focus was on the development of canals as a means for public transport, navigation and trade – to promote national economic prosperity. The governing institutions for supporting this development philosophy drew their imprimatur from the perceptions of the King and other high-level government officials.

- As water was provided as a free and open service, the supply and allocation of water created certain cultural and political constraints for effectively managing and administering water usage, especially for public access. Competing uses for water among the concerned parties, to conduct socioeconomic activities, were only possible in large river basin areas.

- There was no unified framework for physical and budgetary planning for water provision. The entire focus of development of water resources was on large-scale project development, to support national policies and agendas. No specific criteria were followed to assess the viability of these projects.

- During the first three-and-a-half decades of NESDPs (plans 1-7), several water-related government agencies were established. However, these agencies neither had the clear mandate nor legal obligations to other agencies in relation to their activities. This resulted in overlapping mandates and created coordination problems among the agencies. The Royal Irrigation Department (main water resource development agency at the time) had very little authority to enforce its (informal) policies and practices over other governmental agencies.

- Similar to the period prior to NESDP, during this period, water continued to be provided for free, creating certain cultural and political constraints for managing and administering water usage. Unlike the previous period, however, the apparent shortages of water supply, especially for agricultural activities, induced some social and political tensions among the users. Further, there was no avenues for local water users to participate in decision-making processes for developing water resource projects. Hence, the supply-oriented, large-scale water infrastructure continued to be developed. But this still did not prevent social unrest and political turmoil.

- At the beginning of NESDP 8 (in 1996), the National Water Resource Committee was established, with clear directives about measures and programs for water resource development. The purpose of this Committee was to resolve the issues of fragmented institutions and conflicting decision-making structures that were created by several water-related management agencies in the earlier period. In addition, the enactment of the 1997 Constitution allowed citizens to stipulate their rights and participate in water resource development and management processes. While these developments partly resolved social and political conflicts within the local settings, they have however heightened conflict levels across basin areas, as water resources were increasingly diverted from one basin to another, due to the increasing occurrence of floods and droughts events. It is observed that the main reason behind such conflicts was the lack of coherent national water policy framework to manage water resources across the spatial and temporal scales. In addition, the decision-making processes for managing water, especially during periods of flood and drought, have remained largely unsystematic and unresponsive.

- The analysis also suggests that legislative and institutional reforms in the government agency system overseeing the water infrastructure, and enforcing water policy and law, are urgently needed to improve the efficacy of water policy. Policies that put equal emphasis on demand and supply sides, for example, could be powerful in getting the government agencies to focus on inefficiencies in public water services, particularly agricultural water management, to reduce waste and loss in water allocation and consumption.

- Further, the introduction of alternative policy measures (for example, water pricing, permits and licenses) will require that the government clearly specify and enforce water-use rights. There are a number of institutional problems, e.g., poor capacity of government agencies and poor quality of the government services, which may constrain the effectiveness of applying water policies effectively.

Performance of the water sector

One of the main argument for the ongoing restructuring in water resource management practices of the water sector since the establishment of NESDP has been that it would improve the effectiveness (i.e., performance) of the water sector in terms of meeting its primary role, i.e., to enhance the livelihoods of the rural population where most of the household income is obtained from water-dependent farming activities. However, this argument has remained essentially anecdotal, devoid of any substantiation through ex-ante or ex-post analyses. To the best of the knowledge of this author, such an analysis has never been developed before in the Thai context. Once developed, this research contends, it will provide a firmer basis to ascertaining the veracity of the argument that the restructuring of the water sector has contributed to improved performance and, by implication, enhanced livelihoods of people whose socio-economic condition is very much dependent on water.

This research therefore provided a comprehensive analysis of the performance of the water sector in Thailand. It analyzed the performance of the water sector (in terms of benefits for the rural people) in Thailand for the period 1987-2017, at both national and basin levels. For the analysis, this research divided the entire water sector into three ‘functional’ stages, namely: 1) water supply (i.e., use of investments to develop water infrastructure), 2) water usage (i.e., use of water infrastructure to produce agricultural outputs), and 3) water-benefits (i.e., earning of water-dependent farming). To enable this analysis, significant effort has been devoted in this research to develop a panel datasets, at basin levels. To the best of the knowledge of this author, no such datasets exist for Thailand.

The analysis revealed that:

- There has been a decline in overall performance (i.e., productivity) of the water sector over the period 1987-2017 (4.6 percent per year). This decline was largely driven by a deterioration of technology frontier (7.8 percent per year). This suggests that the substantial investments that have been made in developing water infrastructure over the past 30 years did not lead to a commensurate rise in farmer incomes and hence their well-being.

- Further, the performance deteriorated in all three stages of the water sector. The productivity of water usage (stage 2) declined the most (12 percent per year), again driven by technology change. This was followed by the ineffectiveness in water-benefits (stage 3) (5.2 percent per year), where agricultural production did not proportionally convert into increase in income. While the performance of water infrastructure development (stage 1) declined the least (of the three stages), the rate of reduction was nonetheless appreciable (2.3 percent per year).

- Most of the reductions in productivity indices occurred during the period 1987-1997, with rates of decline slowing thereafter. This is particularly true for stages 1 and 2. For example, for stage 1, productivity change indices for the national average for all basins decreased by 3.1 percent per year over the period 1987-1997; the rate of decline was 2 percent during 1997-2007, and 1.8 percent during 2007-2017. For stage 2, the corresponding rates of reduction are 26.7, 4.1 and 3.1 percent per year over the three time periods. The main likely reasons for such trends are: incompatibility between the geographical/natural conditions of river basins, the type of water infrastructure that has been developed during the First and Second national development plans during the 1960s and 1970s (mostly large-scale dams and irrigation canals), and the type of crops that have been promoted (mainly for exports, including rice, tapioca, rubber and sugarcane) during the Third and Fourth national development plans during the 1970s and 1980s. In the subsequent periods, increased production of these so-called strategic crops resulted in a degradation and misuse of natural resources and water infrastructure.

- Contrary to the above, the performance of the stage 3 of water sector has deteriorated significantly in the recent years (6.4 percent per year during 2007-2017, compared with 5.5 and 3.7 percent per year during 1987-1997 and 1997-2007, respectively), driven by appreciable negative performance changes in basins located in the north and northeast of the country (in particular, Salawin, Wang, Kok, Yom, Ping and Nan basins). Most farmers in these basins operate on small and scattered pieces of land, and extensively engage in the production of low-yield, water-intensive agricultural products, mainly rice. This prevents them to benefit from economies-of-scale. Further, they are strongly influenced by political interference and business interests as Thailand is a major exporter of rice in the world market. This means that these farmers are not able to diversify their production into alternative, more profitable, crops. Since 2006, the country has been experiencing political instability, leading to considerable shifts in agricultural pricing and insurance schemes, particularly for rice. This could have been a significant reason for the deteriorating performance, in this stage, in the recent years.

- In addition to uneven growth in performance across the three stages of the water sector over different time periods, there has also been a disparity in performance across different stages of the water sector. For example, the average efficiency of the entire water sector, at the national level, was 0.68. Of the three stages of the water sector, stage 1 has been the least efficient (0.55) and stage 3 has been the most efficient (0.81); the efficiency level of stage 2 is similar to the national average (0.69). Further, there is disparity in efficiency levels across the 25 basins. For example, most large basins in the central plain area (e.g., Chao Phraya, Tha Chin and Mae Klong) have efficiency scores of more than 0.8, while others, relatively small basins in other part of the country (e.g., Wang, Sakae Krang and Petchaburi), have efficiency scores of approximately 0.5. This implies that there could be several factors that affect performance across basins. Such factors could be those that are directly associated with physical/natural characteristics of the basins, or driven by national and sectoral directives, or influenced by a wider socio-economic-political landscape of the country.

In summary, the analysis suggested that the ongoing restructuring of the water sector did not contribute to any noticeable improvement in sectoral performance. In other words, past investments in the water sector did not lead to adequate beneficial outcomes for the rural population whose socio-economic condition is very much dependent on water. This conclusion calls into questions the main argument of restructuring, namely, that the restructuring of water sector will improve its performance and, by implication, enhance the livelihoods of rural population.

Institution-Performance linkages in the water sector

This research further investigated – for 25 basins, for the period 1987-2017 – the influence of institutional factors on the performance of the water sector in Thailand. Two types of institutions are included in this investigation: those directly associated with the water sector (water sector institutions), and those that are outside of the immediate domain of the water sector (socio-political institutions). This investigation is conducted for each of the three stages of water sector (as above): 1) water supply, 2) water usage, and 3) water-benefits.

The analysis revealed that:

- The wider socio-political institutions have historically exerted significant influence on the performance of the water sector in Thailand. Further, these wider influencing factors have affected water sector performance both directly and indirectly, through water sector institutions.

- The bargaining power of the key water users (BAR) seems to have a direct effect on the performance of water usage (stage 2) and the earnings of water-dependent farming (stage 3). In particular, the results show that a basin where farmers have more bargaining power, relative to water users from the industry sector, is likely to utilize water in a more effective way, to produce agricultural outputs (stage 2), and has better ability to raise their income from agricultural production (stage 3).

- The compatibility of geographic-political boundaries (BOUND) could also directly affect water sector performance. However, the effect of this factor is positive in one area and negative in the other. For example, statistical evidence shows that a basin that has large number of provinces is likely to have a better performance in water supply provision (stage 1), due probably to increased competition for budget allocation to develop water infrastructure. In contrast, a basin that has large number of provinces is likely to be relatively less-efficient in the way water is utilized (stage 2), due perhaps to a lack of coordination between different provinces in utilizing water from the same basin.

- Another factor that has the potential to directly affect water sector performance is the level of checks and balances in the political system (CHK). Higher checks and balances in the local electorate at the basin level could result in a better allocation of water resources across the water users, leading to improvement in performance of water usage (stage 2).

- The checks and balances in the political system (CHK) also seem to have an indirect effect on water sector performance, particularly in water supply provision (stage 1).

Evidence suggests that increased checks and balances in the local electorate at the basin level is likely to lead to the establishment of transparent and accountable water sector institutions (ACC), which in turn would result in increased participation of private sector in water infrastructure investments (OWN), thus improving the performance of the water sector.

- There is also strong evidence to suggest that democratic participation by the citizens at the national-level (DEM) affects performance of water supply provision (stage 1), through two water sector institutional channels. In other words, if the members of the constitutional legislative assembly are selected through an open voting system, there will be two channels through which water sector performance will improve. First, there will be increased private sector investments in the water sector (OWN). Second, the criteria for selecting water projects (PRO) will be neutral, that is, not favoring any particular interest groups in society.

- Another factor that could indirectly affect the performance of the water supply provision (stage 1) is the extent of political power at the basin level (POL). If the major political party from the basin-level electorate is in the national-level government, the project selection criteria (PRO) appears to be directly driven by 'politics', favoring specific interest group (e.g., social, environmental or political). In contrast, if the major political party from the basin area is in the opposition, the criteria of project selection tends towards neutrality, leading to improvement in performance of the water sector.

In summary, wider socio-political institutions – due to their influence on shaping water-specific institutions – have also directly and indirectly affected the performance of the water sector in Thailand. This validates a key premise of this research, namely, socio-political institutions do affect the performance of the water sector.

Weaknesses in the existing water resource management framework

This research has analyzed the existing water resource management framework by using insights gained from the analyses above. The analysis revealed that the existing framework is deficient; there are inherent weaknesses and dichotomies, within and across water-specific and wider socio-political institutions. Some of these weaknesses and dichotomies include:

- The current institutional structure is highly fragmented, at all levels – multiple government entities are involved in providing policy direction; several government ministries are responsible for developing water-related policies; and numerous government-initiated committees, subcommittees, and departments to oversee the implementation of policies. As a result, there is lack of policy coherence, leading to uncoordinated project development, supported by disproportionate budgetary allocations. Efforts have been made in the recent years to overcome this fragmentation, primarily through the creation of two overarching committees. However, the lack of authority of these committees, and lack of formal mechanisms and disproportionate budgets to guide policy processes, has prevented these committees to effectively build a shared vision for integrated water resource management, and hence to engender a sense of ownership for the shared vision at the national and local levels.

- The regulatory functions are also disjointed; there is no independent regulatory body to regulate the entire water sector; instead multiple regulatory strands are incoherently embedded within the remits of agencies that are responsible for implementing water policies. This has resulted in the emergence of a planning philosophy that is tied to the operational and budgeting processes, with limited capacity to forge effective integration of water policies, and to coordinate disparate activities of implementing agencies.

- The above weaknesses in water sector institutions make the sector susceptible to political interference – in the realms of policy development and implementation, and in regulation. This precludes the institution of a system of appropriate checks and balances in the political system, which in turn contributes to unaccountability and non-transparency in decision-making processes, resulting in policies that favor specific interest groups, thus diverting scarce resources into areas that do not provide net benefits to society.

- There is a lack of involvement of the broader citizenry in water policy development and implementation, and insufficient participation by the private sector in water provision. This contributes to poor performance of the water sector, as many projects and plans are not implemented due to the opposition by the local communities. Projects that are implemented, specifically in water provision, are often undertaken by state-owned entities, which are relatively less-efficient compared with private sector projects.

A suitable framework for water resource management

The above-noted weaknesses and dichotomies in the existing framework strengthen the case for a new approach. A framework focused solely on water sector institutions (as has been the focus in the past) will be unable to improve water sector performance. The 'key' to improved performance, this research argues, lies in, embedding in the framework, essential elements of socio-political institutions. This would enable the design of water resource management framework that accords with the country's economic, social and political realities. Further, this framework would enable effective management of water resources, improve performance of the water sector and, by implication, enhance the livelihoods of people whose socio-economic condition is very much dependent on water. The proposed framework comprise the following changes:

- Water policy should be consistent with the economic and social developmental priorities of the nation (i.e., in alignment with NESDPs), with the overall objective of improving water security of the country. A new Ministry of Water (MOW) should be established to oversee the overall development of water policies, and it should interact with other government ministries to ensure that there is no conflict between water and other related policies (e.g., energy, food, land, climate, health and ecosystems).
- The new ministry should develop a nation-wide, overarching, water policy, in consultation with the River Basin Committees (RBCs), who should be responsible for providing inputs to this ministry for developing policies and plans that are suitable for, and reflect the need of, local stakeholders at the basin level. The implementation of water policies should be undertaken primarily by the River Basin Organizations (RBOs), underscored by horizontal coordination with other stakeholders to ensure smooth implementation.
- There should be increased private participation in the provision of water (i.e., supply and distribution of water). This means that the former state-owned enterprises, responsible for supply and distribution, need to be operated as public-private entities.

Also, the responsibility for wastewater treatment should be transferred to these entities. This would effectively add more water to meet water needs of the society.

- A new Water Regulatory Commission should be established to regulate the water sector, by monitoring and enforcing water legislations. This Commission needs to be clearly separated from the hierarchy of policy-making entities, and allowed functional autonomy, to ensure accountability in decision-making processes and, thus, limiting the scope for political interference in policy decisions.

- The transparency in the water sector can be further strengthened by integrating public opinions, particularly from self-organized local citizens, in decision-making processes. The 25 RBCs should therefore be operated independently, with its members selected by the public. This will also allow that policies that suit local needs are developed and implemented.

The proposed changes in water resource management framework is underpinned by: adopting a broader 'nexus' approach in planning philosophy, where the concept of Integrated Water Resource Management is applied in a holistic manner (i.e., at intra- and inter-sectoral levels); developing unified decision-making processes, where the roles of government entities change, from being the implementer of policies, to being the facilitators and regulators; limiting the influence of politics in policy decisions, by engaging the public in policy-decision-making processes, and strengthen accountability and transparency of these processes; reinstituting the role of informal institutions, by fostering grassroot/local involvement in decision-making processes, thereby ensuring the 'immersion' of traditional rituals, cognitive strategies, and mutual belief-systems in modern water resource management practices; and the role of 'water' as a multidimensional commodity, by leveling the 'playing field' for various water stakeholders, and hence enabling a meaningful appreciation of the economic, social, cultural and political values associated with water.

The proposed changes in the institutional arrangements are fundamental and significant. The implementation of these changes will inevitably pose some challenges. Firstly, these changes are likely to be seen as confronting the stakeholders who have vested interests in the current institutional arrangements and administrative practices; any changes must reflect a balance between the interests of concerned stakeholders, and a consensus among them on this balance. Secondly, the changes in this magnitude would require a strong political will and leadership. This is unlikely as the country appears to be faced with the prospects of years of political instability. Lastly, the changes require rebalancing of power (between central agencies and grassroot organizations) in the institutional arrangements; 'trust' is an essential element in this process. However, the current distrust in the Thai society is high driven largely by past decades of socio-political instability and social injustice in the country. To successfully implement the proposed change implies that the socio-political landscape need to be reconstructed, and rebuilding of 'trust' should be central in this reconstruction.

7.2. Recommendations for further research

This research has developed a comprehensive analysis of the water sector in Thailand. This analysis has provided an in-depth understanding about the deficiencies in existing water resource management framework, and how this has contributed to poor performance of the water sector, and how to amend the framework to improve sectoral performance. Notwithstanding the novelty and comprehensive of analysis in this research, there is considerable scope for further improvement in future analysis. Some suggestions include:

- The quantitative analysis undertaken in this research (chapters 4 and 5) covers only the period of contemporary Thai economy (1987-2017) where significant part of social, economic and political structures have been relatively more stable than in the past. This analysis therefore did not consider the periods of significant social and political changes within the country, for example: changed system of government in 1932, which ended an almost 800 years of absolute monarchical system, to a constitutional monarchical system, with increased civilian government role in governing the nation; the major coup d'état of 1947 where the military exerted their influence into the politics, and the prevalence of this system until 1973; years prior to the establishment of NESDB. This would enable a more complete analysis as to the effects of socio-political institutions on water sector performance.

- The data employed in the analysis of water sector performance (Chapter 4) and institution-performance linkages (Chapter 5) needs to be validated, or improved. This research is the first attempt, to the best of the knowledge of this author, to compile databases for enabling such assessments to be made at the basin levels. Data at this level does not exist, except for some variables. This research has overcome data deficiency by converting provincial-level data into basin-level data, by using an apportioning method where land area is used as a basis (proxy) for apportioning. To enable an accurate assessment, data at the basin level needs to be collected, or additional variables used as the bases for apportioning.

- This research has considered select social and political variables to estimate the impacts of 'informal' institutions on water sector performance, using econometric techniques. Other 'informal' variables, such as those related to culture, should also be considered. This would enable a deeper understanding on the role of informal institutions on performance.

- The argued soundness of the proposed water resource management framework could be placed on firmer footings by, for example, applying analytical models (such as, cost-benefit analysis, and input-output analysis), to assess the likely socio-economic impacts of the proposed framework. Such impacts could be assessed in terms of various indicators of interest, for example, GDP, sectoral outputs, employment, and trade patterns.

- This research has employed DEA to analyze the performance of the Thai water sector. It is suggested that other methods (e.g., SFA) could also be used. This would provide an opportunity to gain a better understanding into the strengths and weaknesses of various methods, and insights into the robustness of the estimated results.

- The analytical framework developed in this research could be applied for analyzing performance of other resources or infrastructure sectors, in Thailand or other country contexts. This would provide further insights into the nature of institution-performance linkages for different sectors in Thailand, or such linkages in the water sector across countries that have different social, cultural, economic and political landscapes – providing further clarity on the role of informal and socio-political institutions.

APPENDIX A
LIST OF WATER EXPERTS

This appendix presents the list of water experts across the public and private organizations in Thailand whom the author has consulted to obtain data on water sector institutions. This list reflects the individuals' organizations at the time of their contribution.

1. Alin Shintraruk	Department of Groundwater Resources
2. Amornrat	Department of Water Resources
3. Apichart Anukularmphai	Thailand Water Resource Association
4. Arissara Painmanakul	Department of Groundwater Resources
5. Bancha Kwanyuen	Kasetsart University
6. Buppa Ounsangchan	Pollution Control Department
7. Chaitawat Saowapon	Chiang Mai University
8. Chaiyo Juisiri	Pollution Control Department
9. Chalathip Rutsook	Pollution Control Department
10. Chote Trachu	Secretariat of the Prime Minister
11. Duangjai Srithawatchai	Department of Water Resources
12. Haris Prasanchum	Rajamangala University of Technology, Isan
13. Israporn Lohnarai	Pollution Control Department
14. Jesda Kaewkulaya	Kasetsart University (Retired Professor)
15. Jiraphon Ruamruk	Pollution Control Department
16. Kamalate Thonkdeeloet	Pollution Control Department
17. Kamonchai	Dewi Plus Co. Ltd.
18. Kitipong Thongchua	Department of Groundwater Resources
19. Kriangsak Pirarai	Department of Groundwater Resources
20. Manussawee Hengsuwan	Department of Groundwater Resources
21. Mongkol Lukmuang	Department of Water Resources
22. Montri Luengingsoot	Department of Groundwater Resources
23. Naiyana Wongpanarak	Dewi Plus Co. Ltd.
24. Nichapat Petchkeaw	Dewi Plus Co. Ltd.

25.	Nichaya Trongyangkoon	Pollution Control Department
26.	Nirattisai Namthip	Pollution Control Department
27.	Niwat Maneekat	Government Office
28.	Nuttinee Ratanon	Department of Groundwater Resources
29.	Pakorn Intangam	Engineer
30.	Patcharin Nagloh	Pollution Control Department
31.	Pattana Hutakorn	Electricity Generating Authority of Thailand
32.	Phitinun Orathai	Pollution Control Department
33.	Pipat Ruangngam	Suan Rom Ruen
34.	Pirote Panhkawong	Dewi Plus Co. Ltd.
35.	Poonsook	PTT Exploration and Production Public Company
36.	Rath Ruangchotevit	Environment Research and Training Center
37.	Ratikarn Paptib	Department of Water Resources
38.	Sarinee Kulsoontornrat	Navatana Consultant
39.	Sorranai N.	Italian-Thai Development PLC. (ITD)
40.	Srayut R.	Consultant
41.	Suchitra Siriwan	Pollution Control Department
42.	Sukasem Techathanaloet	Private organization
43.	Suphot Tovichakchaikul	Ministry of Natural Resources and Environment
44.	Surin Worakijhamrong	Department of Groundwater Resources
45.	Thanatip Ruksilp	Loei Rajabhat University
46.	Thanes Bamrungcheep	Punya Consultant
47.	Vinai Chaowiwat	Hydro and Agro Informatics
48.	Vithaya Yokchawi	Pollution Control Department
49.	Wannipa Kuycharoenphanitch	Chulalongkorn University

APPENDIX B
QUESTIONAIRE ON WATER SECTOR INSTITUTIONS

This appendix presents the questionnaire designed to obtain information on water sector institutions in Thailand. There were 41 water experts, across the public and private organizations in Thailand, who responded to this questionnaire.

The content of this questionnaire is as follows.

REQUEST TO QUESTIONAIRE RESPONDENTS

This is a short questionnaire, designed to obtain information on water sector institutions in Thailand. The purpose of this information is to conduct research as a part of the Doctoral degree (PhD) at the University of Technology Sydney. Your response will be anonymous, and data will be published at the aggregate level. Thank you for your cooperation and support for this study.

Background information

1. Respondent's name ……………………………………………………………….

2. Affiliation ………………………………………………………………………

3. Specialization ……………………………………………………………………

Survey Questions

(Please see next page)

Please put a cross (X) in the relevant fields for the relevant years.

	YEARS						COMMENTS
	2530-35	2535-40	2540-45	2545-50	2550-55	2555-60	
1) What is the format of water "rights"?							
unclear, unauthorized, or no rights							
common property							
proportional-sharing system							
license or permit system							
2) Is water treated as a legal "property"?							
yes							
no							
3) What is the degree of private sector participation in the provision of water supply (e.g., dams & other types of water storage, water irrigation, etc.)?							
zero (public-ownership)							
partial (public-private partnership)							
full (private-ownership)							
4) What is the criteria of water project-selection (e.g., dams & other types of water storage, water irrigation, etc.)?							
no criteria							
financial/economic (e.g., NPV, IRR)							
social (e.g., equity) & environmental							
political dictate							
5) Existence of independent body for water regulation (e.g., pricing, conflict-resolution)?							
yes							
no							
6) How is water management systems organised?							
by administrative divisions							
by geographic divisions							
7) Please rate the effectiveness of accountability (e.g., administrative oversight, financial auditing, etc.) in water organizational arrangements? (1 means							
1							
2							
3							
4							
5							
8) What is the extent of agricultural policies in the formulation of water policy? (1 means zero, 5 means full involvement)							
1							
2							
3							
4							
5							
9) What is the degree of competition in the agriculture sector? (1 means no competition, 5 means fully competitive markets)							
1							
2							
3							
4							
5							
10) Existence of independent body for regulating the agriculture sector (e.g., pricing, conflict-resolution)?							
yes							
no							

APPENDIX C
DATASET USED IN THIS RESEARCH

This appendix presents all dataset used in this research. The data sources and preparation method are discussed in sections 4.4 (for performance measurement) and 5.4 (for analysis of institution-performance linkages). It contains the following tables:

Table C-1 Investments in water infrastructure (Million Baht, 2002) *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	212	226	278	335	343	350	389	424	478	602	727	553	439	469	427	354
02. Mekong	303	380	519	646	679	820	935	1,071	1,277	1,758	2,225	1,716	1,507	1,639	1,556	1,335
03. Kok	219	233	290	349	362	404	483	543	610	781	960	745	631	673	614	514
04. Chi	260	292	395	513	585	674	883	1,169	1,477	2,195	2,863	2,497	2,028	2,191	2,100	1,887
05. Mun	238	268	362	472	558	609	868	985	1,246	1,795	2,382	2,027	1,673	1,837	1,818	1,592
06. Ping	264	304	401	497	531	557	1,328	1,547	1,780	2,283	2,862	2,202	1,769	1,929	1,776	1,480
07. Wang	213	229	284	350	365	380	423	472	542	694	844	641	516	628	575	474
08. Yom	222	249	324	394	449	584	648	720	859	1,101	1,360	1,042	836	909	831	691
09. Nan	225	259	350	453	562	666	751	858	1,165	1,476	1,830	1,504	1,210	1,319	1,235	1,042
10. Chao Phraya	247	294	422	575	864	956	1,224	1,369	1,580	2,056	2,606	2,010	1,904	2,054	1,876	1,643
11. Sakae Krang	214	229	290	353	368	376	416	455	512	657	810	623	497	535	488	432
12. Pasak	212	226	280	340	352	364	411	447	522	672	823	655	571	611	558	481
13. Tha Chin	213	230	290	352	460	469	512	641	1,647	2,079	2,511	1,911	1,515	1,618	1,476	1,821
14. Mae Klong	258	389	488	874	908	1,148	1,320	1,799	2,125	2,677	3,825	2,919	2,323	2,495	2,470	2,178
15. Prachinburi	231	260	337	428	441	463	535	654	765	982	1,206	925	739	839	812	689
16. Bang Pakong	212	231	283	342	356	364	435	478	542	689	840	662	525	1,475	1,356	1,118
17. Tonle Sap	223	239	300	360	371	378	414	451	505	633	766	580	462	492	459	381
18. East Coast Gulf	232	247	313	376	400	409	461	503	564	724	879	666	532	567	516	459
19. Phetchaburi	214	236	289	481	492	525	578	630	714	902	1,123	851	678	723	660	545
20. West Coast-Gulf	212	225	276	332	358	374	412	448	503	632	761	577	466	496	451	373
21. Peninsular-East Coast	218	249	310	803	834	852	932	1,017	1,143	1,481	1,825	1,625	1,292	1,388	1,284	1,090
22. Tapi	216	231	283	366	375	381	434	478	534	795	955	844	669	712	664	552
23. Thale Sap Songkhla	225	239	309	370	386	396	438	480	542	776	1,011	769	615	661	611	509
24. Pattani	211	224	275	384	393	403	439	480	540	677	814	617	489	521	475	393
25. Peninsular-West Coast	215	230	282	363	372	381	423	465	524	665	802	615	489	543	495	412

Sources: Budget Bureau and Royal Irrigation Department

Table C-1 Investments in water infrastructure (Million Baht, 2002)

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	329	320	319	319	391	407	392	769	438	623	344	447	811	612	514
02. Mekong	1,233	1,218	1,225	1,231	1,515	1,574	1,564	3,085	1,762	2,508	1,369	1,808	3,581	2,827	2,463
03. Kok	475	462	462	463	567	593	580	1,137	648	919	502	653	1,210	922	778
04. Chi	1,825	1,781	1,785	1,809	2,215	2,297	2,245	4,669	2,687	3,879	2,171	2,849	5,429	4,233	3,660
05. Mun	1,487	1,460	1,471	1,492	1,852	1,927	1,876	3,813	2,186	3,149	1,798	2,375	4,449	3,379	2,861
06. Ping	1,401	1,369	1,369	1,406	1,779	1,891	1,843	3,710	2,141	3,053	1,742	2,342	4,353	3,404	2,997
07. Wang	436	433	432	432	529	583	598	1,168	663	951	519	688	1,344	1,019	859
08. Yom	683	686	696	696	916	970	945	1,857	1,126	1,616	911	1,221	2,275	1,771	1,518
09. Nan	996	978	1,001	1,007	1,249	1,307	1,266	2,537	2,164	3,096	1,995	2,676	4,962	3,786	3,209
10. Chao Phraya	1,571	1,535	1,543	1,683	2,081	2,505	3,152	7,119	4,665	6,781	3,679	4,888	9,075	6,948	6,022
11. Sakae Krang	403	392	391	400	493	513	499	1,048	640	908	492	653	1,197	926	861
12. Pasak	443	432	434	434	532	552	696	1,396	810	1,212	660	860	1,596	1,207	1,018
13. Tha Chin	1,675	1,625	1,622	1,619	1,980	2,082	2,009	4,029	2,292	3,258	1,765	2,299	4,246	3,222	2,830
14. Mae Klong	2,005	1,946	1,943	1,952	2,388	2,476	2,403	4,725	2,700	3,832	2,188	2,872	5,379	4,294	3,854
15. Prachinburi	654	637	641	640	785	817	791	1,559	897	1,275	692	902	1,702	1,294	1,143
16. Bang Pakong	1,066	1,036	1,041	1,047	1,282	1,354	1,305	2,550	1,449	2,056	1,115	1,451	2,638	1,987	1,664
17. Tonle Sap	361	350	350	349	427	443	426	836	475	674	365	477	862	657	554
18. East Coast Gulf	441	441	440	528	646	671	646	1,263	720	1,025	556	731	1,355	1,034	868
19. Phetchaburi	501	487	487	486	610	632	621	1,254	716	1,022	556	728	1,542	1,225	1,061
20. West Coast-Gulf	351	340	355	361	443	459	443	876	499	709	385	501	926	703	595
21. Peninsular-East Coast	1,027	1,038	1,067	1,070	1,310	1,359	1,311	2,649	1,518	2,169	1,187	1,573	3,062	2,322	1,969
22. Tapi	558	547	549	551	675	699	674	1,327	755	1,077	586	765	1,421	1,071	911
23. Thale Sap Songkhla	477	469	486	490	606	700	687	1,396	799	1,304	707	922	1,907	1,439	1,205
24. Pattani	361	351	397	397	486	503	484	955	547	777	421	549	1,208	924	775
25. Peninsular-West Coast	396	389	403	404	494	526	511	1,015	582	831	456	596	1,134	861	725

Sources: Budget Bureau and Royal Irrigation Department

Table C-2 Irrigated area (thousand Rai) *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	3	9	14	21	26	28	48	54	64	68	76	80	84	87	90	97
02. Mekong	92	147	188	203	215	295	318	347	384	441	476	488	565	582	617	651
03. Kok	11	13	17	18	22	55	88	101	103	112	121	131	161	163	164	171
04. Chi	46	59	81	101	136	186	257	364	442	556	625	748	775	791	848	947
05. Mun	64	101	162	223	338	406	678	735	896	1,095	1,247	1,430	1,520	1,597	1,798	1,956
06. Ping	23	36	54	61	74	85	343	411	440	462	510	529	546	569	578	592
07. Wang	2	6	8	16	20	26	32	39	47	53	56	57	61	102	104	105
08. Yom	20	43	70	77	131	279	291	306	353	369	390	399	410	427	431	438
09. Nan	16	37	64	89	153	218	233	258	364	370	389	423	433	451	471	486
10. Chao Phraya	7	12	21	29	60	69	88	91	96	101	108	111	140	143	143	155
11. Sakae Krang	2	5	12	15	20	21	24	26	27	33	39	43	45	47	48	65
12. Pasak	1	2	4	7	9	12	19	19	28	34	38	49	72	74	75	87
13. Tha Chin	0	2	6	8	48	48	48	76	351	354	356	359	359	361	362	608
14. Mae Klong	6	26	31	261	265	280	283	512	557	560	568	572	572	578	587	633
15. Prachinburi	11	18	25	34	35	40	49	69	77	82	86	89	90	104	116	123
16. Bang Pakong	0	4	5	5	8	9	24	26	28	30	33	40	41	345	351	351
17. Tonle Sap	16	20	27	27	29	30	32	32	32	32	34	34	36	36	42	44
18. East Coast Gulf	57	59	80	82	108	111	116	119	121	138	146	146	152	153	153	208
19. Phetchaburi	1	5	5	40	40	46	47	47	49	50	55	55	56	56	56	57
20. West Coast-Gulf	1	2	2	3	18	23	26	26	29	29	30	30	35	35	35	36
21. Peninsular-East Coast	9	31	36	402	412	416	418	421	424	446	464	592	595	604	619	646
22. Tapi	3	10	10	21	23	24	26	29	29	34	34	69	69	70	100	110
23. Thale Sap Songkhla	12	13	23	23	27	29	32	34	36	67	88	88	90	93	98	101
24. Pattani	0	0	0	35	35	35	35	36	36	36	36	36	37	37	38	38
25. Peninsular-West Coast	8	13	13	47	48	52	60	66	71	76	78	84	87	110	111	116

Sources: Estimate by the author from the application of Equation 4-5, using provincial level data from the Royal Irrigation Department and Department of Water Resources

Table C-2 Irrigated area (thousand Rai)

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	110	112	113	114	116	122	125	130	135	136	158	158	165	173	178
02. Mekong	654	670	677	683	688	691	719	729	734	737	744	759	854	911	957
03. Kok	173	173	174	176	177	182	189	191	192	193	197	197	210	219	223
04. Chi	1,013	1,020	1,025	1,044	1,045	1,047	1,066	1,155	1,174	1,199	1,250	1,264	1,343	1,400	1,457
05. Mun	1,997	2,030	2,054	2,098	2,139	2,151	2,182	2,304	2,333	2,372	2,541	2,593	2,703	2,744	2,787
06. Ping	632	641	644	661	682	722	738	786	807	814	871	926	967	1,044	1,114
07. Wang	105	112	112	113	113	131	150	151	151	154	157	165	199	205	208
08. Yom	499	528	544	546	617	637	647	654	720	734	780	818	857	905	937
09. Nan	514	523	542	549	559	567	571	586	757	765	1,013	1,053	1,085	1,112	1,134
10. Chao Phraya	163	164	165	184	187	223	303	357	418	429	430	440	453	464	482
11. Sakae Krang	69	70	70	77	78	80	82	104	125	125	126	133	138	147	187
12. Pasak	87	88	90	90	91	92	159	168	176	195	198	198	210	211	215
13. Tha Chin	609	609	609	609	609	620	620	640	641	643	643	644	661	670	710
14. Mae Klong	635	635	636	636	636	637	644	655	664	664	679	687	732	762	819
15. Prachinburi	131	132	134	134	134	136	137	139	142	143	143	144	156	159	169
16. Bang Pakong	367	367	370	375	375	386	386	386	387	387	388	388	392	395	395
17. Tonle Sap	53	53	53	53	53	54	54	55	55	55	55	56	56	60	63
18. East Coast Gulf	240	262	262	413	413	416	416	417	421	425	425	428	457	476	480
19. Phetchaburi	57	57	57	57	57	57	58	63	64	65	66	67	95	106	113
20. West Coast-Gulf	44	44	69	79	79	79	79	86	87	88	89	90	104	109	112
21. Peninsular-East Coast	668	707	737	742	743	744	746	782	791	799	810	831	918	932	949
22. Tapi	117	131	140	140	140	140	141	150	151	151	156	160	178	182	190
23. Thale Sap Songkhla	106	110	121	125	128	164	170	185	188	243	243	244	307	310	311
24. Pattani	39	39	39	39	39	39	39	42	44	45	45	45	53	57	58
25. Peninsular-West Coast	141	149	172	174	175	192	197	208	214	219	228	231	268	278	282

Sources: Estimate by the author from the application of Equation 4-5, using provincial level data from the Royal Irrigation Department and Department of Water Resources

Table C-3 Water storage capacity (Million cubic meters) *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	2	6	6	7	9	9	22	23	23	23	24	24	24	24	25	25
02. Mekong	61	122	164	206	212	257	271	283	335	427	450	462	473	505	533	551
03. Kok	8	9	10	11	15	16	46	48	49	50	51	51	52	53	53	58
04. Chi	19	31	65	90	109	118	179	213	236	309	329	399	401	407	417	446
05. Mun	59	93	160	199	310	326	615	638	808	1,046	1,310	1,740	1,779	1,782	1,876	1,930
06. Ping	38	52	60	67	72	75	306	313	316	319	323	323	324	331	336	337
07. Wang	0	2	2	4	5	9	10	10	11	11	11	11	12	88	88	89
08. Yom	19	39	56	59	72	81	85	94	128	142	142	144	151	173	173	174
09. Nan	0	1	2	3	16	16	18	19	19	21	21	81	81	82	85	90
10. Chao Phraya	0	1	1	1	2	3	7	8	8	8	8	22	23	23	23	25
11. Sakae Krang	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	16
12. Pasak	1	1	2	4	5	6	11	11	18	27	37	59	61	61	61	84
13. Tha Chin	16	19	19	19	19	19	20	20	20	20	26	26	32	32	32	46
14. Mae Klong	11	36	37	38	39	73	82	84	89	89	137	139	140	142	168	183
15. Prachinburi	1	10	12	15	16	16	18	18	19	20	21	23	24	40	99	101
16. Bang Pakong	0	8	8	62	66	66	72	78	78	79	82	86	86	492	492	492
17. Tonle Sap	1	7	8	8	10	10	11	11	11	11	11	11	12	13	54	55
18. East Coast Gulf	3	5	9	9	14	34	205	209	209	209	211	211	211	214	215	258
19. Phetchaburi	1	1	1	7	7	15	16	16	16	16	16	16	17	17	20	20
20. West Coast-Gulf	1	1	2	5	27	46	49	49	49	50	52	52	62	63	64	64
21. Peninsular-East Coast	1	1	1	2	3	5	5	5	6	56	65	133	133	134	134	134
22. Tapi	2	2	2	8	8	8	12	13	13	31	31	48	48	48	48	48
23. Thale Sap Songkhla	0	0	0	0	0	20	20	20	20	21	34	68	68	88	88	88
24. Pattani	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25. Peninsular-West Coast	0	0	0	10	10	11	18	19	19	28	28	36	36	55	55	55

Sources: Estimate by the author from the application of Equation 4-5, using provincial level data from the Budget Bureau and Royal Irrigation Department

Table C-3 Water storage capacity (Million cubic meters)

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	25	25	25	28	28	29	29	29	29	29	49	51	57	57	59
02. Mekong	596	598	604	609	628	632	680	684	710	714	715	724	786	837	864
03. Kok	90	90	90	92	92	92	95	95	95	95	95	95	96	97	99
04. Chi	452	452	453	464	464	466	468	485	489	495	496	499	540	584	596
05. Mun	1,966	1,970	1,988	2,022	2,034	2,048	2,061	2,093	2,099	2,173	2,234	2,245	2,395	2,442	2,455
06. Ping	337	338	338	355	376	376	377	378	382	382	405	407	417	419	442
07. Wang	90	96	96	96	96	231	365	365	365	384	386	387	388	388	395
08. Yom	232	299	300	300	321	420	459	475	626	633	634	645	652	690	695
09. Nan	98	99	99	99	104	107	108	129	935	945	945	971	1,009	1,015	1,018
10. Chao Phraya	48	48	49	49	53	60	572	588	636	640	640	642	648	691	693
11. Sakae Krang	16	16	16	16	19	19	22	22	39	39	39	39	39	54	55
12. Pasak	84	85	85	85	86	92	575	604	618	661	661	661	678	725	725
13. Tha Chin	46	46	46	46	46	48	53	69	70	70	70	73	80	98	100
14. Mae Klong	183	183	183	185	185	186	187	187	188	188	205	207	213	235	255
15. Prachinburi	117	118	119	119	119	120	120	121	121	122	123	130	133	170	450
16. Bang Pakong	680	680	685	685	691	691	692	693	693	693	693	693	695	699	716
17. Tonle Sap	70	71	71	72	72	72	72	73	74	74	75	90	91	115	116
18. East Coast Gulf	309	349	349	597	602	602	602	609	609	609	609	706	708	718	718
19. Phetchaburi	20	20	20	20	57	57	81	81	81	81	81	81	82	84	84
20. West Coast-Gulf	73	73	74	74	79	79	82	82	82	82	83	83	83	88	99
21. Peninsular-East Coast	172	172	175	176	176	176	176	176	176	177	177	177	191	193	197
22. Tapi	62	62	62	63	63	63	63	64	64	65	65	65	68	69	71
23. Thale Sap Songkhla	89	89	89	89	89	89	89	89	89	117	117	117	122	123	127
24. Pattani	0	0	1	1	1	1	1	1	1	1	1	1	3	3	3
25. Peninsular-West Coast	62	62	62	64	64	71	71	81	81	82	82	85	90	91	99

Sources: Estimate by the author from the application of Equation 4-5, using provincial level data from the Budget Bureau and Royal Irrigation Department

Table C-4 Rice production (thousand tons) *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	69	84	70	86	76	84	91	86	91	78	86	72	71	76	111	102
02. Mekong	1,803	1,555	2,324	2,346	2,127	1,946	2,024	2,089	2,072	2,174	2,065	2,237	2,350	2,339	2,446	2,561
03. Kok	250	306	316	306	267	120	251	232	215	226	212	247	260	260	302	307
04. Chi	1,646	1,779	2,222	2,194	2,305	2,474	2,005	2,199	2,326	2,330	2,420	2,341	2,427	2,720	3,161	2,840
05. Mun	2,732	3,448	3,702	3,891	3,876	4,101	3,685	4,142	4,478	4,022	4,719	4,134	4,399	4,822	5,284	4,970
06. Ping	711	885	836	726	731	778	694	722	709	709	684	754	773	798	1,018	885
07. Wang	148	168	148	135	137	128	132	175	169	187	147	162	165	161	202	186
08. Yom	868	1,096	1,104	895	896	1,034	929	981	1,021	1,199	1,255	1,421	1,384	1,431	1,585	1,543
09. Nan	1,209	1,579	1,491	1,135	1,222	1,472	1,182	1,318	1,331	1,756	1,978	2,102	1,764	2,052	2,389	2,181
10. Chao Phraya	2,456	2,943	2,983	1,438	2,436	2,443	2,311	2,383	2,239	3,002	3,227	3,366	3,174	3,589	4,372	4,345
11. Sakae Krang	288	328	336	224	274	291	241	284	260	329	340	378	358	474	539	480
12. Pasak	638	814	825	430	671	573	473	684	663	809	552	528	499	553	771	770
13. Tha Chin	1,625	1,766	1,935	917	1,523	1,412	1,708	1,660	1,954	2,031	2,184	2,216	2,267	2,241	2,444	2,556
14. Mae Klong	593	587	615	413	564	756	653	628	628	587	715	753	805	804	892	904
15. Prachinburi	342	397	404	160	442	318	434	318	272	336	372	387	350	388	426	420
16. Bang Pakong	899	1,070	1,185	639	984	960	933	912	882	948	936	966	895	864	1,106	1,113
17. Tonle Sap	8	9	7	9	8	5	5	88	77	74	90	91	91	93	96	87
18. East Coast Gulf	155	177	161	115	102	98	104	78	76	80	70	66	62	61	63	61
19. Phetchaburi	181	177	199	162	146	174	196	175	200	173	223	253	227	275	300	269
20. West Coast-Gulf	40	48	58	40	34	86	42	39	50	43	58	59	47	63	75	75
21. Peninsular-East Coast	446	374	385	308	418	411	425	415	422	422	429	385	391	362	394	378
22. Tapi	147	134	142	103	154	135	138	141	142	142	142	126	124	108	99	92
23. Thale Sap Songkhla	292	276	264	228	268	240	264	225	243	256	284	269	319	271	267	264
24. Pattani	28	24	22	25	25	22	24	20	23	23	21	22	21	21	24	24
25. Peninsular-West Coast	155	152	122	104	124	123	153	134	132	133	129	121	127	116	99	97

Sources: Estimate by the author from the application of Equation 4-5, using provincial level data from the Office of Agricultural Economics

Table C-4 Rice production (thousand tons)

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	114	101	100	104	108	112	108	110	125	136	143	130	106	119	124
02. Mekong	2,761	2,628	2,740	2,743	2,798	2,898	2,911	3,491	3,555	3,579	3,424	3,389	3,126	3,334	3,356
03. Kok	339	346	350	357	368	395	377	463	511	574	564	510	458	446	405
04. Chi	3,133	3,112	3,229	3,147	3,243	3,284	3,411	4,289	4,892	4,496	4,198	4,489	4,077	4,086	4,306
05. Mun	5,449	5,369	5,546	5,445	5,556	5,580	6,021	7,530	7,472	6,798	6,431	6,634	6,348	6,776	6,904
06. Ping	981	941	941	955	980	1,054	1,015	1,066	1,140	1,485	1,463	1,300	1,023	928	1,145
07. Wang	193	191	194	191	192	206	198	220	217	228	221	208	176	207	211
08. Yom	1,734	1,639	1,656	1,658	1,697	1,900	1,858	2,270	2,429	2,947	2,856	2,486	1,874	1,820	2,056
09. Nan	2,405	2,351	2,447	2,392	2,441	2,716	2,674	3,073	3,100	4,052	3,761	3,288	2,396	2,389	2,862
10. Chao Phraya	4,690	4,578	4,588	4,660	4,816	5,331	5,126	4,596	4,578	5,828	5,710	5,046	3,938	3,947	5,073
11. Sakae Krang	581	551	562	586	595	628	598	598	613	838	818	713	543	537	698
12. Pasak	805	760	766	781	803	891	893	953	957	1,132	1,023	869	647	617	707
13. Tha Chin	2,731	2,797	2,759	2,775	2,766	3,168	2,866	2,290	2,573	2,984	2,822	2,657	1,882	1,905	2,702
14. Mae Klong	958	957	1,002	1,066	1,053	1,085	1,091	1,081	1,191	1,282	1,269	1,192	717	797	1,194
15. Prachinburi	487	493	513	532	502	524	487	458	475	432	463	503	370	473	482
16. Bang Pakong	1,130	1,033	1,002	1,042	1,059	1,091	1,028	1,020	1,155	1,332	1,364	1,334	1,057	1,016	1,020
17. Tonle Sap	104	102	106	116	102	104	102	117	125	99	106	112	75	130	136
18. East Coast Gulf	69	64	64	69	74	77	58	64	63	66	67	63	55	38	22
19. Phetchaburi	266	320	284	337	316	341	339	338	295	424	426	408	208	220	334
20. West Coast-Gulf	71	79	57	82	75	83	84	86	59	87	90	93	53	50	83
21. Peninsular-East Coast	396	392	381	392	398	411	320	283	227	233	209	153	173	219	214
22. Tapi	96	92	91	93	82	79	58	52	28	31	27	13	19	20	17
23. Thale Sap Songkhla	298	309	272	296	312	327	241	194	233	304	293	259	247	245	244
24. Pattani	23	24	24	25	25	24	21	15	21	11	16	15	11	17	15
25. Peninsular-West Coast	101	96	99	99	103	93	58	53	94	92	93	78	80	68	64

Sources: Estimate by the author from the application of Equation 4-5, using provincial level data from the Office of Agricultural Economics

Table C-5 Tapioca production (thousand tons) *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	0	1	2	1	1	2	2	1	1	1	1	1	1	1	1	1
02. Mekong	2,307	2,817	3,072	2,582	2,414	2,589	2,654	2,470	1,975	1,876	1,745	1,440	1,272	1,422	1,301	1,052
03. Kok	79	91	85	56	41	27	23	21	19	21	20	19	17	19	17	16
04. Chi	3,473	4,198	4,837	4,054	3,872	3,855	3,956	3,665	3,282	3,412	3,473	2,771	3,125	3,599	3,268	2,916
05. Mun	5,320	5,757	6,621	5,658	5,703	5,637	5,640	5,379	4,520	5,015	5,142	4,509	4,690	5,277	5,088	4,666
06. Ping	285	316	452	397	403	473	457	446	405	438	481	422	484	623	589	524
07. Wang	2	2	2	11	10	11	8	5	2	2	1	1	1	1	1	1
08. Yom	168	184	287	258	248	286	283	273	233	258	274	237	265	326	314	274
09. Nan	352	379	631	578	547	627	626	600	488	571	574	487	538	607	613	519
10. Chao Phraya	263	348	403	317	364	406	470	453	362	398	446	377	434	537	509	465
11. Sakae Krang	146	181	204	174	199	246	260	264	222	244	270	217	250	330	311	293
12. Pasak	260	340	420	328	349	349	392	382	295	294	318	305	331	376	339	307
13. Tha Chin	345	352	384	354	340	355	371	395	321	345	346	283	301	387	378	329
14. Mae Klong	833	983	976	795	805	923	1,009	944	810	841	917	795	778	934	892	778
15. Prachinburi	828	965	1,158	1,011	875	1,053	988	1,015	686	803	879	802	846	1,003	1,042	1,038
16. Bang Pakong	1,728	1,841	1,505	1,320	1,328	1,551	1,356	1,310	1,065	1,133	1,313	1,201	1,278	1,442	1,498	1,494
17. Tonle Sap	79	118	107	97	89	94	82	81	357	425	453	429	443	551	568	567
18. East Coast Gulf	2,806	3,181	2,795	2,462	1,973	1,744	1,525	1,302	1,098	1,251	1,367	1,242	1,408	1,581	1,621	1,594
19. Phetchaburi	91	92	116	95	71	75	76	67	60	49	53	46	38	41	40	34
20. West Coast-Gulf	183	153	198	146	68	49	25	18	15	10	10	7	7	8	7	1
21. Peninsular-East Coast	8	7	9	7	3	2	1	1	1	0	0	0	0	0	0	0
22. Tapi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23. Thale Sap Songkhla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24. Pattani	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25. Peninsular-West Coast	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Sources: Estimate by the author from the application of Equation 4-5, using provincial level data from the Office of Agricultural Economics

Table C-5 Tapioca production (thousand tons)

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	1	1	1	1	2	5	21	25	35	128	122	147	176	154	96
02. Mekong	1,335	1,539	1,162	1,322	1,585	1,560	1,839	1,708	1,752	2,875	3,125	2,907	3,259	3,282	2,086
03. Kok	20	22	5	7	8	6	17	20	22	50	80	89	96	95	39
04. Chi	3,607	4,019	2,843	3,789	4,201	3,883	4,562	3,382	3,249	3,932	3,564	4,016	4,586	4,764	3,854
05. Mun	5,206	5,651	4,549	6,792	8,483	7,725	8,888	6,433	6,467	8,626	8,570	8,413	8,889	8,801	8,132
06. Ping	603	603	603	747	869	848	1,240	977	969	1,462	1,594	1,614	1,711	1,501	1,429
07. Wang	1	1	1	2	1	2	6	8	11	60	77	87	100	110	54
08. Yom	322	320	303	378	441	431	628	513	524	787	933	939	1,004	947	793
09. Nan	642	644	548	667	798	783	985	824	810	1,124	1,132	1,079	1,114	1,039	1,031
10. Chao Phraya	573	653	629	797	962	937	1,395	1,014	1,044	1,395	1,526	1,533	1,676	1,622	1,462
11. Sakae Krang	350	370	351	436	546	529	681	512	469	589	629	616	667	608	650
12. Pasak	351	427	371	522	653	610	968	665	656	1,160	1,191	1,202	1,282	1,344	1,054
13. Tha Chin	404	465	385	491	629	609	708	483	400	599	560	565	596	590	593
14. Mae Klong	991	1,096	884	1,124	1,521	1,433	1,719	1,207	1,094	1,842	1,796	1,882	1,969	1,884	1,709
15. Prachinburi	1,191	1,287	1,061	1,404	1,475	1,411	1,603	1,142	1,179	1,441	1,439	1,322	1,549	1,346	1,461
16. Bang Pakong	1,621	1,747	1,197	1,484	1,704	1,584	1,700	1,268	1,450	1,531	1,622	1,547	1,555	1,351	1,504
17. Tonle Sap	651	687	532	703	742	704	813	525	527	704	732	661	778	656	862
18. East Coast Gulf	1,800	1,859	1,480	1,881	2,250	2,048	2,259	1,263	1,226	1,507	1,501	1,369	1,317	1,035	1,253
19. Phetchaburi	47	50	31	38	44	46	52	37	27	30	30	29	30	29	17
20. West Coast-Gulf	1	2	1	1	2	2	2	1	0	6	4	3	3	3	1
21. Peninsular-East Coast	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22. Tapi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23. Thale Sap Songkhla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24. Pattani	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25. Peninsular-West Coast	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Sources: Estimate by the author from the application of Equation 4-5, using provincial level data from the Office of Agricultural Economics

Table C-6 Rubber production (thousand tons) *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02. Mekong	0	0	0	0	0	0	0	1	1	3	6	10	15	27	33	39
03. Kok	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04. Chi	0	0	0	0	0	0	0	0	0	1	2	2	4	6	8	11
05. Mun	0	0	0	0	0	0	0	1	2	5	7	10	15	20	22	24
06. Ping	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07. Wang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08. Yom	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09. Nan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10. Chao Phraya	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11. Sakae Krang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12. Pasak	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13. Tha Chin	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
14. Mae Klong	0	0	0	0	0	0	0	1	2	3	3	4	5	6	7	7
15. Prachinburi	3	4	4	4	5	5	5	4	4	5	5	5	5	5	6	6
16. Bang Pakong	2	2	3	3	3	4	5	5	6	7	8	8	11	13	14	16
17. Tonle Sap	8	9	10	11	11	12	11	8	9	10	10	10	10	10	11	11
18. East Coast Gulf	78	81	90	95	97	108	108	106	117	115	119	123	138	151	156	172
19. Phetchaburi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20. West Coast-Gulf	0	0	0	0	0	0	0	1	2	2	4	5	7	7	9	9
21. Peninsular-East Coast	164	214	262	305	333	416	448	488	510	544	580	606	641	697	763	803
22. Tapi	112	148	171	188	203	247	255	244	258	286	271	275	295	355	404	411
23. Thale Sap Songkhla	74	76	99	114	130	162	179	197	206	206	217	213	221	248	282	291
24. Pattani	36	49	58	66	74	83	107	151	147	146	143	147	157	155	166	155
25. Peninsular-West Coast	177	213	252	272	306	344	389	423	427	469	517	525	521	576	641	676

Sources: Estimate by the author from the application of Equation 4-5, using provincial level data from the Office of Agricultural Economics

Table C-6 Rubber production (thousand tons)

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1
02. Mekong	46	51	51	62	73	87	124	197	280	259	312	349	391	430	470
03. Kok	0	0	0	0	0	1	2	7	11	11	14	16	18	21	23
04. Chi	12	13	12	15	17	21	29	41	55	57	70	80	86	95	104
05. Mun	26	29	20	25	31	40	48	68	98	99	119	140	148	163	178
06. Ping	0	0	0	0	0	0	0	1	2	3	4	5	5	5	6
07. Wang	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
08. Yom	0	0	0	0	0	0	1	2	4	5	7	10	9	11	12
09. Nan	0	0	0	0	0	1	1	4	9	14	18	21	22	25	27
10. Chao Phraya	0	0	0	0	0	0	0	0	1	1	1	1	1	2	2
11. Sakae Krang	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2
12. Pasak	1	1	1	1	1	1	2	3	5	5	6	7	8	9	9
13. Tha Chin	1	1	1	1	1	1	1	2	2	2	3	3	3	3	4
14. Mae Klong	7	7	5	5	5	6	7	10	14	12	14	16	18	19	20
15. Prachinburi	7	8	6	7	7	8	9	13	15	15	19	21	14	15	15
16. Bang Pakong	17	19	16	17	19	20	24	35	43	44	51	53	41	43	44
17. Tonle Sap	13	15	13	13	15	15	16	20	22	23	26	29	22	22	23
18. East Coast Gulf	198	222	168	173	192	208	219	244	269	287	309	322	286	294	302
19. Phetchaburi	0	0	0	0	0	0	0	0	0	1	1	2	1	1	2
20. West Coast-Gulf	11	13	11	11	12	13	14	15	19	21	24	27	29	32	34
21. Peninsular-East Coast	864	894	854	911	934	975	984	1,006	1,039	1,026	1,087	1,124	1,204	1,239	1,274
22. Tapi	439	458	452	490	513	545	564	589	632	600	631	652	671	691	711
23. Thale Sap Songkhla	318	346	368	376	397	414	411	421	437	421	441	454	492	507	522
24. Pattani	173	173	168	168	170	175	186	191	208	216	225	237	237	243	249
25. Peninsular-West Coast	725	756	650	657	668	680	685	715	758	774	808	843	883	906	929

Sources: Estimate by the author from the application of Equation 4-5, using provincial level data from the Office of Agricultural Economics

Table C-7 Sugarcane production (thousand tons) *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	18	19	9	16	20	16	35	19	21	28	26	24	27	26	25	30
02. Mekong	2,308	2,461	2,065	1,989	2,660	2,760	3,202	2,832	4,200	5,123	4,316	3,964	4,969	5,004	4,241	5,808
03. Kok	9	9	7	10	13	12	3	5	6	6	3	5	5	6	5	5
04. Chi	982	1,625	2,554	2,646	3,503	3,770	4,658	3,743	7,034	8,861	8,802	7,412	9,248	10,112	9,059	12,186
05. Mun	1,467	1,593	1,165	1,211	1,603	2,632	2,524	2,682	4,046	4,840	4,440	3,792	4,421	4,975	4,627	5,754
06. Ping	1,887	1,936	2,248	1,888	2,381	2,740	2,543	1,838	2,370	2,810	2,875	1,906	2,148	2,375	1,869	2,514
07. Wang	315	309	275	256	291	411	205	278	233	223	221	210	250	267	258	282
08. Yom	1,697	1,773	1,754	1,423	2,053	2,814	2,075	1,954	2,695	3,179	2,869	2,269	2,712	2,785	2,389	2,684
09. Nan	747	889	1,646	1,413	1,886	2,275	1,494	1,475	1,932	2,186	2,073	1,839	2,081	2,166	1,946	2,374
10. Chao Phraya	743	1,053	1,640	1,638	2,500	3,739	2,688	2,955	4,189	4,747	4,622	3,308	3,492	3,674	3,310	4,143
11. Sakae Krang	152	267	628	582	961	1,287	915	843	1,303	1,544	1,545	1,140	1,193	1,280	1,101	1,424
12. Pasak	625	684	628	706	1,093	1,686	1,025	1,152	1,503	1,764	1,822	1,356	1,493	1,537	1,490	1,652
13. Tha Chin	5,329	5,437	6,448	5,007	6,427	7,265	5,354	5,556	7,058	7,756	8,021	4,872	5,634	6,223	6,183	6,989
14. Mae Klong	8,636	8,684	10,233	8,610	9,527	10,904	8,769	7,917	9,169	9,274	9,998	7,568	8,583	9,042	8,752	9,485
15. Prachinburi	81	91	31	26	65	161	353	393	372	524	505	383	383	703	623	668
16. Bang Pakong	1,923	1,882	2,148	2,044	1,842	1,906	1,569	1,547	1,473	1,782	1,432	1,079	1,193	1,193	1,162	1,284
17. Tonle Sap	25	29	20	18	26	31	40	35	180	295	278	230	233	446	394	422
18. East Coast Gulf	2,228	2,166	2,682	2,486	2,223	2,120	1,565	1,639	1,613	1,853	1,428	1,068	1,150	1,127	1,057	1,180
19. Phetchaburi	643	634	695	628	671	677	590	493	553	567	536	489	528	539	522	539
20. West Coast-Gulf	898	874	1,072	977	1,151	716	650	449	620	585	556	528	564	548	525	565
21. Peninsular-East Coast	41	40	49	44	53	32	29	20	28	26	25	24	26	25	24	26
22. Tapi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23. Thale Sap Songkhla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24. Pattani	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25. Peninsular-West Coast	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Sources: Estimate by the author from the application of Equation 4-5, using provincial level data from the Office of Agricultural Economics

Table C-7 Sugarcane production (thousand tons)

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	31	30	24	24	27	29	27	27	27	29	30	32	32	32	33
02. Mekong	7,373	5,516	3,655	3,048	3,642	4,665	4,347	3,995	6,015	6,128	7,623	8,390	9,194	10,056	10,918
03. Kok	6	7	5	5	6	3	2	2	2	3	3	3	2	2	1
04. Chi	15,636	12,488	9,699	8,447	12,059	13,921	11,630	11,986	19,025	18,535	19,468	21,424	21,645	22,458	23,271
05. Mun	7,701	6,145	5,311	4,096	6,699	9,209	6,880	7,832	13,017	12,479	13,113	13,706	13,754	14,024	14,294
06. Ping	2,561	2,556	1,683	1,754	2,918	3,060	2,923	2,900	3,349	3,631	3,690	3,772	3,943	4,076	4,209
07. Wang	306	275	215	200	176	170	207	215	224	224	70	43	151	145	139
08. Yom	3,113	2,986	2,117	2,119	2,907	3,094	3,090	3,098	3,762	4,142	4,199	4,294	4,513	4,678	4,844
09. Nan	2,682	3,019	2,732	2,789	3,442	3,847	3,872	3,974	4,755	5,056	4,975	4,972	5,082	5,138	5,195
10. Chao Phraya	5,380	5,583	5,098	5,138	6,738	7,314	7,518	7,735	9,539	10,234	9,530	9,724	9,720	9,705	9,690
11. Sakae Krang	1,664	1,911	1,633	1,697	2,297	2,459	2,519	2,763	3,372	3,684	3,639	3,754	3,888	3,998	4,108
12. Pasak	2,892	3,721	2,939	2,445	4,335	4,783	4,851	4,832	6,223	6,788	6,802	7,033	7,322	7,567	7,811
13. Tha Chin	8,232	7,608	4,793	5,449	6,177	6,369	6,145	6,196	9,222	10,216	10,220	10,106	10,605	10,871	11,136
14. Mae Klong	10,757	8,466	6,265	7,109	8,673	9,240	8,818	8,896	11,513	12,082	11,472	11,351	11,330	11,220	11,111
15. Prachinburi	1,052	814	589	578	676	1,405	1,105	1,198	1,563	1,485	1,543	1,463	1,514	1,573	1,633
16. Bang Pakong	1,543	1,214	958	923	1,187	1,177	783	833	1,223	1,025	1,054	1,027	1,005	998	990
17. Tonle Sap	681	517	375	371	432	923	723	787	986	931	964	912	984	1,025	1,066
18. East Coast Gulf	1,358	1,021	756	773	1,228	1,142	726	827	1,201	819	795	759	555	420	285
19. Phetchaburi	618	522	330	310	382	380	362	392	525	511	509	525	517	517	517
20. West Coast-Gulf	644	571	393	367	349	301	276	306	390	381	381	390	386	386	387
21. Peninsular-East Coast	29	26	18	17	15	13	12	13	17	17	17	17	17	17	17
22. Tapi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23. Thale Sap Songkhla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24. Pattani	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25. Peninsular-West Coast	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Sources: Estimate by the author from the application of Equation 4-5, using provincial level data from the Office of Agricultural Economics

Table C-8 Palm oil production (thousand tons) *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02. Mekong	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03. Kok	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04. Chi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05. Mun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06. Ping	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07. Wang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08. Yom	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09. Nan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10. Chao Phraya	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11. Sakae Krang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12. Pasak	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13. Tha Chin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14. Mae Klong	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15. Prachinburi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16. Bang Pakong	0	0	0	0	0	1	10	11	16	17	16	15	17	17	37	43
17. Tonle Sap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18. East Coast Gulf	0	0	0	0	0	1	12	15	21	22	20	19	21	22	52	68
19. Phetchaburi	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
20. West Coast-Gulf	17	22	24	27	34	30	44	50	64	85	84	81	108	111	121	128
21. Peninsular-East Coast	144	164	214	220	255	275	406	427	530	685	652	614	899	871	1,039	1,084
22. Tapi	235	314	386	436	487	504	685	719	819	914	906	878	1,227	1,177	1,423	1,367
23. Thale Sap Songkhla	6	7	7	7	8	9	10	9	11	16	16	13	17	16	18	21
24. Pattani	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25. Peninsular-West Coast	324	376	453	491	528	497	662	691	790	872	882	904	1,124	1,128	1,404	1,290

Sources: Estimate by the author from the application of Equation 4-5, using provincial level data from the Office of Agricultural Economics

Table C-8 Palm oil production (thousand tons)

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
02. Mekong	0	0	0	0	0	1	12	14	20	34	37	53	72	30	32
03. Kok	0	0	0	0	0	0	0	1	1	1	1	3	4	1	2
04. Chi	0	0	0	0	0	0	1	1	2	6	5	7	13	4	5
05. Mun	0	0	0	0	0	5	6	16	16	22	26	34	42	20	21
06. Ping	0	0	0	0	0	0	0	0	0	1	2	3	4	1	1
07. Wang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08. Yom	0	0	0	0	0	0	0	0	0	1	2	3	6	2	2
09. Nan	0	0	0	0	0	0	0	0	2	3	4	8	10	3	4
10. Chao Phraya	0	0	0	0	0	1	1	8	13	26	28	34	34	18	19
11. Sakae Krang	0	0	0	0	0	0	0	0	0	0	1	2	3	1	1
12. Pasak	0	0	0	0	0	0	0	0	2	11	8	11	15	6	6
13. Tha Chin	0	0	0	0	0	0	1	1	2	2	3	5	7	3	3
14. Mae Klong	0	0	0	1	1	3	3	8	11	10	18	24	27	13	14
15. Prachinburi	0	1	1	1	1	8	7	9	19	25	39	50	54	26	28
16. Bang Pakong	65	74	74	82	70	121	109	137	165	154	167	178	189	167	174
17. Tonle Sap	1	1	1	1	1	6	6	6	14	18	19	24	30	15	16
18. East Coast Gulf	112	123	130	154	148	296	288	278	362	318	336	364	370	345	360
19. Phetchaburi	2	1	1	2	2	3	6	7	8	18	21	22	22	14	14
20. West Coast-Gulf	162	165	156	234	211	337	342	369	400	335	391	406	394	403	418
21. Peninsular-East Coast	1,287	1,390	1,344	1,913	1,880	2,931	2,544	2,577	3,361	3,391	3,727	3,690	3,655	3,514	3,651
22. Tapi	1,634	1,712	1,642	2,225	2,100	2,881	2,511	2,613	3,422	3,609	3,946	3,852	3,599	3,654	3,787
23. Thale Sap Songkhla	23	26	26	32	30	45	51	58	65	64	84	103	133	80	83
24. Pattani	0	1	1	1	1	2	6	3	5	4	6	7	9	5	5
25. Peninsular-West Coast	1,617	1,689	1,626	2,068	1,944	2,630	2,271	2,121	2,868	3,258	3,566	3,586	3,352	3,294	3,410

Sources: Estimate by the author from the application of Equation 4-5, using provincial level data from the Office of Agricultural Economics

Table C-9 Gross income from agricultural production (Billion Baht, 2002) *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	2.3	2.8	2.5	2.4	2.3	2.3	2.3	2.3	2.2	2.3	2.1	2.0	2.3	2.5	2.7	3.0
02. Mekong	23.4	25.6	27.7	27.6	27.8	25.7	25.4	24.8	25.7	25.9	23.8	25.6	28.6	30.4	30.6	29.4
03. Kok	4.0	4.2	3.2	3.3	3.2	2.5	3.0	2.9	2.8	3.2	3.0	3.1	3.7	4.1	4.4	4.8
04. Chi	18.5	20.6	26.0	25.0	26.6	26.6	23.2	24.0	23.7	22.4	21.9	22.3	23.1	25.8	27.7	25.7
05. Mun	30.1	30.9	39.7	40.9	41.2	41.8	39.1	40.7	38.9	36.0	36.2	35.6	36.7	40.2	42.2	39.2
06. Ping	12.8	15.0	14.4	14.4	15.3	15.1	14.9	14.4	13.6	14.2	13.6	12.2	15.2	17.5	17.7	20.6
07. Wang	2.3	2.5	2.6	2.4	2.4	2.3	2.2	2.3	2.2	2.1	1.8	2.1	2.1	2.2	2.2	2.2
08. Yom	9.5	11.8	12.4	11.4	11.8	12.3	11.1	10.8	10.6	11.0	10.6	11.3	11.8	12.4	12.8	12.3
09. Nan	12.6	16.4	17.6	14.7	15.3	16.5	14.4	14.6	14.0	14.7	15.0	16.2	15.3	16.7	18.1	17.0
10. Chao Phraya	34.1	38.3	41.7	33.8	37.9	40.3	38.9	40.9	33.6	26.2	27.2	27.9	27.7	31.1	33.4	32.9
11. Sakae Krang	3.0	3.6	3.7	3.0	3.4	3.5	3.0	3.1	3.0	3.1	3.1	3.2	3.3	4.0	4.0	3.6
12. Pasak	10.5	14.3	13.5	11.1	11.9	12.5	10.6	11.6	11.7	11.3	10.4	10.8	10.9	11.7	13.1	13.2
13. Tha Chin	27.1	28.5	31.8	25.5	28.7	32.3	31.2	33.1	27.8	22.6	24.2	24.8	25.8	26.9	26.8	28.2
14. Mae Klong	18.3	19.9	20.7	18.3	19.6	21.5	20.3	20.4	19.3	17.6	17.6	17.4	19.3	20.8	20.4	21.3
15. Prachinburi	8.3	9.5	9.6	7.8	9.4	9.0	9.4	7.4	6.6	6.7	6.9	7.3	7.3	8.1	8.4	8.6
16. Bang Pakong	23.5	25.4	26.6	23.5	28.0	28.1	27.0	28.2	23.4	19.1	20.9	21.8	22.5	23.9	25.6	26.1
17. Tonle Sap	1.1	1.2	1.5	1.4	1.7	1.9	1.8	2.9	4.3	5.5	5.6	5.1	5.2	5.9	6.1	6.1
18. East Coast Gulf	26.0	28.1	28.6	26.7	25.4	31.5	34.7	36.6	36.6	40.5	40.2	35.2	37.4	41.2	41.8	43.3
19. Phetchaburi	3.4	3.3	3.7	3.4	3.3	3.5	3.9	3.4	3.6	3.5	3.7	3.8	3.9	4.4	4.6	4.4
20. West Coast-Gulf	8.6	8.9	6.5	6.4	6.7	8.4	7.3	7.9	8.0	7.8	7.6	6.9	7.7	8.2	7.5	7.4
21. Peninsular-East Coast	34.4	35.5	41.8	46.6	52.0	55.7	59.4	66.9	59.5	54.1	53.5	56.0	59.3	59.5	59.0	61.4
22. Tapi	13.4	15.7	18.0	18.8	20.7	22.0	22.1	25.2	21.3	17.7	16.5	16.9	18.7	19.1	21.3	21.0
23. Thale Sap Songkhla	13.9	14.2	16.8	16.9	20.5	21.5	23.3	24.5	20.2	15.7	15.2	17.1	17.1	18.6	19.1	18.8
24. Pattani	3.6	3.4	4.7	5.0	5.6	5.8	6.1	6.7	6.3	5.9	6.0	6.2	5.9	6.0	5.8	5.6
25. Peninsular-West Coast	31.1	33.5	36.6	40.0	42.2	47.1	47.5	51.1	49.6	46.3	46.5	44.5	45.4	45.7	46.6	45.6

Sources: Estimate by the author from the application of Equation 4-5, using provincial level data from NESDB and NSO

Table C-9 Gross income from agricultural production (Billion Baht, 2002)

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	2.9	2.8	3.1	3.2	3.3	3.3	3.4	3.0	3.4	3.2	3.3	3.3	3.1	3.4	3.4
02. Mekong	34.8	35.6	36.0	33.5	34.7	36.4	38.0	39.4	49.6	54.3	55.9	58.9	58.6	51.0	52.1
03. Kok	5.0	5.0	5.8	5.5	5.8	5.8	5.9	6.0	6.6	7.1	7.1	7.1	6.9	7.1	7.2
04. Chi	30.9	29.6	27.7	29.5	32.1	33.1	33.4	34.9	39.8	39.4	38.2	40.1	39.7	38.7	39.4
05. Mun	46.8	44.9	44.1	47.5	51.0	51.8	52.2	55.6	63.8	62.2	60.2	61.8	60.7	60.4	61.4
06. Ping	21.2	22.2	24.7	23.5	23.1	23.3	24.6	22.9	29.2	29.3	23.6	23.4	21.7	26.9	27.4
07. Wang	2.5	2.4	2.5	2.6	2.7	2.6	2.6	2.4	2.6	2.6	2.5	2.4	2.3	2.5	2.5
08. Yom	14.6	13.8	13.5	13.7	14.3	14.6	14.7	15.7	17.6	19.1	18.6	17.1	14.5	17.0	17.2
09. Nan	19.5	18.5	19.4	19.5	20.2	21.1	21.2	21.9	23.5	26.8	25.7	23.8	20.2	23.9	24.3
10. Chao Phraya	36.6	33.9	32.6	33.6	33.5	34.9	34.1	32.4	33.4	34.1	36.5	33.3	29.1	31.8	31.6
11. Sakae Krang	4.6	4.4	4.1	4.5	4.9	4.9	4.9	4.6	5.3	5.7	5.9	5.4	4.6	5.4	5.5
12. Pasak	14.5	13.8	14.2	14.3	15.1	15.7	16.1	15.5	16.4	17.0	17.0	16.3	15.4	16.5	16.7
13. Tha Chin	38.2	36.6	33.7	38.6	40.1	43.4	40.5	39.8	42.4	43.2	43.7	40.9	37.7	42.5	43.1
14. Mae Klong	25.1	24.5	23.5	27.3	29.0	29.6	28.6	27.4	30.5	30.9	31.1	30.6	28.9	30.9	31.4
15. Prachinburi	9.4	8.7	9.0	9.5	9.4	9.4	9.3	9.0	9.9	9.9	10.3	10.6	10.5	9.8	9.9
16. Bang Pakong	28.2	22.7	22.1	23.0	22.7	22.8	22.7	22.0	23.5	23.0	23.3	23.6	21.6	22.3	22.1
17. Tonle Sap	6.3	6.0	5.8	6.1	5.9	6.5	6.1	6.5	7.3	7.4	8.0	8.3	8.3	8.8	9.1
18. East Coast Gulf	45.6	42.3	41.3	44.4	45.6	50.4	46.2	51.5	54.7	52.8	53.1	54.4	53.9	56.5	57.5
19. Phetchaburi	4.7	5.2	5.2	5.9	6.0	5.9	5.8	5.4	5.5	6.0	5.9	6.0	5.2	6.2	6.3
20. West Coast-Gulf	7.4	8.1	8.6	11.4	12.1	12.4	11.6	11.4	12.6	12.0	11.8	11.9	11.4	12.1	12.3
21. Peninsular-East Coast	65.5	67.5	67.6	68.9	68.4	68.3	71.2	66.9	62.0	62.6	69.7	69.6	65.8	73.9	74.8
22. Tapi	23.4	24.4	23.9	24.8	23.3	25.1	25.0	24.0	23.1	26.4	30.0	29.8	28.7	28.0	28.4
23. Thale Sap Songkhla	19.9	21.2	22.2	22.5	21.8	20.3	19.4	18.1	17.8	20.8	21.3	21.7	21.2	21.4	21.5
24. Pattani	6.0	5.7	6.0	5.9	6.2	6.2	6.7	6.7	6.3	6.3	6.0	6.3	6.1	6.7	6.8
25. Peninsular-West Coast	48.0	53.3	54.7	55.7	55.4	56.6	57.0	54.8	53.4	53.9	55.5	53.5	51.2	58.4	59.1

Sources: Estimate by the author from the application of Equation 4-5, using provincial level data from NESDB and NSO

Table C-10 Proxy variables for water sector institutions

	PRO	OWN	ORG	ACC	RIGHTS	INT	COMP	REG_2	REG_3
1987	0	0	0	1.00	0	1.00	1.00	0	0
1988	0	0	0	1.15	0	1.21	1.29	0	0
1989	0	0	0	1.30	0	1.41	1.57	0	0
1990	0	0	0	1.45	0	1.62	1.86	0	0
1991	0	0	0	1.60	0	1.83	2.14	0	0
1992	0	0	0	1.75	0	2.03	2.43	0	0
1993	2	0	0	1.82	0	2.09	2.47	0	0
1994	2	0	0	1.89	0	2.14	2.52	0	0
1995	2	0	0	1.96	0	2.19	2.57	0	0
1996	2	0	0	2.03	0	2.25	2.61	0	0
1997	2	0	0	2.09	0	2.30	2.66	0	0
1998	2	1	0	2.14	0	2.35	2.70	0	0
1999	2	1	0	2.19	0	2.39	2.75	0	0
2000	2	1	0	2.24	0	2.44	2.79	0	0
2001	2	1	0	2.29	0	2.49	2.84	0	0
2002	2	1	0	2.34	0	2.53	2.89	0	0
2003	3	1	0	2.41	0	2.64	2.97	0	1
2004	3	1	0	2.47	0	2.75	3.05	0	1
2005	3	1	0	2.53	0	2.85	3.13	0	1
2006	3	1	0	2.59	0	2.96	3.21	0	1
2007	3	1	0	2.66	0	3.07	3.29	0	1
2008	3	1	1	2.74	1	3.10	3.31	1	1
2009	3	1	1	2.82	1	3.13	3.33	1	1
2010	3	1	1	2.90	1	3.17	3.35	1	1
2011	3	1	1	2.98	1	3.20	3.38	1	1
2012	3	1	1	3.06	1	3.23	3.40	1	1
2013	1	1	1	3.08	1	3.29	3.42	1	1
2014	1	1	1	3.09	1	3.35	3.45	1	1
2015	1	1	1	3.10	1	3.41	3.47	1	1
2016	1	1	1	3.11	1	3.47	3.49	1	1
2017	1	1	1	3.13	1	3.53	3.51	1	1

Sources: Data for the proxies in this table are obtained from a survey of 41 water experts in Thailand. The list of these experts is provided in Appendix A.

Notes:
- PRO - Project selection criteria; OWN – Ownership; ORG – Organizational structure; ACC – Accountability; RIGHTS – Water 'rights'; INT – Policy integration; REG_2 – Independent regulation in stage 2; REG_3 – Independent regulation in stage 3
- The definitions of these proxy variables are provided in Section 5.4.1, Chapter 5
- Data for these variables are the same for all water basins

Table C-11 Proxy variables for socio-political institutions: POL & DEM

	POL	DEM
1987	1	0
1988	1	0
1989	1	0
1990	1	0
1991	0	0
1992	0	0
1993	1	0
1994	1	0
1995	1	0
1996	1	0
1997	1	1
1998	1	1
1999	1	1
2000	1	1
2001	1	1
2002	1	1
2003	1	1
2004	1	1
2005	1	1
2006	1	0
2007	0	0
2008	1	0
2009	1	0
2010	1	0
2011	1	0
2012	1	0
2013	1	0
2014	1	0
2015	0	0
2016	0	0
2017	0	0

Sources: Election Commission of Thailand, Secretariat of the Cabinet, Office of the Council of State

Notes:
- POL – Political power; DEM – Level of democracy
- The definitions of these proxy variables are provided in Section 5.4.1, Chapter 5
- Data for these variables are the same for all water basins

Table C-12 Proxy variable for socio-political institutions: BOUND

Basins	Number of provinces
01. Salawin	4
02. Mekong	21
03. Kok	3
04. Chi	16
05. Mun	15
06. Ping	9
07. Wang	7
08. Yom	11
09. Nan	11
10. Chao Phraya	19
11. Sakae Krang	4
12. Pasak	9
13. Tha Chin	13
14. Mae Klong	11
15. Prachinburi	7
16. Bang Pakong	11
17. Tonle Sap	3
18. East Coast Gulf	6
19. Phetchaburi	4
20. West Coast-Gulf	3
21. Peninsular-East Coast	11
22. Tapi	5
23. Thale Sap Songkhla	5
24. Pattani	4
25. Peninsular-West Coast	11

Sources: Royal Irrigation Department

Notes: - BOUND – Compatibility of geographic-political boundaries
- The definitions of this proxy variable is provided in Section 5.4.1, Chapter 5
- Data for this variable is the same for all years

Table C-13 Proxy variables for socio-political institutions: CHK *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	0.38	0.38	0.35	0.35	1.00	1.00	0.33	0.33	0.33	0.34	0.71	0.71	0.71	0.71	0.51	0.51
02. Mekong	0.18	0.18	0.18	0.18	1.00	1.00	0.19	0.19	0.19	0.19	0.39	0.39	0.39	0.39	0.36	0.36
03. Kok	0.36	0.36	0.38	0.38	1.00	1.00	0.33	0.33	0.33	0.27	0.37	0.37	0.37	0.37	0.96	0.96
04. Chi	0.26	0.26	0.22	0.22	1.00	1.00	0.16	0.16	0.16	0.19	0.53	0.53	0.53	0.53	0.32	0.32
05. Mun	0.16	0.16	0.15	0.15	1.00	1.00	0.18	0.18	0.18	0.21	0.29	0.29	0.29	0.29	0.33	0.33
06. Ping	0.25	0.25	0.34	0.34	1.00	1.00	0.23	0.23	0.23	0.20	0.36	0.36	0.36	0.36	0.64	0.64
07. Wang	0.34	0.34	0.64	0.64	1.00	1.00	0.34	0.34	0.34	0.47	0.47	0.47	0.47	0.47	0.94	0.94
08. Yom	0.18	0.18	0.26	0.26	1.00	1.00	0.22	0.22	0.22	0.25	0.20	0.20	0.20	0.20	0.56	0.56
09. Nan	0.22	0.22	0.18	0.18	1.00	1.00	0.18	0.18	0.18	0.17	0.25	0.25	0.25	0.25	0.46	0.46
10. Chao Phraya	0.21	0.21	0.20	0.20	1.00	1.00	0.25	0.25	0.25	0.17	0.25	0.25	0.25	0.25	0.58	0.58
11. Sakae Krang	0.40	0.40	0.23	0.23	1.00	1.00	0.26	0.26	0.26	0.23	0.23	0.23	0.23	0.23	0.42	0.42
12. Pasak	0.25	0.25	0.32	0.32	1.00	1.00	0.23	0.23	0.23	0.19	0.29	0.29	0.29	0.29	0.63	0.63
13. Tha Chin	0.36	0.36	0.39	0.39	1.00	1.00	0.43	0.43	0.43	0.34	0.43	0.43	0.43	0.43	0.36	0.36
14. Mae Klong	0.31	0.31	0.28	0.28	1.00	1.00	0.47	0.47	0.47	0.27	0.31	0.31	0.31	0.31	0.36	0.36
15. Prachinburi	0.37	0.37	0.87	0.87	1.00	1.00	0.52	0.52	0.52	0.59	0.46	0.46	0.46	0.46	0.60	0.60
16. Bang Pakong	0.22	0.22	0.15	0.15	1.00	1.00	0.20	0.20	0.20	0.21	0.27	0.27	0.27	0.27	0.40	0.40
17. Tonle Sap	0.55	0.55	0.98	0.98	1.00	1.00	0.55	0.55	0.55	0.56	0.50	0.50	0.50	0.50	0.63	0.63
18. East Coast Gulf	0.22	0.22	0.24	0.24	1.00	1.00	0.29	0.29	0.29	0.43	0.34	0.34	0.34	0.34	0.31	0.31
19. Phetchaburi	0.59	0.59	0.70	0.70	1.00	1.00	0.33	0.33	0.33	0.26	0.30	0.30	0.30	0.30	0.54	0.54
20. West Coast-Gulf	0.87	0.87	0.94	0.94	1.00	1.00	0.73	0.73	0.73	0.78	0.78	0.78	0.78	0.78	0.93	0.93
21. Peninsular-East Coast	0.75	0.75	0.21	0.21	1.00	1.00	0.53	0.53	0.53	0.74	0.74	0.74	0.74	0.74	0.67	0.67
22. Tapi	0.72	0.72	0.28	0.28	1.00	1.00	0.81	0.81	0.81	1.00	1.00	1.00	1.00	1.00	1.00	1.00
23. Thale Sap Songkhla	1.00	1.00	0.33	0.33	1.00	1.00	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
24. Pattani	0.50	0.50	0.46	0.46	1.00	1.00	1.00	1.00	1.00	0.54	0.54	0.54	0.54	0.54	0.52	0.52
25. Peninsular-West Coast	0.54	0.54	0.29	0.29	1.00	1.00	0.93	0.93	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Sources: Estimated by the author, by using variable POL

Notes: CHK – Checks and balances in political system. The definitions of this proxy variable is provided in Section 5.4.1, Chapter 5.

Table C-13 Proxy variables for socio-political institutions: CHK

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	0.51	0.51	0.70	0.70	1.00	0.48	0.48	0.48	0.48	0.67	0.67	0.67	1.00	1.00	1.00
02. Mekong	0.36	0.36	0.92	0.92	1.00	0.76	0.76	0.76	0.76	0.95	0.95	0.95	1.00	1.00	1.00
03. Kok	0.96	0.96	1.00	1.00	1.00	0.92	0.92	0.92	0.92	1.00	1.00	1.00	1.00	1.00	1.00
04. Chi	0.32	0.32	0.93	0.93	1.00	0.81	0.81	0.81	0.81	0.92	0.92	0.92	1.00	1.00	1.00
05. Mun	0.33	0.33	0.79	0.79	1.00	0.38	0.38	0.38	0.38	0.49	0.49	0.49	1.00	1.00	1.00
06. Ping	0.64	0.64	0.91	0.91	1.00	0.55	0.55	0.55	0.55	0.79	0.79	0.79	1.00	1.00	1.00
07. Wang	0.94	0.94	0.96	0.96	1.00	0.94	0.94	0.94	0.94	0.92	0.92	0.92	1.00	1.00	1.00
08. Yom	0.56	0.56	0.90	0.90	1.00	0.33	0.33	0.33	0.33	0.36	0.36	0.36	1.00	1.00	1.00
09. Nan	0.46	0.46	0.75	0.75	1.00	0.43	0.43	0.43	0.43	0.50	0.50	0.50	1.00	1.00	1.00
10. Chao Phraya	0.58	0.58	0.83	0.83	1.00	0.37	0.37	0.37	0.37	0.43	0.43	0.43	1.00	1.00	1.00
11. Sakae Krang	0.42	0.42	0.77	0.77	1.00	0.29	0.29	0.29	0.29	0.33	0.33	0.33	1.00	1.00	1.00
12. Pasak	0.63	0.63	0.99	0.99	1.00	0.49	0.49	0.49	0.49	0.49	0.49	0.49	1.00	1.00	1.00
13. Tha Chin	0.36	0.36	0.50	0.50	1.00	0.36	0.36	0.36	0.36	0.31	0.31	0.31	1.00	1.00	1.00
14. Mae Klong	0.36	0.36	0.70	0.70	1.00	0.32	0.32	0.32	0.32	0.28	0.28	0.28	1.00	1.00	1.00
15. Prachinburi	0.60	0.60	1.00	1.00	1.00	0.32	0.32	0.32	0.32	0.32	0.32	0.32	1.00	1.00	1.00
16. Bang Pakong	0.40	0.40	0.87	0.87	1.00	0.45	0.45	0.45	0.45	0.35	0.35	0.35	1.00	1.00	1.00
17. Tonle Sap	0.63	0.63	1.00	1.00	1.00	0.55	0.55	0.55	0.55	0.55	0.55	0.55	1.00	1.00	1.00
18. East Coast Gulf	0.31	0.31	0.83	0.83	1.00	1.00	1.00	1.00	1.00	0.54	0.54	0.54	1.00	1.00	1.00
19. Phetchaburi	0.54	0.54	0.52	0.52	1.00	0.83	0.83	0.83	0.83	0.73	0.73	0.73	1.00	1.00	1.00
20. West Coast-Gulf	0.93	0.93	0.93	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
21. Peninsular-East Coast	0.67	0.67	0.92	0.92	1.00	0.58	0.58	0.58	0.58	0.84	0.84	0.84	1.00	1.00	1.00
22. Tapi	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
23. Thale Sap Songkhla	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
24. Pattani	0.52	0.52	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.87	0.87	0.87	1.00	1.00	1.00
25. Peninsular-West Coast	1.00	1.00	0.86	0.86	1.00	1.00	1.00	1.00	1.00	0.86	0.86	0.86	1.00	1.00	1.00

Sources: Estimated by the author, by using variable POL

Notes: CHK – Checks and balances in political system. The definitions of this proxy variable is provided in Section 5.4.1, Chapter 5.

Table C-14 Proxy variables for socio-political institutions: BAR *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	4.00	5.63	7.07	3.31	3.93	3.12	4.50	5.44	3.87	0.11	3.26	1.08	0.81	1.08	4.11	0.14
02. Mekong	4.43	6.21	4.20	0.11	3.66	1.29	0.75	1.07	3.24	0.12	3.09	0.89	1.63	2.66	7.48	4.99
03. Kok	0.80	0.90	3.16	0.11	3.37	0.62	1.45	1.52	6.71	4.84	7.31	6.15	5.89	3.32	4.87	4.01
04. Chi	1.25	1.71	6.55	4.49	6.53	5.47	5.71	2.97	4.60	3.58	2.49	2.75	1.62	3.37	5.14	3.08
05. Mun	5.73	2.24	3.68	1.87	1.74	2.15	0.81	3.02	4.48	3.05	0.07	2.07	0.47	0.42	0.63	1.81
06. Ping	0.76	2.79	3.91	2.75	0.06	1.87	0.35	0.36	0.54	1.25	0.08	2.04	0.40	0.87	0.98	6.01
07. Wang	0.32	0.28	0.44	0.83	0.08	2.66	0.34	0.68	0.88	6.24	5.01	7.19	4.63	5.35	1.70	2.51
08. Yom	0.24	0.66	0.82	3.46	2.87	2.35	3.42	4.54	1.85	2.26	1.88	0.97	1.05	0.62	0.81	2.37
09. Nan	3.29	3.84	1.84	1.93	1.89	0.77	1.00	0.59	0.75	2.37	1.73	0.06	1.00	0.27	0.18	0.31
10. Chao Phraya	1.15	0.65	0.90	2.82	2.17	0.06	1.34	0.32	0.23	0.36	0.27	0.07	7.38	0.22	0.57	1.00
11. Sakae Krang	1.16	0.32	0.22	0.34	0.28	0.07	6.97	0.24	0.35	0.59	2.52	1.79	1.31	3.51	4.20	2.20
12. Pasak	5.97	0.23	0.37	0.55	2.44	2.10	1.14	3.19	3.49	2.14	3.37	3.75	1.09	1.37	0.94	0.88
13. Tha Chin	1.18	3.44	3.67	2.19	2.47	3.60	0.89	0.99	0.80	0.72	1.93	2.34	0.06	1.32	0.28	0.19
14. Mae Klong	0.91	1.05	0.63	0.78	1.67	1.94	0.06	1.17	0.27	0.23	0.36	0.15	0.07	4.70	0.21	0.40
15. Prachinburi	0.05	1.15	0.24	0.21	0.34	0.12	0.05	4.72	0.17	0.43	0.53	2.34	1.97	1.18	3.65	4.08
16. Bang Pakong	0.05	4.45	0.16	0.43	0.56	2.23	1.89	1.14	4.20	4.21	1.74	2.71	3.30	0.64	0.87	0.63
17. Tonle Sap	1.97	1.21	4.41	4.35	1.67	2.55	3.20	0.62	0.87	0.56	0.70	1.49	1.88	0.05	1.01	0.23
18. East Coast Gulf	2.87	0.57	0.93	0.55	0.69	1.56	1.98	0.05	0.99	0.22	0.23	0.38	0.07	0.04	3.39	0.17
19. Phetchaburi	2.09	0.05	1.02	0.22	0.21	0.36	0.07	0.05	3.32	0.15	0.47	0.78	2.33	1.95	1.07	4.74
20. West Coast-Gulf	0.06	0.04	3.51	0.15	0.40	0.72	2.12	1.72	1.03	4.81	4.08	1.29	2.71	3.14	0.65	0.99
21. Peninsular-East Coast	1.94	1.63	1.02	4.39	3.99	1.33	2.48	3.25	0.57	0.86	0.70	0.59	1.94	2.06	0.05	1.09
22. Tapi	2.15	3.04	0.57	0.80	0.65	0.55	1.91	2.00	0.05	1.09	0.20	0.18	0.34	0.07	0.04	3.80
23. Thale Sap Songkhla	1.78	1.73	0.04	1.01	0.20	0.17	0.32	0.07	0.04	3.31	0.15	0.46	0.72	2.02	1.78	1.14
24. Pattani	0.31	0.07	0.04	2.96	0.13	0.40	0.70	1.86	1.64	1.14	3.77	3.75	1.04	1.99	2.52	0.60
25. Peninsular-West Coast	0.66	1.96	1.63	1.16	3.81	3.84	1.12	2.04	2.75	0.53	0.76	0.53	0.55	1.51	1.69	0.04

Sources: National Economic and Social Development Board
Notes: BAR – Bargaining power. The definition of this proxy variable is provided in Section 5.4.1, Chapter 5.

Table C-14 Proxy variables for socio-political institutions: BAR

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	3.32	0.91	1.86	3.32	7.77	4.93	6.54	8.18	9.10	4.42	5.33	6.25	2.92	3.46	3.03
02. Mekong	6.55	7.77	9.05	3.88	5.46	4.39	3.29	3.48	2.44	3.96	6.06	3.92	0.10	3.21	0.93
03. Kok	2.57	2.92	2.05	3.60	5.24	3.23	0.07	2.40	0.63	0.56	0.78	2.11	0.09	2.27	0.51
04. Chi	0.07	2.24	0.58	0.52	0.72	2.31	0.09	2.41	0.44	1.10	1.15	6.61	4.80	7.04	5.54
05. Mun	0.09	2.22	0.46	0.93	1.25	6.14	4.89	7.12	4.62	5.82	2.20	3.64	2.03	1.43	1.64
06. Ping	4.83	6.98	4.55	5.54	1.89	3.16	1.56	1.23	1.46	0.61	2.57	3.45	2.29	0.06	1.72
07. Wang	1.60	1.07	1.17	0.58	1.34	2.69	1.86	0.06	1.19	0.31	0.21	0.36	0.43	0.07	4.28
08. Yom	1.74	0.05	1.00	0.29	0.17	0.30	0.34	0.06	5.80	0.23	0.67	0.80	2.46	1.91	1.33
09. Nan	0.23	0.07	6.00	0.21	0.70	0.83	2.36	1.68	1.25	3.45	3.85	1.93	2.32	2.15	0.92
10. Chao Phraya	2.73	1.98	1.44	4.20	4.28	1.97	2.12	2.42	0.83	1.00	0.73	0.89	2.55	1.37	0.05
11. Sakae Krang	3.27	3.70	0.96	1.38	0.91	0.95	3.02	2.61	0.06	2.12	0.33	0.21	0.39	0.29	0.07
12. Pasak	3.10	3.30	0.06	2.27	0.34	0.20	0.38	0.32	0.07	6.50	0.24	0.48	0.54	2.42	2.45
13. Tha Chin	0.33	0.19	0.07	5.64	0.20	0.39	0.54	2.41	2.05	1.14	3.63	3.81	1.88	2.66	3.26
14. Mae Klong	0.48	2.39	2.11	1.10	3.62	3.75	1.76	2.84	3.12	0.80	0.93	0.65	0.74	1.63	1.96
15. Prachinburi	1.77	3.06	3.74	0.77	0.87	0.73	0.72	1.62	2.19	0.05	1.10	0.23	0.19	0.32	0.11
16. Bang Pakong	0.70	1.52	2.02	0.05	1.15	0.21	0.20	0.36	0.10	0.05	4.39	0.16	0.45	0.69	2.30
17. Tonle Sap	0.21	0.36	0.08	0.04	2.91	0.15	0.45	0.83	2.22	1.75	1.15	4.50	3.99	1.47	2.50
18. East Coast Gulf	0.47	0.80	2.24	2.00	1.15	4.48	3.96	1.38	2.61	2.89	0.59	0.92	0.61	0.68	1.68
19. Phetchaburi	4.20	1.10	2.58	2.81	0.59	0.90	0.46	0.57	1.75	2.28	0.04	1.03	0.20	0.18	0.31
20. West Coast-Gulf	0.64	0.61	1.84	2.04	0.05	0.95	0.21	0.19	0.32	0.09	0.04	4.04	0.17	0.39	0.72
21. Peninsular-East Coast	0.20	0.18	0.33	0.06	0.04	3.75	0.17	0.47	0.73	1.87	1.80	1.16	4.10	3.86	1.26
22. Tapi	0.16	0.47	0.66	2.01	1.91	1.15	3.80	3.96	1.19	2.00	3.01	0.58	0.80	0.63	0.58
23. Thale Sap Songkhla	4.03	4.12	1.09	2.02	2.86	0.59	0.78	0.51	0.53	1.41	1.46	0.04	0.93	0.19	0.15
24. Pattani	0.76	0.44	0.52	1.19	1.28	0.04	0.74	0.19	0.14	0.30	0.06	0.03	2.81	0.12	0.40
25. Peninsular-West Coast	0.89	0.18	0.17	0.31	0.06	0.04	3.03	0.14	0.43	0.72	1.94	1.65	1.11	4.35	4.00

Sources: National Economic and Social Development Board

Notes: BAR – Bargaining power. The definition of this proxy variable is provided in Section 5.4.1, Chapter 5

Table C-15 Non-institutional factors: WAT, LAND & RIV

Basins	WAT	LAND	RIV
01. Salawin	13.2	1.20	17
02. Mekong	34.0	17.16	37
03. Kok	3.7	1.69	4
04. Chi	7.4	16.17	20
05. Mun	8.2	25.67	31
06. Ping	7.4	4.16	20
07. Wang	1.7	1.39	7
08. Yom	4.6	5.79	11
09. Nan	11.8	8.85	16
10. Chao Phraya	3.2	8.83	2
11. Sakae Krang	1.3	1.18	4
12. Pasak	1.9	5.48	8
13. Tha Chin	1.3	6.05	2
14. Mae Klong	20.4	3.62	11
15. Prachinburi	3.9	2.82	4
16. Bang Pakong	2.5	3.27	4
17. Tonle Sap	2.0	0.92	3
18. East Coast Gulf	14.9	4.61	6
19. Phetchaburi	2.3	1.08	3
20. West Coast-Gulf	2.7	1.60	5
21. Peninsular-East Coast	18.6	7.58	13
22. Tapi	6.0	2.99	8
23. Thale Sap Songkhla	3.5	2.68	3
24. Pattani	3.2	1.11	2
25. Peninsular-West Coast	17.5	3.92	13

Sources: Department of Water Resources

Notes: - WAT – Water resources (billion cubic meters); LAND – Land area (million Rai); RIV – tributary. The definitions of these variables are provided in Section 5.4.1, Chapter 5.

- Data for these variables is the same for all years

Table C-16 Rainfall (meters per year) *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	1.53	1.12	1.20	1.22	1.00	1.23	1.38	1.12	1.18	1.70	1.49	1.59	1.31	0.87	1.55	1.42
02. Mekong	1.66	1.71	1.53	1.72	1.73	1.73	1.60	1.37	1.53	1.81	1.81	1.61	1.79	1.57	1.81	1.87
03. Kok	1.56	1.34	1.23	1.67	1.29	1.35	1.33	1.16	1.35	1.80	1.69	1.22	1.35	1.39	1.54	1.47
04. Chi	1.10	1.14	1.18	1.18	1.22	1.31	1.20	1.08	1.07	1.18	1.25	1.25	1.04	1.10	1.34	1.54
05. Mun	1.33	1.20	1.28	1.28	1.23	1.36	1.25	1.18	1.17	1.20	1.27	1.43	1.20	1.18	1.43	1.66
06. Ping	1.19	1.05	1.01	1.28	1.00	1.04	1.02	1.00	0.86	1.20	1.25	1.22	0.87	0.89	1.26	1.28
07. Wang	1.01	1.04	1.02	1.21	1.00	1.03	0.91	1.05	1.03	1.27	1.17	1.22	0.92	1.01	1.20	1.15
08. Yom	1.28	1.11	1.20	1.25	1.22	1.09	1.06	1.05	1.02	1.37	1.43	1.25	0.95	1.13	1.33	1.49
09. Nan	1.37	1.12	1.09	1.23	1.09	1.12	1.09	1.11	1.01	1.41	1.53	1.39	1.04	1.11	1.48	1.43
10. Chao Phraya	1.23	1.08	1.07	1.24	1.06	1.08	1.03	1.06	0.98	1.32	1.37	1.29	0.97	1.04	1.35	1.34
11. Sakae Krang	1.21	1.17	1.00	1.54	1.06	0.99	0.82	1.18	0.85	0.92	1.43	1.44	0.97	1.19	1.48	1.17
12. Pasak	1.15	1.15	1.17	1.17	1.16	1.19	1.04	0.98	0.89	1.08	1.27	1.26	0.98	1.15	1.22	1.14
13. Tha Chin	0.95	1.13	0.89	1.35	0.91	1.06	0.92	1.04	0.95	0.79	1.15	1.07	0.74	1.16	1.36	1.07
14. Mae Klong	1.42	1.24	1.24	1.55	1.06	1.18	1.22	1.17	1.18	1.37	1.48	1.61	1.32	1.19	1.64	1.53
15. Prachinburi	1.68	1.73	1.59	1.84	1.64	1.77	1.76	1.38	1.56	1.72	1.86	1.49	1.53	1.52	1.77	2.10
16. Bang Pakong	1.33	1.41	1.19	1.59	1.13	1.39	1.22	1.28	1.30	1.24	1.38	1.25	0.84	1.24	1.56	1.42
17. Tonle Sap	1.63	1.84	1.51	1.63	1.42	1.38	1.28	1.08	1.14	1.64	1.71	1.65	1.24	1.44	1.52	2.12
18. East Coast Gulf	1.88	2.01	1.94	2.41	1.60	1.69	1.74	1.77	2.37	2.14	2.27	2.34	2.05	2.68	2.58	2.93
19. Phetchaburi	1.16	1.01	1.04	1.07	1.03	0.74	0.89	1.00	1.06	0.78	1.13	1.26	0.94	1.03	1.28	1.24
20. West Coast-Gulf	1.15	1.15	1.18	1.16	1.01	0.84	1.17	0.98	0.96	0.76	1.02	1.34	0.90	1.07	1.43	1.41
21. Peninsular-East Coast	1.88	2.01	1.94	2.41	1.60	1.69	1.74	1.77	2.37	2.14	2.27	2.34	2.05	2.68	2.58	2.93
22. Tapi	1.56	2.41	1.69	1.84	1.38	1.47	1.48	1.67	2.18	2.01	2.07	2.54	2.56	2.65	2.04	2.22
23. Thale Sap Songkhla	1.70	1.80	1.74	2.06	1.39	1.43	1.68	1.64	2.33	1.95	1.88	2.39	1.93	2.39	2.23	2.30
24. Pattani	1.41	1.62	1.98	2.26	1.61	1.56	1.89	1.83	2.15	1.92	2.07	2.11	2.15	2.52	2.69	2.62
25. Peninsular-West Coast	2.09	2.73	2.11	2.59	1.99	2.07	2.12	1.89	2.49	2.63	2.41	2.61	2.34	2.87	2.71	2.71

Source: Estimate by the author from the application of Equation 4-5, using provincial level data from the Department of Meteorology

Table C-16 Rainfall (meters per year)

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	1.29	1.56	1.10	1.21	1.40	1.55	1.56	1.44	1.46	1.34	1.68	1.82	1.24	1.25	1.50
02. Mekong	1.96	2.02	1.52	1.77	1.82	1.77	1.90	1.74	1.62	1.81	1.93	1.58	1.67	1.57	1.20
03. Kok	1.86	1.86	1.33	1.66	1.63	1.66	1.60	1.37	1.45	1.69	1.64	1.77	1.82	1.66	0.97
04. Chi	1.50	1.44	1.16	1.18	1.21	1.35	1.39	1.67	1.43	1.38	1.44	1.00	1.12	0.99	0.81
05. Mun	1.42	1.50	1.17	1.12	1.23	1.30	1.31	1.42	1.40	1.25	1.39	1.02	1.22	1.21	1.31
06. Ping	1.14	1.37	1.04	0.96	1.16	1.21	1.15	1.29	1.06	1.26	1.32	1.12	1.10	0.94	0.82
07. Wang	1.25	1.37	0.89	0.98	1.04	1.30	1.07	1.16	0.96	1.15	1.23	1.05	0.94	0.70	0.72
08. Yom	1.47	1.54	1.00	1.31	1.25	1.53	1.35	1.28	1.21	1.39	1.57	1.37	1.19	1.24	0.87
09. Nan	1.24	1.42	1.10	1.25	1.30	1.45	1.31	1.24	1.08	1.39	1.57	1.23	1.14	1.11	0.83
10. Chao Phraya	1.24	1.41	1.03	1.12	1.20	1.37	1.22	1.24	1.07	1.30	1.46	1.19	1.11	1.08	0.81
11. Sakae Krang	1.11	1.23	0.95	0.94	0.96	0.96	1.12	1.28	0.85	1.45	1.34	0.95	1.07	0.89	0.59
12. Pasak	0.90	1.13	0.92	0.76	1.09	1.28	1.05	1.24	0.96	1.27	1.15	1.24	1.27	1.02	0.81
13. Tha Chin	0.94	1.04	0.91	0.77	1.07	0.94	1.01	1.07	0.95	1.24	0.87	0.98	0.91	1.05	0.92
14. Mae Klong	1.26	1.60	1.24	1.17	1.42	1.56	1.34	1.36	1.26	1.27	1.01	1.44	1.11	1.17	0.95
15. Prachinburi	1.44	1.84	1.42	1.46	1.35	1.76	1.53	1.89	1.51	1.18	1.91	1.69	1.98	1.33	1.06
16. Bang Pakong	1.09	1.31	1.35	0.92	1.30	1.34	1.18	1.45	1.45	1.36	1.36	1.55	1.35	1.03	0.99
17. Tonle Sap	1.55	1.77	1.86	1.52	1.50	1.60	1.57	1.58	1.32	1.20	1.75	1.71	1.70	1.14	0.81
18. East Coast Gulf	1.92	2.01	1.90	1.35	2.69	1.66	1.93	2.23	1.61	2.98	2.18	1.76	1.50	1.47	0.98
19. Phetchaburi	0.99	0.82	1.23	1.04	0.92	0.98	1.16	0.78	0.66	0.52	0.49	0.87	0.69	0.88	0.81
20. West Coast-Gulf	1.16	1.02	1.36	0.96	1.09	1.08	1.43	0.77	0.75	0.77	0.77	0.93	1.21	0.80	0.71
21. Peninsular-East Coast	1.92	2.01	1.90	1.35	2.69	1.66	1.93	2.23	1.61	2.98	2.18	1.76	1.50	1.25	1.40
22. Tapi	1.60	1.57	1.55	1.49	1.76	1.88	1.85	1.63	1.06	2.07	1.74	1.65	1.76	1.30	1.31
23. Thale Sap Songkhla	1.65	1.78	1.74	1.39	3.03	1.34	1.88	2.13	1.17	2.68	2.19	1.79	1.71	1.60	0.91
24. Pattani	1.78	1.71	1.69	1.81	2.54	2.05	1.95	1.72	1.89	2.22	1.97	2.03	1.77	1.01	1.03
25. Peninsular-West Coast	2.37	2.20	2.13	2.16	2.49	2.16	2.67	2.35	2.14	2.84	2.97	2.28	3.13	2.42	2.28

Source: Estimate by the author from the application of Equation 4-5, using provincial level data from the Department of Meteorology

Table C-17 Per-capita income ('000 baht per year, 2002) *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	23.9	13.5	21.3	12.9	12.7	27.0	24.2	17.6	19.1	22.0	23.6	29.2	54.2	43.4	32.3	31.7
02. Mekong	25.9	19.5	21.7	27.0	26.0	34.2	58.8	45.6	36.5	51.4	45.6	42.4	30.7	46.6	31.4	36.7
03. Kok	63.9	49.3	36.7	47.1	52.0	44.9	36.1	46.2	34.5	40.1	40.9	38.6	52.3	25.4	15.9	23.7
04. Chi	38.1	47.8	38.3	42.6	44.0	42.9	56.4	29.8	16.6	24.4	17.9	16.9	36.5	33.5	22.0	24.1
05. Mun	58.9	30.7	16.9	25.0	19.1	17.7	40.9	34.8	23.1	25.4	33.5	29.8	49.1	54.9	58.7	44.1
06. Ping	42.4	34.7	23.0	25.4	28.8	28.8	50.8	61.9	61.6	49.1	64.0	72.4	73.8	46.6	59.9	45.0
07. Wang	58.7	109.2	68.1	55.6	53.0	40.6	46.8	48.1	68.4	49.0	54.5	57.1	49.0	67.1	33.0	20.9
08. Yom	51.9	52.3	72.5	51.9	58.4	61.3	52.6	72.5	34.4	22.4	32.0	24.2	24.0	51.5	43.7	28.6
09. Nan	51.9	76.2	32.7	21.6	31.6	24.7	23.9	51.6	42.6	27.8	32.0	33.2	36.2	65.8	68.3	74.5
10. Chao Phraya	21.9	46.6	38.2	27.1	31.1	31.4	33.7	59.2	61.6	65.8	73.8	52.5	41.7	48.8	54.7	61.9
11. Sakae Krang	35.6	58.9	63.7	70.7	70.6	59.3	42.2	55.9	64.3	77.2	56.1	63.6	60.2	48.3	78.6	31.3
12. Pasak	45.0	57.1	67.2	81.7	52.6	60.1	60.1	45.2	79.5	31.7	22.0	31.7	24.4	23.4	49.3	40.0
13. Tha Chin	60.0	42.9	79.6	33.2	23.6	34.2	25.5	25.3	54.9	43.1	31.5	34.3	34.5	38.2	70.6	75.3
14. Mae Klong	28.3	27.8	59.3	43.9	34.8	37.2	41.5	45.8	75.9	78.6	88.5	80.9	68.3	48.3	72.1	72.0
15. Prachinburi	50.7	45.8	49.3	53.0	61.1	61.0	70.4	46.9	67.4	77.6	82.5	60.5	76.1	66.8	48.0	88.4
16. Bang Pakong	55.2	47.7	62.7	79.5	76.5	62.1	76.5	71.6	50.4	82.9	37.4	28.4	39.0	32.7	31.9	63.8
17. Tonle Sap	51.1	51.9	50.2	51.2	37.8	30.3	40.3	35.3	33.8	64.5	47.8	37.8	39.6	43.9	52.2	87.5
18. East Coast Gulf	40.8	36.3	33.2	64.9	46.9	37.6	40.2	45.4	52.4	61.7	59.8	67.0	60.6	63.7	53.5	64.5
19. Phetchaburi	41.1	54.0	53.7	55.5	57.1	58.6	56.9	62.0	52.6	61.3	81.0	81.2	64.6	80.7	71.0	52.7
20. West Coast-Gulf	51.9	51.6	55.0	52.4	55.0	55.8	68.1	84.5	75.4	56.5	55.9	41.1	39.8	45.8	43.4	41.5
21. Peninsular-East Coast	66.4	85.3	75.3	56.3	59.8	43.7	43.7	50.2	47.0	44.5	77.0	55.7	46.9	50.5	54.6	64.5
22. Tapi	45.3	50.6	46.4	45.2	75.5	55.7	46.8	49.8	67.3	65.4	68.8	59.7	58.5	62.0	60.8	58.6
23. Thale Sap Songkhla	44.3	47.5	49.7	62.2	59.7	62.7	61.3	62.5	63.4	58.3	53.1	65.8	64.7	67.8	66.1	79.0
24. Pattani	62.9	62.0	58.8	57.2	59.1	86.3	75.2	68.3	79.4	82.0	54.1	60.0	48.2	48.4	54.0	48.5
25. Peninsular-West Coast	60.1	69.8	61.4	62.2	55.2	67.0	48.1	50.7	55.0	52.9	51.1	83.3	59.0	48.4	51.0	54.7

Source: Estimate by the author from the application of Equation 4-5, using provincial level data from NESDB

Table C-17 Per-capita income ('000 baht per year, 2002)

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	43.6	34.8	28.6	42.9	30.0	32.7	36.3	32.9	44.4	27.1	14.4	22.5	14.1	13.3	30.1
02. Mekong	38.0	34.0	46.6	24.0	15.3	22.5	15.8	15.1	31.3	27.3	20.6	23.1	42.1	27.1	38.9
03. Kok	16.6	16.2	33.7	30.6	21.1	22.9	25.3	26.7	41.6	64.4	48.7	36.8	45.7	56.2	31.8
04. Chi	32.3	28.7	43.6	72.2	53.4	42.3	59.0	62.7	39.5	40.0	54.3	40.9	45.4	48.3	45.1
05. Mun	58.7	69.6	55.6	42.7	60.5	42.4	47.1	49.9	44.7	61.6	31.8	17.5	27.2	19.3	18.5
06. Ping	49.2	53.2	45.4	63.6	33.0	19.2	29.0	20.6	20.4	45.4	37.1	24.3	27.2	29.7	30.4
07. Wang	30.0	22.7	22.4	47.8	39.6	26.0	29.2	33.6	33.6	63.4	67.1	73.9	60.4	53.6	45.1
08. Yom	32.6	33.2	36.8	68.9	60.1	76.3	64.4	61.5	48.3	52.4	55.4	75.0	54.4	62.4	60.6
09. Nan	79.7	55.7	46.4	55.1	56.0	70.2	53.7	60.0	59.3	49.9	74.9	31.0	20.7	29.7	22.8
10. Chao Phraya	53.3	59.0	59.3	48.7	75.6	32.1	22.0	31.5	23.8	22.9	48.9	38.2	28.3	33.1	37.2
11. Sakae Krang	21.9	31.1	24.0	22.7	49.1	37.9	28.4	31.3	37.4	35.3	60.2	68.3	70.1	75.1	68.9
12. Pasak	28.9	31.7	32.3	34.8	63.3	63.3	74.3	71.7	62.4	45.0	51.8	67.1	79.7	52.0	61.5
13. Tha Chin	82.2	79.6	48.5	46.0	55.0	69.5	83.0	54.7	64.7	61.3	43.9	79.1	34.1	25.7	35.4
14. Mae Klong	87.2	57.6	69.3	64.9	46.9	80.6	35.4	26.6	36.5	29.4	28.8	60.6	45.1	34.9	36.0
15. Prachinburi	36.8	27.8	39.5	29.7	30.1	63.5	47.2	36.0	37.5	44.5	46.4	54.0	63.5	72.1	62.7
16. Bang Pakong	46.8	36.4	38.1	38.2	48.4	85.7	79.2	75.4	85.1	83.0	50.3	77.4	81.7	73.4	62.7
17. Tonle Sap	69.1	68.2	66.1	68.4	52.8	60.6	82.8	72.8	62.8	78.8	71.6	51.7	95.1	37.4	30.8
18. East Coast Gulf	61.0	65.9	61.7	80.1	70.2	50.1	55.0	38.9	33.3	41.2	39.0	35.6	64.3	50.2	38.5
19. Phetchaburi	93.0	39.7	35.2	42.7	40.8	38.9	68.4	52.6	40.5	41.9	55.8	53.2	58.8	55.6	52.9
20. West Coast-Gulf	73.0	54.7	42.5	43.7	51.5	58.5	58.1	58.9	55.9	51.5	56.7	58.4	57.4	53.9	51.1
21. Peninsular-East Coast	58.4	57.8	59.8	53.1	59.9	60.1	61.3	59.8	62.8	67.4	92.7	78.6	55.8	55.3	44.0
22. Tapi	67.7	87.0	55.0	69.6	57.7	61.4	51.5	59.5	44.8	45.3	50.6	46.6	44.8	77.4	54.9
23. Thale Sap Songkhla	52.2	62.8	47.2	47.1	52.2	47.7	46.4	77.8	53.4	43.4	46.2	59.4	60.7	60.7	65.0
24. Pattani	47.9	81.0	56.1	44.2	46.9	54.4	59.4	63.8	67.8	64.6	63.9	57.7	57.7	61.4	67.8
25. Peninsular-West Coast	68.5	60.9	63.8	60.5	62.3	64.7	62.0	67.6	62.7	64.6	73.1	64.8	65.5	57.5	61.6

Source: Estimate by the author from the application of Equation 4-5, using provincial level data from NESDB

Table C-18 Population density (person per km^2) *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	20	92	71	110	123	59	57	78	61	68	73	91	145	56	75	64
02. Mekong	57	79	62	75	74	92	146	57	76	75	20	97	95	68	116	82
03. Kok	148	58	78	84	21	99	95	69	119	83	133	87	78	21	96	78
04. Chi	93	68	118	84	133	85	78	21	97	78	114	129	64	58	80	63
05. Mun	79	21	98	79	115	131	64	58	81	64	48	76	94	156	59	80
06. Ping	65	59	81	64	45	76	94	159	60	81	42	21	107	95	70	123
07. Wang	95	161	60	74	46	63	109	96	71	125	89	141	90	83	22	98
08. Yom	110	97	72	127	90	143	92	84	22	100	81	124	136	66	60	83
09. Nan	93	85	23	101	82	125	137	67	60	83	66	49	78	98	169	63
10. Chao Phraya	138	67	61	83	66	44	78	99	172	64	77	46	69	116	100	74
11. Sakae Krang	79	100	175	65	77	47	71	118	101	75	132	94	149	98	89	25
12. Pasak	73	121	102	76	134	95	150	100	91	25	103	84	128	139	69	61
13. Tha Chin	152	100	92	25	102	84	127	138	70	61	84	67	47	78	102	182
14. Mae Klong	126	136	71	61	84	67	49	78	102	184	67	83	57	74	132	103
15. Prachinburi	51	77	102	187	67	85	52	75	136	104	77	135	97	155	101	97
16. Bang Pakong	58	76	140	104	77	135	98	156	101	99	25	97	86	123	131	73
17. Tonle Sap	99	157	101	100	25	96	86	122	129	73	59	82	67	55	76	103
18. East Coast Gulf	87	121	128	74	59	82	67	55	75	104	98	69	91	58	77	152
19. Phetchaburi	67	68	74	104	61	69	93	66	78	157	105	77	136	100	160	101
20. West Coast-Gulf	94	63	78	161	105	77	136	101	161	101	108	25	92	87	118	124
21. Peninsular-East Coast	137	102	162	102	109	25	92	87	118	124	75	58	81	67	59	73
22. Tapi	91	86	118	123	74	58	80	66	61	73	104	211	70	99	69	82
23. Thale Sap Songkhla	80	66	66	73	104	213	70	101	67	84	171	106	77	139	104	166
24. Pattani	71	102	67	85	173	106	77	140	104	167	104	112	25	90	86	117
25. Peninsular-West Coast	77	141	105	168	104	112	25	89	87	116	120	76	57	80	66	63

Source: Estimate by the author from the application of Equation 4-5, using provincial level data from NESDB and DWR

Table C-18 Population density (person per km^2)

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	20	95	94	67	114	80	129	81	73	20	93	72	112	125	61
02. Mekong	131	84	76	21	95	74	113	126	62	58	80	63	83	75	94
03. Kok	113	128	63	57	80	63	92	75	92	151	58	78	97	21	102
04. Chi	40	75	93	154	59	79	44	21	104	94	69	119	85	135	86
05. Mun	42	21	106	95	70	121	86	137	87	80	21	99	79	116	132
06. Ping	87	139	89	81	21	98	80	121	133	65	59	82	64	42	77
07. Wang	80	122	134	65	59	82	65	50	77	96	164	61	75	44	64
08. Yom	65	44	77	97	167	62	75	50	65	112	98	72	128	91	144
09. Nan	76	45	67	114	99	73	129	92	146	95	86	24	102	82	126
10. Chao Phraya	131	93	147	96	88	24	103	83	127	140	68	61	84	66	48
11. Sakae Krang	104	83	129	141	68	62	84	67	46	79	101	177	66	78	46
12. Pasak	84	67	46	78	101	180	66	80	48	73	124	103	76	134	95
13. Tha Chin	67	81	50	74	128	103	76	135	96	153	100	94	25	101	85
14. Mae Klong	77	135	97	154	101	95	25	99	85	125	135	71	60	83	67
15. Prachinburi	25	98	86	124	133	72	60	83	67	54	77	103	190	68	86
16. Bang Pakong	60	83	67	57	76	103	192	68	88	55	76	144	104	77	136
17. Tonle Sap	195	69	90	57	77	148	104	77	136	99	158	101	102	26	95
18. East Coast Gulf	104	77	136	100	159	101	104	26	93	87	119	126	75	58	81
19. Phetchaburi	106	26	92	87	118	124	75	58	81	67	59	74	104	74	70
20. West Coast-Gulf	75	58	81	67	59	74	104	76	70	96	63	79	164	105	77
21. Peninsular-East Coast	104	208	70	98	64	81	166	105	77	138	102	163	102	110	25
22. Tapi	168	105	77	139	103	165	103	110	25	91	86	118	123	74	58
23. Thale Sap Songkhla	103	111	25	90	86	117	123	74	58	80	66	62	73	103	215
24. Pattani	122	74	57	80	66	67	73	103	217	71	104	67	86	175	106
25. Peninsular-West Coast	72	104	217	71	103	69	84	178	106	78	139	105	167	103	114

Source: Estimate by the author from the application of Equation 4-5, using provincial level data from NESDB and DWR

APPENDIX D
RESULTS ON WATER SECTOR PERFORMANCE

This appendix presents detailed results obtained from the application of DEAP software version 2.1. The methodology used to obtain these results are discussed in Section 4.3. It contains the following tables:

Table D-1 Efficiency Scores: Stage 1 *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	0.010	0.020	0.027	0.031	0.036	0.037	0.059	0.064	0.074	0.078	0.084	0.087	0.087	0.090	0.092	0.095
02. Mekong	0.998	0.998	0.998	0.829	0.824	0.905	0.862	0.880	0.888	0.929	0.936	0.936	0.925	0.929	0.941	0.919
03. Kok	0.122	0.100	0.114	0.098	0.116	0.241	0.329	0.359	0.356	0.375	0.391	0.409	0.446	0.448	0.449	0.444
04. Chi	0.655	0.561	0.656	0.592	0.686	0.748	0.821	0.900	0.933	0.995	0.999	0.999	0.999	0.999	0.999	0.999
05. Mun	0.401	0.401	0.520	0.505	0.645	0.671	0.812	0.814	0.857	0.917	0.933	0.936	0.943	0.950	0.962	0.960
06. Ping	0.999	0.628	0.708	0.809	0.821	0.554	1.000	1.000	1.000	1.000	0.938	0.936	0.939	0.943	0.934	0.924
07. Wang	0.026	0.057	0.069	0.105	0.129	0.157	0.172	0.202	0.227	0.250	0.260	0.260	0.263	0.388	0.392	0.380
08. Yom	0.165	0.244	0.325	0.279	0.410	0.644	0.610	0.620	0.651	0.665	0.673	0.674	0.649	0.660	0.661	0.642
09. Nan	0.208	0.333	0.457	0.466	0.657	0.756	0.724	0.747	0.842	0.846	0.847	0.859	0.838	0.845	0.851	0.835
10. Chao Phraya	0.483	0.587	0.744	0.724	0.998	0.998	0.998	0.998	0.987	0.999	0.999	0.999	0.999	0.999	0.999	0.981
11. Sakae Krang	0.037	0.061	0.116	0.117	0.141	0.143	0.151	0.158	0.160	0.186	0.215	0.230	0.226	0.236	0.239	0.297
12. Pasak	0.012	0.024	0.042	0.057	0.075	0.096	0.134	0.134	0.182	0.212	0.229	0.278	0.358	0.363	0.364	0.391
13. Tha Chin	0.056	0.067	0.114	0.109	0.442	0.421	0.391	0.521	1.002	1.002	0.987	0.981	0.930	0.928	0.927	1.001
14. Mae Klong	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
15. Prachinburi	0.285	0.335	0.393	0.393	0.388	0.408	0.435	0.540	0.562	0.579	0.587	0.592	0.567	0.609	0.646	0.640
16. Bang Pakong	0.007	0.072	0.066	0.066	0.090	0.096	0.206	0.216	0.227	0.240	0.253	0.290	0.281	0.892	0.893	0.862
17. Tonle Sap	0.173	0.159	0.184	0.149	0.155	0.150	0.145	0.146	0.142	0.142	0.147	0.146	0.144	0.145	0.170	0.173
18. East Coast Gulf	0.299	0.227	0.261	0.213	0.261	0.257	0.273	0.269	0.265	0.291	0.295	0.284	0.289	0.290	0.286	0.350
19. Phetchaburi	0.049	0.124	0.109	0.534	0.519	0.541	0.509	0.504	0.502	0.507	0.528	0.520	0.502	0.502	0.503	0.487
20. West Coast-Gulf	0.012	0.012	0.014	0.020	0.099	0.127	0.134	0.126	0.129	0.130	0.129	0.128	0.148	0.149	0.148	0.148
21. Peninsular-East Coast	0.108	0.250	0.244	1.003	0.980	0.935	0.865	0.857	0.838	0.851	0.849	0.916	0.870	0.871	0.876	0.855
22. Tapi	0.114	0.072	0.068	0.299	0.292	0.195	0.269	0.312	0.317	0.680	0.575	0.751	0.748	0.744	0.666	0.650
23. Thale Sap Songkhla	0.207	0.157	0.238	0.191	0.213	0.215	0.216	0.223	0.226	0.369	0.440	0.439	0.425	0.432	0.445	0.437
24. Pattani	0.004	0.003	0.004	0.247	0.240	0.236	0.219	0.220	0.221	0.220	0.216	0.211	0.206	0.208	0.209	0.205
25. Peninsular-West Coast	0.056	0.068	0.060	0.160	0.158	0.163	0.170	0.182	0.188	0.201	0.202	0.213	0.207	0.251	0.252	0.253

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-4
- A score of 'one' is assigned to the most efficient basin, and 'zero', to the least efficient basin

Table D-1 Efficiency Scores: Stage 1

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	0.106	0.108	0.108	0.109	0.111	0.113	0.110	0.113	0.115	0.116	0.134	0.134	0.139	0.144	0.147
02. Mekong	0.920	0.925	0.927	0.920	0.920	0.897	0.871	0.858	0.848	0.847	0.849	0.851	0.870	0.880	0.885
03. Kok	0.448	0.449	0.450	0.449	0.450	0.445	0.439	0.435	0.431	0.430	0.436	0.435	0.451	0.460	0.464
04. Chi	0.999	0.999	0.999	0.999	0.999	0.984	0.955	0.952	0.944	0.945	0.947	0.947	0.953	0.956	0.956
05. Mun	0.954	0.956	0.958	0.959	0.962	0.949	0.922	0.917	0.909	0.911	0.918	0.919	0.924	0.923	0.921
06. Ping	0.928	0.930	0.930	0.936	0.943	0.945	0.937	0.938	0.937	0.937	0.940	0.944	0.945	0.944	0.946
07. Wang	0.379	0.397	0.397	0.396	0.396	0.434	0.462	0.456	0.451	0.457	0.460	0.471	0.517	0.522	0.524
08. Yom	0.681	0.699	0.707	0.702	0.736	0.727	0.705	0.696	0.713	0.716	0.730	0.740	0.748	0.760	0.765
09. Nan	0.845	0.849	0.858	0.855	0.859	0.844	0.816	0.812	0.927	0.928	0.949	0.953	0.954	0.951	0.947
10. Chao Phraya	0.990	0.992	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11. Sakae Krang	0.309	0.312	0.312	0.331	0.336	0.332	0.328	0.379	0.425	0.424	0.424	0.437	0.446	0.465	0.525
12. Pasak	0.391	0.395	0.400	0.398	0.399	0.393	0.559	0.567	0.572	0.599	0.600	0.599	0.611	0.614	0.615
13. Tha Chin	1.001	1.001	1.001	0.992	0.990	0.966	0.930	0.919	0.906	0.905	0.905	0.903	0.905	0.906	0.911
14. Mae Klong	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
15. Prachinburi	0.657	0.659	0.664	0.659	0.659	0.644	0.622	0.617	0.615	0.615	0.615	0.615	0.635	0.640	0.662
16. Bang Pakong	0.872	0.872	0.874	0.870	0.869	0.854	0.822	0.809	0.799	0.797	0.797	0.795	0.795	0.795	0.793
17. Tonle Sap	0.202	0.202	0.202	0.202	0.202	0.199	0.193	0.193	0.192	0.192	0.192	0.195	0.197	0.210	0.216
18. East Coast Gulf	0.382	0.406	0.406	0.536	0.537	0.530	0.514	0.508	0.505	0.506	0.505	0.511	0.525	0.533	0.533
19. Phetchaburi	0.486	0.486	0.488	0.485	0.499	0.490	0.488	0.503	0.500	0.503	0.504	0.507	0.591	0.617	0.631
20. West Coast-Gulf	0.171	0.171	0.216	0.233	0.236	0.234	0.233	0.242	0.242	0.243	0.243	0.244	0.263	0.272	0.281
21. Peninsular-East Coast	0.863	0.877	0.887	0.881	0.879	0.856	0.823	0.820	0.811	0.811	0.813	0.817	0.834	0.836	0.837
22. Tapi	0.767	0.759	0.755	0.757	0.757	0.756	0.756	0.758	0.762	0.768	0.738	0.739	0.755	0.733	0.732
23. Thale Sap Songkhla	0.452	0.462	0.490	0.493	0.500	0.557	0.546	0.559	0.556	0.625	0.625	0.625	0.682	0.683	0.682
24. Pattani	0.205	0.204	0.317	0.318	0.318	0.317	0.314	0.321	0.326	0.327	0.325	0.325	0.518	0.511	0.502
25. Peninsular-West Coast	0.294	0.306	0.339	0.339	0.340	0.353	0.346	0.354	0.356	0.360	0.370	0.372	0.408	0.416	0.419

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-4
- A score of 'one' is assigned to the most efficient basin, and 'zero', to the least efficient basin

Table D-2 Efficiency Scores: Stage 2 *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	0.080	0.142	0.140	0.389	0.250	0.389	0.484	0.285	0.400	0.338	0.486	0.429	0.413	0.624	0.867	0.970
02. Mekong	0.013	0.229	0.310	0.574	0.585	0.647	0.773	0.698	0.618	0.559	0.630	0.657	0.602	0.539	0.513	1.000
03. Kok	0.022	0.091	0.141	0.406	0.253	0.118	0.196	0.122	0.180	0.217	0.278	0.304	0.273	0.290	0.322	0.489
04. Chi	0.024	0.254	0.278	0.396	0.274	0.256	0.409	0.321	0.406	0.382	0.386	0.408	0.480	0.521	0.508	0.606
05. Mun	0.076	0.572	0.494	0.851	0.498	0.534	0.712	0.685	0.783	0.652	0.803	0.690	0.702	1.000	1.000	1.000
06. Ping	0.016	0.097	0.133	0.248	0.271	0.306	0.167	0.124	0.162	0.185	0.185	0.193	0.208	0.221	0.249	0.294
07. Wang	0.060	0.360	0.310	0.403	0.294	0.203	0.358	0.327	0.403	0.437	0.423	0.459	0.433	0.232	0.279	0.345
08. Yom	0.049	0.228	0.180	0.615	0.365	0.385	0.486	0.430	0.455	0.466	0.589	0.641	0.709	0.732	0.635	1.001
09. Nan	0.047	0.388	0.302	0.870	0.190	0.307	0.276	0.233	0.323	0.400	0.477	0.400	0.416	0.738	0.570	0.807
10. Chao Phraya	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11. Sakae Krang	0.073	0.539	0.929	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
12. Pasak	0.576	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.748	0.710	0.947	1.001
13. Tha Chin	1.001	1.001	1.001	1.001	1.001	0.900	1.000	1.000	0.862	0.712	0.729	0.709	0.995	0.729	0.575	0.915
14. Mae Klong	0.065	0.327	0.360	0.068	0.266	0.324	0.570	0.376	0.434	0.441	0.507	0.461	0.581	0.596	0.594	0.584
15. Prachinburi	0.012	0.214	0.349	0.307	0.518	0.969	0.998	0.962	0.742	0.771	0.765	0.857	0.800	0.580	0.571	1.000
16. Bang Pakong	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.276	0.309	0.582
17. Tonle Sap	0.007	0.034	0.035	0.083	0.097	0.136	0.181	0.198	0.936	1.001	1.001	1.001	1.001	1.001	0.898	1.000
18. East Coast Gulf	0.058	0.999	0.999	0.999	0.999	0.999	0.999	0.991	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
19. Phetchaburi	0.052	0.184	0.201	0.094	0.091	0.059	0.085	0.091	0.114	0.107	0.134	0.160	0.162	0.302	0.270	0.410
20. West Coast-Gulf	0.690	0.998	0.998	0.998	0.884	0.492	0.824	0.761	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
21. Peninsular-East Coast	0.335	0.378	0.490	1.002	0.887	1.002	1.002	1.002	1.002	0.472	0.397	0.259	0.274	0.408	0.401	0.400
22. Tapi	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
23. Thale Sap Songkhla	0.620	0.998	0.998	0.998	0.998	0.507	0.806	0.722	0.818	0.726	0.506	0.411	0.471	0.438	0.419	0.578
24. Pattani	1.001	1.001	1.001	0.402	0.459	0.160	0.210	0.294	0.294	0.293	0.267	0.293	0.321	0.356	0.341	0.322
25. Peninsular-West Coast	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-4
- A score of 'one' is assigned to the most efficient basin, and 'zero', to the least efficient basin

Table D-2 Efficiency Scores: Stage 2

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	0.986	0.908	0.852	0.893	0.893	0.917	0.970	0.850	0.948	1.000	0.950	0.905	0.887	0.892	0.858
02. Mekong	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
03. Kok	0.505	0.543	0.525	0.552	0.547	0.539	0.562	0.572	0.685	0.668	0.681	0.732	0.961	1.000	0.673
04. Chi	0.594	0.530	0.512	0.508	0.477	0.477	0.510	0.583	0.740	0.664	0.683	0.742	0.728	0.704	0.736
05. Mun	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
06. Ping	0.274	0.273	0.265	0.270	0.263	0.248	0.277	0.334	0.368	0.425	0.418	0.445	0.427	0.398	0.424
07. Wang	0.355	0.351	0.338	0.352	0.348	0.269	0.222	0.220	0.222	0.242	0.252	0.232	0.195	0.222	0.222
08. Yom	1.001	0.935	0.884	0.936	0.852	0.885	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
09. Nan	0.646	0.666	0.773	0.737	0.747	0.749	0.964	0.941	0.776	0.865	0.639	0.638	0.573	0.627	0.742
10. Chao Phraya	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11. Sakae Krang	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
12. Pasak	1.001	1.001	1.001	1.001	1.001	1.001	0.902	0.989	1.000	1.000	1.000	1.000	1.000	1.000	1.000
13. Tha Chin	0.886	0.775	0.803	0.810	0.794	0.912	1.000	0.870	1.000	1.000	1.000	1.000	1.000	1.000	1.000
14. Mae Klong	0.699	0.450	0.433	0.575	0.420	0.404	0.565	0.650	0.682	0.729	0.684	0.681	0.617	0.608	0.726
15. Prachinburi	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.977	1.000	1.000	1.000	0.651
16. Bang Pakong	0.518	0.532	0.450	0.441	0.471	0.460	0.469	0.491	0.717	0.604	0.656	0.725	0.791	1.000	0.709
17. Tonle Sap	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
18. East Coast Gulf	0.999	0.999	0.999	0.798	0.898	0.899	0.869	0.796	0.781	0.749	0.749	0.746	0.660	0.714	0.588
19. Phetchaburi	0.274	0.476	0.399	0.491	0.438	0.372	0.489	0.460	0.274	0.430	0.482	0.578	0.175	0.161	0.391
20. West Coast-Gulf	0.999	0.996	0.598	0.621	0.546	0.558	0.721	0.719	0.566	0.502	0.556	0.713	0.555	0.505	0.736
21. Peninsular-East Coast	0.352	0.348	0.380	0.411	0.414	0.473	0.488	0.541	0.524	0.509	0.517	0.525	0.539	0.551	0.569
22. Tapi	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
23. Thale Sap Songkhla	0.657	0.701	0.676	0.702	0.707	0.627	0.600	0.590	0.626	0.481	0.491	0.500	0.526	0.572	0.511
24. Pattani	0.393	0.406	0.473	0.460	0.454	0.483	0.529	0.500	0.506	0.522	0.534	0.545	0.424	0.417	0.425
25. Peninsular-West Coast	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-4
- A score of 'one' is assigned to the most efficient basin, and 'zero', to the least efficient basin

Table D-3 Efficiency Scores: Stage 3 *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
02. Mekong	0.812	0.700	1.000	1.000	0.918	1.000	0.498	0.436	0.516	0.763	0.662	0.498	0.367	0.839	0.823	0.597
03. Kok	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
04. Chi	0.341	0.342	0.331	0.396	0.385	0.404	0.444	0.402	0.425	0.329	0.377	0.338	0.296	0.291	0.369	0.312
05. Mun	0.519	0.508	0.653	0.699	0.428	0.382	0.421	0.362	0.458	0.947	0.588	0.788	0.627	0.595	0.481	0.779
06. Ping	0.558	0.512	0.493	0.711	0.689	0.716	0.811	0.780	0.885	0.811	0.999	0.717	0.777	0.839	0.918	0.966
07. Wang	0.914	0.761	0.999	0.999	0.719	0.999	0.863	0.492	0.555	0.999	0.999	0.999	0.630	0.968	0.999	0.698
08. Yom	0.353	0.326	0.329	0.467	0.447	0.462	0.488	0.454	0.521	0.391	0.457	0.371	0.353	0.354	0.464	0.355
09. Nan	0.379	0.337	0.382	0.530	0.454	0.499	0.563	0.448	0.576	0.419	0.472	0.433	0.427	0.372	0.463	0.368
10. Chao Phraya	0.553	0.520	0.523	1.000	0.643	0.767	0.849	0.793	0.927	0.466	0.528	0.420	0.365	0.389	0.482	0.391
11. Sakae Krang	0.348	0.349	0.328	0.508	0.413	0.447	0.494	0.429	0.552	0.400	0.510	0.405	0.356	0.332	0.427	0.320
12. Pasak	0.497	0.539	0.508	0.884	0.585	0.811	0.884	0.620	0.772	0.541	0.898	0.789	0.718	0.775	0.851	0.725
13. Tha Chin	0.761	0.720	0.771	0.999	0.825	0.998	0.998	0.998	0.998	0.722	0.854	0.730	0.658	0.648	0.797	0.668
14. Mae Klong	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
15. Prachinburi	0.793	0.711	1.001	1.001	1.001	1.001	0.808	0.841	0.888	0.626	0.693	0.670	0.616	0.616	0.715	0.615
16. Bang Pakong	0.999	0.882	0.814	1.001	1.001	1.001	1.001	1.001	1.001	0.847	1.001	0.975	0.892	0.973	1.000	0.886
17. Tonle Sap	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
18. East Coast Gulf	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
19. Phetchaburi	0.688	0.563	0.681	0.729	0.803	0.812	0.852	0.865	1.001	1.001	1.001	0.745	0.682	0.732	1.000	0.873
20. West Coast-Gulf	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
21. Peninsular-East Coast	1.000	1.000	1.000	1.000	1.000	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
22. Tapi	0.675	0.668	0.705	0.679	0.719	1.001	1.001	0.849	0.710	0.629	0.679	0.725	0.728	0.679	0.728	0.760
23. Thale Sap Songkhla	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
24. Pattani	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
25. Peninsular-West Coast	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-4
- A score of 'one' is assigned to the most efficient basin, and 'zero', to the least efficient basin

Table D-3 Efficiency Scores: Stage 3

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
02. Mekong	0.597	0.710	0.653	0.566	0.656	0.422	0.388	0.366	0.471	0.620	0.621	0.726	0.676	0.510	0.545
03. Kok	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
04. Chi	0.406	0.350	0.288	0.310	0.335	0.363	0.329	0.310	0.437	0.444	0.570	0.626	0.507	0.452	0.457
05. Mun	0.456	0.637	0.795	0.904	0.726	0.444	0.383	0.281	0.311	0.387	0.657	0.479	0.499	0.329	0.696
06. Ping	0.999	0.999	0.999	0.981	0.959	1.000	1.000	0.989	1.000	1.000	0.940	0.957	0.933	1.000	1.000
07. Wang	0.679	0.806	0.971	0.775	0.987	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
08. Yom	0.449	0.397	0.346	0.368	0.373	0.405	0.375	0.346	0.557	0.613	0.520	0.561	0.474	0.541	0.525
09. Nan	0.456	0.383	0.352	0.391	0.388	0.434	0.399	0.364	0.410	0.572	0.521	0.547	0.535	0.578	0.476
10. Chao Phraya	0.468	0.394	0.329	1.001	0.862	0.512	0.582	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11. Sakae Krang	0.430	0.376	0.295	0.345	0.360	0.362	0.337	0.368	0.380	0.527	0.464	0.422	0.349	0.384	0.373
12. Pasak	0.886	0.803	0.746	0.776	0.800	0.840	0.786	0.783	0.721	0.735	0.757	0.772	0.728	0.802	0.842
13. Tha Chin	0.992	0.864	0.715	0.893	0.867	0.971	0.876	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
14. Mae Klong	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
15. Prachinburi	0.682	0.606	0.579	0.587	0.597	0.578	0.607	0.636	0.649	0.776	0.765	0.697	0.819	0.649	0.645
16. Bang Pakong	1.002	0.851	0.747	0.769	0.750	0.757	0.807	0.789	0.773	0.755	0.786	0.760	0.750	0.743	0.735
17. Tonle Sap	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
18. East Coast Gulf	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
19. Phetchaburi	1.001	1.001	0.910	0.990	0.982	0.972	0.895	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
20. West Coast-Gulf	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
21. Peninsular-East Coast	1.000	1.000	1.000	0.992	0.989	0.930	0.964	0.925	0.914	0.976	1.000	1.000	1.000	1.000	1.000
22. Tapi	0.805	0.755	0.629	0.597	0.584	0.586	0.531	0.538	1.000	1.000	1.000	1.000	1.000	1.000	1.000
23. Thale Sap Songkhla	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
24. Pattani	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
25. Peninsular-West Coast	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-4
- A score of ‘one’ is assigned to the most efficient basin, and ‘zero’, to the least efficient basin

Table D-4 Productivity change indices: Stage 1 *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	1.000	1.371	1.335	1.418	1.308	1.177	1.740	1.647	1.689	1.484	1.359	1.284	1.239	1.216	1.178	1.236
02. Mekong	1.000	0.677	0.483	0.368	0.292	0.278	0.248	0.217	0.197	0.172	0.147	0.133	0.128	0.122	0.116	0.116
03. Kok	1.000	0.568	0.461	0.364	0.343	0.619	0.791	0.742	0.661	0.581	0.514	0.487	0.518	0.493	0.465	0.471
04. Chi	1.000	0.628	0.515	0.443	0.405	0.388	0.393	0.378	0.351	0.311	0.267	0.249	0.233	0.221	0.209	0.211
05. Mun	1.000	0.739	0.675	0.615	0.623	0.567	0.636	0.557	0.527	0.468	0.407	0.380	0.357	0.341	0.328	0.330
06. Ping	1.000	0.653	0.485	0.378	0.302	0.251	0.405	0.340	0.295	0.243	0.204	0.185	0.172	0.164	0.154	0.153
07. Wang	1.000	1.497	1.280	1.787	1.754	1.855	1.905	1.916	1.942	1.779	1.567	1.416	1.398	1.961	1.865	1.845
08. Yom	1.000	1.019	0.967	0.761	0.894	1.218	1.080	0.942	0.891	0.757	0.650	0.589	0.553	0.533	0.502	0.500
09. Nan	1.000	1.089	1.068	0.995	1.119	1.118	1.002	0.890	0.903	0.754	0.641	0.593	0.553	0.529	0.503	0.503
10. Chao Phraya	1.000	0.821	0.743	0.666	0.733	0.635	0.595	0.510	0.453	0.381	0.324	0.293	0.286	0.272	0.255	0.256
11. Sakae Krang	1.000	1.109	1.513	1.391	1.344	1.182	1.167	1.047	0.958	0.927	0.906	0.877	0.842	0.834	0.792	1.009
12. Pasak	1.000	1.357	1.690	2.097	2.191	2.436	3.180	2.746	3.351	3.256	2.992	3.309	4.115	3.960	3.741	4.099
13. Tha Chin	1.000	1.183	1.395	1.268	4.074	3.370	2.921	3.355	5.800	4.826	4.031	3.626	3.358	3.177	2.984	3.306
14. Mae Klong	1.000	1.126	0.716	0.506	0.396	0.417	0.378	0.320	0.284	0.236	0.216	0.194	0.181	0.171	0.169	0.169
15. Prachinburi	1.000	0.795	0.666	0.609	0.481	0.439	0.438	0.466	0.436	0.374	0.322	0.293	0.274	0.279	0.278	0.283
16. Bang Pakong	1.000	7.114	4.655	4.326	4.697	4.394	8.724	7.907	7.457	6.582	5.886	6.162	5.756	17.354	16.346	16.137
17. Tonle Sap	1.000	0.627	0.518	0.385	0.318	0.268	0.243	0.210	0.184	0.153	0.135	0.121	0.116	0.111	0.123	0.127
18. East Coast Gulf	1.000	0.514	0.422	0.315	0.309	0.264	0.260	0.225	0.199	0.181	0.157	0.141	0.134	0.128	0.120	0.147
19. Phetchaburi	1.000	1.798	1.123	5.076	3.933	3.558	3.130	2.668	2.394	2.010	1.777	1.594	1.491	1.414	1.334	1.320
20. West Coast-Gulf	1.000	0.755	0.654	0.898	3.454	4.344	4.101	3.480	3.137	2.629	2.254	2.030	2.178	2.069	1.956	1.960
21. Peninsular-East Coast	1.000	1.560	1.088	4.119	3.215	2.656	2.302	1.957	1.717	1.450	1.227	1.198	1.112	1.056	0.998	0.999
22. Tapi	1.000	0.663	0.413	1.154	0.888	0.732	0.934	0.844	0.738	1.297	1.081	1.272	1.178	1.113	1.018	0.996
23. Thale Sap Songkhla	1.000	0.512	0.553	0.410	0.364	0.319	0.300	0.266	0.243	0.330	0.333	0.301	0.284	0.274	0.265	0.267
24. Pattani	1.000	0.500	0.454	28.956	22.419	19.148	16.579	14.408	12.965	10.753	8.987	8.070	7.499	7.180	6.826	6.818
25. Peninsular-West Coast	1.000	0.823	0.524	1.270	1.003	0.896	0.878	0.807	0.748	0.666	0.567	0.543	0.514	0.590	0.559	0.573

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-2
- Productivity change refers to the change in overall performance

Table D-4 Productivity change indices: Stage 1

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	1.336	1.290	1.237	1.209	1.162	1.169	1.165	1.122	1.146	1.082	1.230	1.187	1.176	1.172	1.172
02. Mekong	0.112	0.107	0.102	0.099	0.094	0.090	0.089	0.083	0.082	0.077	0.076	0.073	0.072	0.070	0.069
03. Kok	0.457	0.435	0.416	0.404	0.383	0.374	0.376	0.352	0.349	0.326	0.326	0.313	0.310	0.304	0.300
04. Chi	0.205	0.195	0.186	0.180	0.170	0.163	0.161	0.151	0.150	0.140	0.139	0.134	0.128	0.124	0.121
05. Mun	0.318	0.303	0.290	0.281	0.266	0.256	0.252	0.236	0.234	0.219	0.218	0.210	0.202	0.194	0.190
06. Ping	0.148	0.141	0.134	0.130	0.124	0.120	0.118	0.111	0.110	0.103	0.102	0.099	0.095	0.091	0.090
07. Wang	1.772	1.762	1.683	1.634	1.548	1.669	1.806	1.679	1.661	1.574	1.566	1.543	1.615	1.569	1.544
08. Yom	0.510	0.497	0.480	0.464	0.461	0.449	0.443	0.414	0.424	0.398	0.401	0.391	0.378	0.369	0.364
09. Nan	0.491	0.469	0.452	0.438	0.416	0.402	0.395	0.371	0.422	0.395	0.400	0.386	0.369	0.355	0.348
10. Chao Phraya	0.248	0.236	0.226	0.222	0.210	0.208	0.212	0.201	0.201	0.188	0.185	0.179	0.170	0.164	0.160
11. Sakae Krang	1.012	0.968	0.925	0.953	0.918	0.894	0.898	0.978	1.100	1.026	1.013	1.005	0.979	0.981	1.086
12. Pasak	3.951	3.783	3.660	3.536	3.362	3.256	4.705	4.490	4.526	4.430	4.386	4.215	4.106	3.970	3.902
13. Tha Chin	3.174	3.015	2.876	2.774	2.624	2.530	2.485	2.323	2.295	2.141	2.111	2.029	1.940	1.868	1.840
14. Mae Klong	0.162	0.154	0.147	0.143	0.135	0.130	0.127	0.118	0.116	0.109	0.110	0.106	0.100	0.098	0.097
15. Prachinburi	0.279	0.266	0.256	0.247	0.234	0.226	0.222	0.208	0.208	0.194	0.192	0.185	0.182	0.176	0.179
16. Bang Pakong	15.710	14.924	14.281	13.826	13.081	12.665	12.429	11.545	11.418	10.654	10.516	10.106	9.641	9.275	9.062
17. Tonle Sap	0.143	0.136	0.130	0.126	0.119	0.115	0.113	0.107	0.106	0.099	0.098	0.096	0.092	0.095	0.096
18. East Coast Gulf	0.157	0.158	0.151	0.193	0.183	0.176	0.173	0.161	0.160	0.150	0.148	0.144	0.141	0.138	0.135
19. Phetchaburi	1.268	1.205	1.154	1.114	1.085	1.043	1.053	1.021	1.016	0.955	0.946	0.916	1.019	1.024	1.026
20. West Coast-Gulf	2.183	2.074	2.502	2.603	2.502	2.402	2.383	2.318	2.308	2.165	2.152	2.078	2.133	2.131	2.164
21. Peninsular-East Coast	0.968	0.934	0.902	0.872	0.825	0.792	0.778	0.732	0.726	0.678	0.671	0.649	0.632	0.610	0.597
22. Tapi	1.126	1.059	1.005	0.978	0.926	0.889	0.872	0.808	0.799	0.752	0.739	0.711	0.686	0.660	0.653
23. Thale Sap Songkhla	0.265	0.258	0.261	0.256	0.245	0.270	0.270	0.262	0.261	0.274	0.270	0.260	0.271	0.261	0.255
24. Pattani	6.566	6.238	9.240	8.944	8.469	8.132	7.978	7.599	7.651	7.168	7.082	6.826	10.331	10.095	9.824
25. Peninsular-West Coast	0.640	0.633	0.670	0.653	0.619	0.636	0.635	0.614	0.618	0.584	0.591	0.574	0.600	0.588	0.580

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-2
- Productivity change refers to the change in overall performance

Table D-5 Productivity change indices: Stage 2 *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	1.000	0.429	0.216	0.182	0.135	0.138	0.086	0.072	0.064	0.050	0.050	0.039	0.037	0.038	0.054	0.046
02. Mekong	1.000	0.550	0.480	0.360	0.320	0.262	0.252	0.225	0.162	0.139	0.123	0.128	0.118	0.115	0.113	0.106
03. Kok	1.000	1.039	0.867	0.757	0.541	0.163	0.136	0.113	0.102	0.103	0.091	0.098	0.087	0.087	0.100	0.096
04. Chi	1.000	0.879	0.746	0.539	0.415	0.319	0.198	0.145	0.147	0.143	0.127	0.089	0.104	0.112	0.103	0.105
05. Mun	1.000	0.753	0.527	0.383	0.252	0.219	0.120	0.119	0.097	0.074	0.075	0.058	0.058	0.060	0.057	0.049
06. Ping	1.000	0.804	0.554	0.392	0.388	0.391	0.089	0.058	0.070	0.080	0.074	0.055	0.058	0.060	0.065	0.061
07. Wang	1.000	0.293	0.223	0.124	0.105	0.068	0.061	0.076	0.066	0.067	0.050	0.055	0.052	0.024	0.029	0.027
08. Yom	1.000	0.550	0.343	0.286	0.172	0.177	0.145	0.136	0.126	0.145	0.145	0.156	0.148	0.157	0.174	0.165
09. Nan	1.000	0.549	0.312	0.192	0.040	0.059	0.041	0.036	0.041	0.060	0.067	0.047	0.038	0.041	0.043	0.034
10. Chao Phraya	1.000	0.228	0.201	0.108	0.090	0.080	0.038	0.034	0.036	0.046	0.046	0.024	0.020	0.024	0.026	0.025
11. Sakae Krang	1.000	0.585	0.828	0.440	0.405	0.477	0.311	0.302	0.338	0.410	0.386	0.328	0.288	0.348	0.373	0.171
12. Pasak	1.000	0.424	0.260	0.085	0.087	0.075	0.038	0.046	0.033	0.030	0.023	0.015	0.011	0.010	0.013	0.011
13. Tha Chin	1.000	0.050	0.032	0.016	0.010	0.010	0.009	0.007	0.005	0.006	0.006	0.006	0.006	0.005	0.006	0.004
14. Mae Klong	1.000	0.259	0.255	0.024	0.027	0.029	0.023	0.012	0.012	0.012	0.013	0.010	0.011	0.012	0.011	0.011
15. Prachinburi	1.000	0.381	0.375	0.222	0.251	0.272	0.223	0.208	0.135	0.151	0.154	0.134	0.138	0.119	0.079	0.075
16. Bang Pakong	1.000	0.025	0.024	0.008	0.007	0.006	0.003	0.003	0.002	0.003	0.002	0.002	0.002	0.000	0.000	0.000
17. Tonle Sap	1.000	0.549	0.414	0.373	0.335	0.348	0.279	0.295	1.058	1.245	1.285	1.199	1.182	1.360	0.847	0.786
18. East Coast Gulf	1.000	0.843	0.508	0.438	0.264	0.153	0.077	0.069	0.062	0.061	0.057	0.049	0.052	0.055	0.055	0.042
19. Phetchaburi	1.000	0.318	0.326	0.046	0.043	0.030	0.028	0.023	0.026	0.027	0.029	0.026	0.025	0.037	0.045	0.038
20. West Coast-Gulf	1.000	0.580	0.487	0.249	0.055	0.027	0.023	0.016	0.020	0.019	0.018	0.017	0.015	0.016	0.016	0.016
21. Peninsular-East Coast	1.000	0.390	0.354	0.056	0.050	0.037	0.044	0.047	0.050	0.010	0.009	0.005	0.005	0.005	0.006	0.006
22. Tapi	1.000	0.542	0.648	0.263	0.274	0.294	0.284	0.270	0.276	0.202	0.198	0.103	0.122	0.126	0.109	0.095
23. Thale Sap Songkhla	1.000	0.888	0.767	0.506	0.516	0.013	0.014	0.012	0.013	0.010	0.007	0.005	0.006	0.005	0.005	0.006
24. Pattani	1.000	1.086	0.981	0.025	0.028	0.005	0.007	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.010	0.009
25. Peninsular-West Coast	1.000	0.858	0.830	0.030	0.032	0.032	0.029	0.026	0.027	0.024	0.024	0.021	0.023	0.018	0.020	0.019

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-2
- Productivity change refers to the change in overall performance

Table D-5 Productivity change indices: Stage 2

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	0.048	0.041	0.041	0.040	0.040	0.040	0.038	0.036	0.040	0.046	0.039	0.036	0.032	0.032	0.030
02. Mekong	0.121	0.117	0.105	0.107	0.112	0.113	0.111	0.117	0.131	0.166	0.179	0.178	0.160	0.137	0.110
03. Kok	0.095	0.095	0.097	0.097	0.097	0.094	0.090	0.103	0.116	0.130	0.124	0.115	0.098	0.066	0.051
04. Chi	0.123	0.116	0.101	0.103	0.112	0.112	0.109	0.111	0.150	0.138	0.139	0.145	0.135	0.131	0.135
05. Mun	0.053	0.052	0.051	0.053	0.055	0.054	0.057	0.057	0.060	0.060	0.054	0.054	0.050	0.049	0.048
06. Ping	0.063	0.060	0.060	0.060	0.061	0.062	0.063	0.060	0.062	0.090	0.086	0.074	0.051	0.029	0.049
07. Wang	0.028	0.026	0.026	0.025	0.025	0.019	0.015	0.017	0.016	0.017	0.016	0.015	0.011	0.013	0.013
08. Yom	0.162	0.140	0.139	0.142	0.131	0.148	0.136	0.151	0.149	0.182	0.168	0.141	0.095	0.062	0.083
09. Nan	0.037	0.034	0.034	0.038	0.036	0.049	0.047	0.046	0.040	0.055	0.036	0.029	0.017	0.011	0.020
10. Chao Phraya	0.021	0.022	0.021	0.021	0.023	0.022	0.006	0.005	0.005	0.006	0.006	0.005	0.004	0.003	0.005
11. Sakae Krang	0.210	0.205	0.197	0.208	0.225	0.231	0.223	0.195	0.167	0.198	0.193	0.172	0.139	0.103	0.131
12. Pasak	0.013	0.014	0.012	0.011	0.015	0.017	0.011	0.010	0.012	0.012	0.012	0.012	0.011	0.010	0.012
13. Tha Chin	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.003	0.004	0.005	0.004	0.004	0.003	0.002	0.004
14. Mae Klong	0.013	0.010	0.008	0.009	0.010	0.011	0.010	0.010	0.013	0.014	0.013	0.012	0.010	0.009	0.015
15. Prachinburi	0.078	0.083	0.069	0.088	0.092	0.090	0.098	0.073	0.075	0.091	0.091	0.083	0.086	0.068	0.045
16. Bang Pakong	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17. Tonle Sap	0.774	0.772	0.625	0.781	0.817	0.853	0.891	0.661	0.707	0.815	0.849	0.734	0.777	0.656	0.759
18. East Coast Gulf	0.041	0.038	0.030	0.024	0.028	0.027	0.029	0.019	0.019	0.023	0.023	0.022	0.019	0.016	0.016
19. Phetchaburi	0.035	0.053	0.038	0.056	0.047	0.054	0.053	0.050	0.031	0.057	0.056	0.054	0.012	0.012	0.039
20. West Coast-Gulf	0.015	0.015	0.007	0.008	0.007	0.010	0.010	0.010	0.009	0.009	0.010	0.011	0.006	0.005	0.009
21. Peninsular-East Coast	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.006	0.007	0.007	0.007	0.006	0.006
22. Tapi	0.100	0.094	0.087	0.104	0.102	0.121	0.113	0.111	0.125	0.126	0.129	0.120	0.109	0.105	0.105
23. Thale Sap Songkhla	0.006	0.006	0.005	0.006	0.006	0.005	0.004	0.003	0.004	0.003	0.003	0.003	0.002	0.002	0.002
24. Pattani	0.010	0.010	0.009	0.009	0.009	0.009	0.010	0.009	0.009	0.010	0.010	0.010	0.007	0.007	0.007
25. Peninsular-West Coast	0.019	0.019	0.016	0.018	0.017	0.018	0.016	0.015	0.017	0.018	0.019	0.019	0.017	0.016	0.016

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-2
- Productivity change refers to the change in overall performance

Table D-6 Productivity change indices: Stage 3 *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	1.000	0.069	0.066	0.063	0.068	0.061	0.056	0.141	0.137	0.055	0.054	0.056	0.063	0.055	0.053	0.058
02. Mekong	1.000	0.526	0.611	0.652	0.809	0.883	0.580	0.749	0.779	0.658	0.630	0.420	0.364	0.506	0.437	0.392
03. Kok	1.000	0.711	0.715	0.557	0.553	0.570	0.909	0.981	0.939	0.922	1.222	0.880	0.370	0.351	0.362	0.385
04. Chi	1.000	1.028	0.924	0.919	0.929	0.878	0.918	1.707	1.579	1.104	1.036	1.089	1.080	0.924	0.860	0.883
05. Mun	1.000	0.517	0.466	0.600	0.549	0.425	0.555	1.016	1.030	0.533	0.373	0.415	0.362	0.210	0.149	0.296
06. Ping	1.000	0.942	0.964	1.200	1.143	1.071	1.172	1.071	1.064	1.236	1.235	1.060	1.288	1.461	1.151	1.492
07. Wang	1.000	0.463	0.498	0.531	0.508	0.622	0.806	0.709	0.738	0.547	0.635	0.477	0.351	0.367	0.338	0.288
08. Yom	1.000	0.948	1.021	1.210	1.161	1.098	1.090	0.994	0.999	0.950	0.900	0.875	0.932	0.982	0.930	0.874
09. Nan	1.000	0.914	1.109	1.307	1.100	1.097	1.159	0.940	1.057	0.975	0.891	0.978	1.078	0.986	0.890	0.867
10. Chao Phraya	1.000	0.966	1.041	1.682	1.050	1.134	1.179	1.111	1.137	0.725	0.665	0.634	0.617	0.690	0.616	0.616
11. Sakae Krang	1.000	1.030	1.036	1.395	1.099	1.077	1.141	0.926	1.043	0.959	0.992	0.942	0.927	0.907	0.842	0.776
12. Pasak	1.000	1.110	1.061	1.631	1.143	1.397	1.648	1.491	1.609	1.411	1.899	1.970	2.004	2.264	1.815	1.885
13. Tha Chin	1.000	0.960	1.100	1.473	1.043	1.166	1.130	1.045	0.877	0.759	0.729	0.730	0.735	0.758	0.680	0.696
14. Mae Klong	1.000	1.027	1.071	1.283	1.068	1.000	0.964	0.765	0.665	0.615	0.505	0.482	0.517	0.527	0.469	0.516
15. Prachinburi	1.000	0.992	1.504	1.689	1.028	1.046	0.790	0.845	0.864	0.756	0.705	0.752	0.757	0.806	0.742	0.714
16. Bang Pakong	1.000	0.907	0.889	1.377	1.010	0.914	0.750	0.791	0.665	0.534	0.578	0.579	0.576	0.657	0.541	0.545
17. Tonle Sap	1.000	0.899	1.327	1.223	1.364	1.370	1.628	2.404	1.649	0.054	0.051	0.044	0.040	0.010	0.005	0.003
18. East Coast Gulf	1.000	0.751	0.768	0.838	0.723	0.739	0.679	0.768	0.699	0.965	0.855	0.661	0.574	0.621	0.461	0.693
19. Phetchaburi	1.000	0.838	1.067	1.074	1.123	1.061	1.054	1.016	1.036	1.337	1.161	0.879	0.901	1.015	1.048	1.069
20. West Coast-Gulf	1.000	1.463	0.534	0.821	1.091	0.660	1.101	0.822	0.547	0.576	0.420	0.384	0.544	0.372	0.318	0.541
21. Peninsular-East Coast	1.000	0.893	0.894	0.986	1.006	0.965	1.049	1.011	0.841	0.699	0.659	0.695	0.626	0.611	0.542	0.590
22. Tapi	1.000	0.906	0.901	0.919	0.927	1.015	0.950	0.952	0.759	0.572	0.563	0.565	0.584	0.497	0.487	0.472
23. Thale Sap Songkhla	1.000	0.850	0.862	0.915	1.021	1.068	0.822	0.965	0.715	0.519	0.435	0.517	0.427	0.450	0.458	0.482
24. Pattani	1.000	0.696	0.922	1.225	1.148	1.205	0.921	0.904	0.555	1.350	0.881	1.412	0.909	0.809	0.531	0.710
25. Peninsular-West Coast	1.000	0.934	1.014	1.911	1.380	0.929	0.751	1.843	1.660	1.390	1.349	1.384	1.074	1.081	1.066	1.308

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-2
- Productivity change refers to the change in overall performance

Table D-6 Productivity change indices: Stage 3

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	0.047	0.046	0.050	0.042	0.036	0.021	0.017	0.011	0.004	0.002	0.002	0.001	0.002	0.003	0.002
02. Mekong	0.377	0.375	0.432	0.336	0.288	0.184	0.176	0.129	0.156	0.146	0.146	0.155	0.143	0.134	0.166
03. Kok	0.336	0.294	0.546	0.413	0.330	0.150	0.096	0.055	0.049	0.036	0.029	0.019	0.020	0.030	0.043
04. Chi	0.975	0.935	0.844	0.910	0.988	1.015	0.993	0.850	0.824	0.592	0.747	0.586	0.396	0.764	0.748
05. Mun	0.166	0.195	0.305	0.311	0.184	0.113	0.086	0.045	0.050	0.051	0.083	0.066	0.109	0.144	0.140
06. Ping	1.388	1.516	1.649	1.579	1.549	1.551	1.686	1.112	0.895	0.499	0.368	0.287	0.265	0.511	0.493
07. Wang	0.268	0.266	0.371	0.266	0.264	0.140	0.051	0.031	0.023	0.010	0.012	0.006	0.005	0.010	0.012
08. Yom	0.959	0.940	0.899	0.951	0.969	1.005	0.876	0.677	0.369	0.256	0.191	0.130	0.087	0.187	0.191
09. Nan	0.933	0.866	0.875	0.961	0.960	1.026	0.888	0.736	0.315	0.283	0.254	0.219	0.190	0.311	0.303
10. Chao Phraya	0.638	0.597	0.543	0.426	0.264	0.115	0.077	0.024	0.014	0.012	0.010	0.009	0.008	0.010	0.007
11. Sakae Krang	0.937	0.897	0.769	0.879	0.920	0.884	0.894	0.878	0.943	0.900	0.614	0.392	0.352	0.583	0.501
12. Pasak	2.004	1.990	2.033	2.068	2.143	2.099	2.128	1.929	1.936	1.664	1.641	1.674	1.796	2.037	1.922
13. Tha Chin	0.898	0.855	0.769	0.957	0.934	0.993	0.958	1.032	0.999	0.815	0.715	0.493	0.495	0.808	0.654
14. Mae Klong	0.444	0.404	0.385	0.378	0.383	0.333	0.318	0.283	0.295	0.263	0.246	0.244	0.283	0.293	0.268
15. Prachinburi	0.685	0.652	0.667	0.686	0.695	0.632	0.691	0.671	0.683	0.742	0.695	0.646	0.861	0.638	0.633
16. Bang Pakong	0.550	0.483	0.467	0.490	0.481	0.451	0.494	0.450	0.436	0.386	0.382	0.379	0.414	0.391	0.383
17. Tonle Sap	0.003	0.002	0.003	0.002	0.002	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001
18. East Coast Gulf	0.555	0.418	0.460	0.419	0.364	0.315	0.339	0.392	0.365	0.375	0.360	0.386	0.435	0.578	1.005
19. Phetchaburi	1.096	1.187	1.173	1.292	1.292	1.223	1.188	1.200	1.214	0.843	0.795	0.686	1.306	1.827	1.239
20. West Coast-Gulf	0.475	0.497	0.758	0.677	0.636	0.567	0.518	0.660	1.006	0.427	0.471	0.499	0.659	1.244	0.984
21. Peninsular-East Coast	0.573	0.542	0.572	0.515	0.503	0.418	0.462	0.426	0.356	0.360	0.377	0.378	0.353	0.388	0.383
22. Tapi	0.490	0.490	0.487	0.466	0.440	0.491	0.602	0.600	1.933	2.264	2.671	3.916	3.062	2.226	4.484
23. Thale Sap Songkhla	0.454	0.439	0.505	0.460	0.414	0.350	0.351	0.324	0.300	0.335	0.315	0.311	0.280	0.305	0.299
24. Pattani	1.915	0.450	0.378	0.357	0.393	0.320	0.184	0.280	0.197	0.279	0.217	0.530	0.273	0.310	1.028
25. Peninsular-West Coast	1.209	1.173	1.279	1.235	1.219	1.163	1.426	1.455	1.041	0.985	1.060	1.493	1.154	1.446	1.674

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-2
- Productivity change refers to the change in overall performance

Table D-7 Technology change indices: Stage 1 *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	1.000	0.724	0.513	0.474	0.378	0.329	0.306	0.265	0.239	0.198	0.169	0.154	0.149	0.141	0.133	0.136
02. Mekong	1.000	0.677	0.483	0.442	0.353	0.306	0.287	0.246	0.222	0.184	0.156	0.142	0.138	0.131	0.123	0.126
03. Kok	1.000	0.690	0.492	0.452	0.361	0.313	0.293	0.252	0.227	0.189	0.160	0.145	0.141	0.134	0.126	0.129
04. Chi	1.000	0.733	0.514	0.490	0.387	0.340	0.314	0.275	0.247	0.205	0.175	0.163	0.153	0.145	0.137	0.138
05. Mun	1.000	0.740	0.520	0.489	0.388	0.339	0.314	0.275	0.247	0.205	0.175	0.163	0.152	0.144	0.137	0.138
06. Ping	1.000	1.040	0.685	0.467	0.368	0.454	0.405	0.340	0.295	0.243	0.218	0.197	0.183	0.173	0.165	0.165
07. Wang	1.000	0.680	0.486	0.445	0.355	0.308	0.288	0.247	0.223	0.185	0.157	0.142	0.139	0.132	0.124	0.127
08. Yom	1.000	0.691	0.492	0.452	0.361	0.313	0.293	0.252	0.226	0.188	0.160	0.145	0.141	0.134	0.126	0.129
09. Nan	1.000	0.679	0.485	0.444	0.354	0.307	0.287	0.247	0.223	0.185	0.157	0.143	0.137	0.130	0.123	0.125
10. Chao Phraya	1.000	0.676	0.483	0.444	0.355	0.307	0.288	0.247	0.222	0.184	0.157	0.141	0.139	0.131	0.123	0.126
11. Sakae Krang	1.000	0.679	0.485	0.444	0.355	0.308	0.288	0.247	0.223	0.185	0.157	0.142	0.139	0.132	0.124	0.126
12. Pasak	1.000	0.700	0.499	0.458	0.366	0.317	0.297	0.255	0.230	0.191	0.163	0.149	0.143	0.136	0.128	0.131
13. Tha Chin	1.000	0.987	0.680	0.647	0.513	0.446	0.416	0.358	0.323	0.268	0.228	0.206	0.201	0.191	0.179	0.184
14. Mae Klong	1.000	1.126	0.716	0.506	0.396	0.417	0.378	0.320	0.284	0.236	0.216	0.194	0.181	0.171	0.169	0.169
15. Prachinburi	1.000	0.678	0.484	0.443	0.353	0.306	0.287	0.246	0.222	0.184	0.156	0.141	0.138	0.131	0.123	0.126
16. Bang Pakong	1.000	0.683	0.486	0.454	0.360	0.315	0.293	0.253	0.227	0.189	0.161	0.147	0.142	0.134	0.127	0.129
17. Tonle Sap	1.000	0.681	0.486	0.446	0.356	0.309	0.289	0.249	0.224	0.186	0.158	0.144	0.139	0.132	0.125	0.126
18. East Coast Gulf	1.000	0.678	0.484	0.443	0.354	0.307	0.285	0.250	0.224	0.187	0.159	0.149	0.139	0.132	0.125	0.126
19. Phetchaburi	1.000	0.704	0.502	0.461	0.368	0.319	0.298	0.257	0.231	0.192	0.163	0.149	0.144	0.137	0.129	0.131
20. West Coast-Gulf	1.000	0.808	0.558	0.545	0.429	0.422	0.377	0.339	0.299	0.248	0.215	0.195	0.181	0.171	0.163	0.163
21. Peninsular-East Coast	1.000	0.676	0.483	0.444	0.355	0.307	0.288	0.247	0.222	0.184	0.156	0.141	0.138	0.131	0.123	0.126
22. Tapi	1.000	1.046	0.695	0.440	0.347	0.427	0.397	0.309	0.265	0.218	0.214	0.193	0.180	0.171	0.174	0.175
23. Thale Sap Songkhla	1.000	0.676	0.483	0.444	0.355	0.308	0.288	0.247	0.223	0.185	0.157	0.142	0.139	0.132	0.124	0.127
24. Pattani	1.000	0.677	0.483	0.444	0.355	0.308	0.287	0.248	0.223	0.185	0.158	0.145	0.138	0.131	0.124	0.126
25. Peninsular-West Coast	1.000	0.676	0.483	0.443	0.354	0.307	0.287	0.246	0.222	0.185	0.157	0.142	0.138	0.131	0.123	0.126

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-2
- Technology change refers to the change (movement) of the frontier over time

Table D-7 Technology change indices: Stage 1

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	0.131	0.124	0.119	0.115	0.109	0.107	0.110	0.103	0.104	0.097	0.096	0.092	0.088	0.084	0.083
02. Mekong	0.121	0.115	0.110	0.107	0.101	0.100	0.102	0.097	0.097	0.091	0.089	0.086	0.082	0.079	0.077
03. Kok	0.124	0.118	0.113	0.109	0.104	0.102	0.104	0.099	0.099	0.092	0.091	0.088	0.084	0.081	0.079
04. Chi	0.134	0.128	0.122	0.118	0.111	0.109	0.110	0.104	0.104	0.097	0.096	0.092	0.088	0.085	0.083
05. Mun	0.134	0.127	0.121	0.117	0.111	0.108	0.110	0.103	0.103	0.096	0.095	0.092	0.088	0.084	0.083
06. Ping	0.159	0.151	0.144	0.139	0.132	0.127	0.126	0.118	0.117	0.110	0.109	0.105	0.100	0.097	0.095
07. Wang	0.122	0.116	0.111	0.108	0.102	0.100	0.102	0.096	0.096	0.090	0.089	0.085	0.081	0.078	0.077
08. Yom	0.124	0.118	0.112	0.109	0.104	0.102	0.104	0.098	0.098	0.092	0.091	0.088	0.083	0.080	0.079
09. Nan	0.121	0.115	0.110	0.106	0.101	0.099	0.101	0.095	0.095	0.088	0.088	0.084	0.080	0.078	0.076
10. Chao Phraya	0.121	0.115	0.110	0.107	0.102	0.100	0.103	0.097	0.097	0.091	0.090	0.086	0.082	0.079	0.077
11. Sakae Krang	0.122	0.116	0.110	0.107	0.102	0.100	0.102	0.096	0.096	0.090	0.089	0.086	0.082	0.079	0.077
12. Pasak	0.126	0.120	0.114	0.111	0.105	0.103	0.105	0.099	0.099	0.092	0.091	0.088	0.084	0.081	0.079
13. Tha Chin	0.177	0.168	0.160	0.156	0.148	0.146	0.149	0.141	0.141	0.132	0.130	0.125	0.119	0.115	0.113
14. Mae Klong	0.162	0.154	0.147	0.143	0.135	0.130	0.127	0.118	0.116	0.109	0.110	0.106	0.100	0.098	0.097
15. Prachinburi	0.121	0.115	0.110	0.107	0.101	0.100	0.102	0.096	0.096	0.090	0.089	0.086	0.082	0.079	0.077
16. Bang Pakong	0.124	0.118	0.113	0.110	0.104	0.103	0.104	0.099	0.099	0.092	0.091	0.088	0.084	0.081	0.079
17. Tonle Sap	0.122	0.116	0.111	0.108	0.102	0.100	0.101	0.095	0.095	0.089	0.088	0.085	0.081	0.078	0.076
18. East Coast Gulf	0.122	0.116	0.111	0.108	0.102	0.099	0.101	0.095	0.095	0.089	0.087	0.084	0.080	0.077	0.076
19. Phetchaburi	0.126	0.120	0.115	0.111	0.106	0.103	0.105	0.099	0.099	0.092	0.091	0.088	0.084	0.080	0.079
20. West Coast-Gulf	0.157	0.149	0.143	0.138	0.130	0.126	0.126	0.118	0.117	0.110	0.109	0.105	0.100	0.097	0.095
21. Peninsular-East Coast	0.121	0.115	0.110	0.107	0.101	0.100	0.102	0.097	0.097	0.090	0.089	0.086	0.082	0.079	0.077
22. Tapi	0.168	0.159	0.152	0.147	0.139	0.134	0.131	0.122	0.120	0.112	0.114	0.110	0.104	0.103	0.102
23. Thale Sap Songkhla	0.122	0.116	0.110	0.107	0.102	0.101	0.103	0.097	0.097	0.091	0.090	0.086	0.082	0.079	0.078
24. Pattani	0.122	0.116	0.111	0.107	0.101	0.097	0.096	0.090	0.089	0.083	0.083	0.080	0.076	0.075	0.074
25. Peninsular-West Coast	0.121	0.115	0.110	0.107	0.101	0.100	0.102	0.096	0.097	0.090	0.089	0.086	0.082	0.079	0.077

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-2
- Technology change refers to the change (movement) of the frontier over time

Table D-8 Technology change indices: Stage 2 *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	1.000	0.241	0.123	0.037	0.043	0.028	0.014	0.020	0.013	0.012	0.008	0.007	0.007	0.005	0.005	0.004
02. Mekong	1.000	0.032	0.021	0.008	0.007	0.005	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.001
03. Kok	1.000	0.247	0.133	0.040	0.046	0.030	0.015	0.020	0.012	0.010	0.007	0.007	0.007	0.006	0.007	0.004
04. Chi	1.000	0.083	0.065	0.033	0.036	0.030	0.012	0.011	0.009	0.009	0.008	0.005	0.005	0.005	0.005	0.004
05. Mun	1.000	0.100	0.081	0.034	0.038	0.031	0.013	0.013	0.009	0.009	0.007	0.006	0.006	0.005	0.004	0.004
06. Ping	1.000	0.129	0.065	0.025	0.022	0.020	0.008	0.007	0.007	0.007	0.006	0.004	0.004	0.004	0.004	0.003
07. Wang	1.000	0.049	0.043	0.019	0.021	0.020	0.010	0.014	0.010	0.009	0.007	0.007	0.007	0.006	0.006	0.005
08. Yom	1.000	0.118	0.093	0.023	0.023	0.022	0.015	0.016	0.014	0.015	0.012	0.012	0.010	0.010	0.013	0.008
09. Nan	1.000	0.067	0.049	0.010	0.010	0.009	0.007	0.007	0.006	0.007	0.007	0.006	0.004	0.003	0.004	0.002
10. Chao Phraya	1.000	0.228	0.201	0.108	0.090	0.080	0.038	0.034	0.036	0.046	0.046	0.024	0.020	0.024	0.026	0.025
11. Sakae Krang	1.000	0.079	0.065	0.032	0.029	0.035	0.023	0.022	0.025	0.030	0.028	0.024	0.021	0.025	0.027	0.012
12. Pasak	1.000	0.244	0.150	0.049	0.050	0.043	0.022	0.026	0.019	0.017	0.013	0.009	0.008	0.008	0.008	0.006
13. Tha Chin	1.000	0.050	0.032	0.016	0.010	0.011	0.009	0.007	0.006	0.008	0.008	0.008	0.006	0.007	0.010	0.004
14. Mae Klong	1.000	0.052	0.046	0.023	0.007	0.006	0.003	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001
15. Prachinburi	1.000	0.021	0.013	0.009	0.006	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001
16. Bang Pakong	1.000	0.025	0.024	0.008	0.007	0.006	0.003	0.003	0.002	0.003	0.002	0.002	0.002	0.001	0.001	0.001
17. Tonle Sap	1.000	0.112	0.082	0.031	0.024	0.018	0.011	0.010	0.008	0.009	0.009	0.008	0.008	0.009	0.007	0.005
18. East Coast Gulf	1.000	0.049	0.029	0.025	0.015	0.009	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.002
19. Phetchaburi	1.000	0.090	0.084	0.025	0.024	0.026	0.017	0.013	0.012	0.013	0.011	0.008	0.008	0.006	0.009	0.005
20. West Coast-Gulf	1.000	0.401	0.337	0.172	0.043	0.039	0.019	0.015	0.014	0.013	0.012	0.012	0.011	0.011	0.011	0.011
21. Peninsular-East Coast	1.000	0.346	0.243	0.019	0.019	0.012	0.015	0.016	0.017	0.007	0.008	0.006	0.006	0.004	0.005	0.005
22. Tapi	1.000	0.542	0.648	0.263	0.274	0.294	0.284	0.270	0.276	0.202	0.198	0.103	0.122	0.126	0.109	0.095
23. Thale Sap Songkhla	1.000	0.552	0.477	0.315	0.321	0.015	0.010	0.010	0.010	0.009	0.009	0.008	0.008	0.008	0.008	0.006
24. Pattani	1.000	1.086	0.981	0.063	0.062	0.033	0.032	0.032	0.030	0.030	0.032	0.030	0.029	0.026	0.028	0.028
25. Peninsular-West Coast	1.000	0.858	0.830	0.030	0.032	0.032	0.029	0.026	0.027	0.024	0.024	0.021	0.023	0.018	0.020	0.019

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-2

- Technology change refers to the change (movement) of the frontier over time

Table D-8 Technology change indices: Stage 2

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.004	0.003	0.003	0.003	0.003	0.003
02. Mekong	0.002	0.002	0.001	0.001	0.001	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001
03. Kok	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.004	0.004	0.004	0.004	0.003	0.002	0.001	0.002
04. Chi	0.005	0.005	0.005	0.005	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.004	0.004	0.004
05. Mun	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.004	0.004	0.004	0.004	0.004
06. Ping	0.004	0.003	0.004	0.003	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.002	0.001	0.002
07. Wang	0.005	0.004	0.005	0.004	0.004	0.004	0.004	0.005	0.004	0.004	0.004	0.004	0.003	0.004	0.003
08. Yom	0.008	0.007	0.008	0.007	0.008	0.008	0.007	0.007	0.007	0.009	0.008	0.007	0.005	0.003	0.004
09. Nan	0.003	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.002	0.003	0.003	0.002	0.001	0.001	0.001
10. Chao Phraya	0.021	0.022	0.021	0.021	0.023	0.022	0.006	0.005	0.005	0.006	0.006	0.005	0.004	0.003	0.005
11. Sakae Krang	0.015	0.015	0.014	0.015	0.016	0.017	0.016	0.014	0.012	0.014	0.014	0.012	0.010	0.007	0.010
12. Pasak	0.007	0.008	0.007	0.007	0.009	0.010	0.007	0.006	0.007	0.007	0.007	0.007	0.006	0.006	0.007
13. Tha Chin	0.005	0.006	0.005	0.005	0.005	0.006	0.005	0.004	0.004	0.005	0.004	0.004	0.003	0.002	0.004
14. Mae Klong	0.001	0.001	0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
15. Prachinburi	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
16. Bang Pakong	0.000	0.001	0.000	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17. Tonle Sap	0.005	0.005	0.004	0.005	0.006	0.006	0.006	0.005	0.005	0.006	0.006	0.005	0.005	0.005	0.005
18. East Coast Gulf	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.002	0.002	0.002	0.002	0.001	0.002
19. Phetchaburi	0.007	0.006	0.005	0.006	0.006	0.008	0.006	0.006	0.006	0.007	0.006	0.005	0.004	0.004	0.005
20. West Coast-Gulf	0.010	0.010	0.009	0.009	0.009	0.012	0.010	0.009	0.011	0.012	0.012	0.010	0.008	0.006	0.008
21. Peninsular-East Coast	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
22. Tapi	0.100	0.094	0.087	0.104	0.102	0.121	0.113	0.111	0.125	0.126	0.129	0.120	0.109	0.105	0.105
23. Thale Sap Songkhla	0.006	0.005	0.005	0.005	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.002	0.003
24. Pattani	0.025	0.024	0.019	0.019	0.020	0.019	0.018	0.018	0.019	0.018	0.019	0.019	0.017	0.018	0.017
25. Peninsular-West Coast	0.019	0.019	0.016	0.018	0.017	0.018	0.016	0.015	0.017	0.018	0.019	0.019	0.017	0.016	0.016

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-2
- Technology change refers to the change (movement) of the frontier over time

Table D-9 Technology change indices: Stage 3 *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	1.000	0.069	0.066	0.063	0.068	0.061	0.056	0.141	0.137	0.055	0.054	0.056	0.063	0.055	0.053	0.058
02. Mekong	1.000	0.610	0.497	0.530	0.716	0.717	0.945	1.396	1.226	0.700	0.773	0.685	0.804	0.490	0.432	0.533
03. Kok	1.000	0.711	0.715	0.557	0.553	0.570	0.909	0.981	0.939	0.922	1.222	0.880	0.370	0.351	0.362	0.385
04. Chi	1.000	1.023	0.950	0.792	0.823	0.741	0.705	1.448	1.267	1.142	0.936	1.096	1.244	1.080	0.794	0.964
05. Mun	1.000	0.528	0.370	0.446	0.666	0.578	0.684	1.457	1.168	0.292	0.330	0.273	0.300	0.183	0.161	0.197
06. Ping	1.000	1.027	1.092	0.942	0.926	0.834	0.807	0.767	0.671	0.850	0.690	0.825	0.926	0.972	0.700	0.861
07. Wang	1.000	0.556	0.455	0.486	0.646	0.569	0.853	1.317	1.214	0.500	0.581	0.436	0.509	0.346	0.309	0.377
08. Yom	1.000	1.026	1.096	0.914	0.917	0.839	0.788	0.773	0.676	0.857	0.695	0.831	0.932	0.979	0.707	0.868
09. Nan	1.000	1.028	1.101	0.936	0.919	0.834	0.781	0.796	0.696	0.883	0.716	0.856	0.958	1.005	0.728	0.893
10. Chao Phraya	1.000	1.028	1.102	0.930	0.903	0.818	0.768	0.775	0.678	0.860	0.698	0.834	0.936	0.983	0.708	0.871
11. Sakae Krang	1.000	1.028	1.099	0.956	0.926	0.837	0.803	0.752	0.658	0.834	0.677	0.809	0.907	0.952	0.686	0.844
12. Pasak	1.000	1.023	1.037	0.916	0.970	0.856	0.927	1.194	1.035	1.295	1.051	1.240	1.386	1.451	1.059	1.291
13. Tha Chin	1.000	1.015	1.086	1.122	0.961	0.888	0.861	0.796	0.668	0.800	0.649	0.761	0.850	0.890	0.649	0.792
14. Mae Klong	1.000	1.027	1.071	1.283	1.068	1.000	0.964	0.765	0.665	0.615	0.505	0.482	0.517	0.527	0.469	0.516
15. Prachinburi	1.000	1.107	1.191	1.338	0.815	0.828	0.775	0.797	0.772	0.958	0.807	0.890	0.975	1.037	0.824	0.921
16. Bang Pakong	1.000	1.027	1.092	1.376	1.008	0.912	0.749	0.790	0.664	0.631	0.577	0.593	0.645	0.675	0.540	0.614
17. Tonle Sap	1.000	0.899	1.327	1.223	1.364	1.370	1.628	2.404	1.649	0.054	0.051	0.044	0.040	0.010	0.005	0.003
18. East Coast Gulf	1.000	0.751	0.768	0.838	0.723	0.739	0.679	0.768	0.699	0.965	0.855	0.661	0.574	0.621	0.461	0.693
19. Phetchaburi	1.000	1.025	1.078	1.014	0.962	0.898	0.851	0.808	0.711	0.918	0.797	0.811	0.908	0.953	0.721	0.842
20. West Coast-Gulf	1.000	1.463	0.534	0.821	1.091	0.660	1.101	0.822	0.547	0.576	0.420	0.384	0.544	0.372	0.318	0.541
21. Peninsular-East Coast	1.000	0.893	0.894	0.986	1.006	0.968	1.049	1.011	0.841	0.699	0.659	0.695	0.626	0.611	0.542	0.590
22. Tapi	1.000	0.914	0.862	0.913	0.870	0.684	0.640	0.756	0.722	0.613	0.559	0.526	0.541	0.493	0.451	0.419
23. Thale Sap Songkhla	1.000	0.850	0.862	0.915	1.021	1.068	0.822	0.965	0.715	0.519	0.435	0.517	0.427	0.450	0.458	0.482
24. Pattani	1.000	0.696	0.922	1.225	1.148	1.205	0.921	0.904	0.555	1.350	0.881	1.412	0.909	0.809	0.531	0.710
25. Peninsular-West Coast	1.000	0.934	1.014	1.911	1.380	0.929	0.751	1.843	1.660	1.390	1.349	1.384	1.074	1.081	1.066	1.308

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-2
- Technology change refers to the change (movement) of the frontier over time

Table D-9 Technology change indices: Stage 3

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	0.047	0.046	0.050	0.042	0.036	0.021	0.017	0.011	0.004	0.002	0.002	0.001	0.002	0.003	0.002
02. Mekong	0.512	0.429	0.538	0.483	0.356	0.353	0.368	0.286	0.269	0.191	0.191	0.174	0.172	0.213	0.248
03. Kok	0.336	0.294	0.546	0.413	0.330	0.150	0.096	0.055	0.049	0.036	0.029	0.019	0.020	0.030	0.043
04. Chi	0.818	0.910	0.999	1.000	1.004	0.952	1.028	0.935	0.642	0.454	0.446	0.319	0.266	0.576	0.557
05. Mun	0.190	0.159	0.199	0.179	0.132	0.132	0.116	0.083	0.083	0.069	0.065	0.072	0.114	0.227	0.105
06. Ping	0.775	0.847	0.921	0.898	0.902	0.866	0.941	0.628	0.500	0.279	0.219	0.168	0.159	0.285	0.275
07. Wang	0.360	0.301	0.349	0.313	0.244	0.128	0.047	0.029	0.021	0.009	0.011	0.006	0.004	0.010	0.011
08. Yom	0.754	0.837	0.917	0.912	0.916	0.876	0.825	0.691	0.234	0.147	0.129	0.082	0.064	0.122	0.128
09. Nan	0.776	0.858	0.942	0.933	0.937	0.896	0.844	0.766	0.292	0.188	0.184	0.152	0.134	0.204	0.241
10. Chao Phraya	0.754	0.839	0.913	0.235	0.170	0.125	0.073	0.013	0.008	0.006	0.006	0.005	0.005	0.005	0.004
11. Sakae Krang	0.760	0.830	0.908	0.886	0.889	0.849	0.922	0.830	0.863	0.595	0.460	0.323	0.351	0.529	0.468
12. Pasak	1.123	1.231	1.354	1.325	1.330	1.242	1.345	1.223	1.334	1.125	1.077	1.077	1.226	1.262	1.134
13. Tha Chin	0.689	0.753	0.818	0.815	0.820	0.778	0.832	0.785	0.760	0.620	0.544	0.375	0.376	0.615	0.497
14. Mae Klong	0.444	0.404	0.385	0.378	0.383	0.333	0.318	0.283	0.295	0.263	0.246	0.244	0.283	0.293	0.268
15. Prachinburi	0.797	0.853	0.914	0.926	0.924	0.867	0.902	0.837	0.835	0.759	0.721	0.736	0.834	0.780	0.779
16. Bang Pakong	0.549	0.567	0.624	0.637	0.640	0.595	0.612	0.569	0.564	0.511	0.486	0.498	0.551	0.525	0.521
17. Tonle Sap	0.003	0.002	0.003	0.002	0.002	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001
18. East Coast Gulf	0.555	0.418	0.460	0.419	0.364	0.315	0.339	0.392	0.365	0.375	0.360	0.386	0.435	0.578	1.005
19. Phetchaburi	0.753	0.816	0.887	0.898	0.905	0.865	0.913	0.825	0.835	0.579	0.547	0.471	0.898	1.256	0.852
20. West Coast-Gulf	0.475	0.497	0.758	0.677	0.636	0.567	0.518	0.660	1.006	0.427	0.471	0.499	0.659	1.244	0.984
21. Peninsular-East Coast	0.573	0.542	0.572	0.519	0.509	0.450	0.479	0.460	0.390	0.369	0.377	0.378	0.353	0.388	0.383
22. Tapi	0.411	0.437	0.523	0.527	0.508	0.566	0.764	0.753	1.304	1.527	1.802	2.642	2.066	1.502	3.025
23. Thale Sap Songkhla	0.454	0.439	0.505	0.460	0.414	0.350	0.351	0.324	0.300	0.335	0.315	0.311	0.280	0.305	0.299
24. Pattani	1.915	0.450	0.378	0.357	0.393	0.320	0.184	0.280	0.197	0.279	0.217	0.530	0.273	0.310	1.028
25. Peninsular-West Coast	1.209	1.173	1.279	1.235	1.219	1.163	1.426	1.455	1.041	0.985	1.060	1.493	1.154	1.446	1.674

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-2
- Technology change refers to the change (movement) of the frontier over time

Table D-10 Efficiency change indices: Stage 1 *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	1.000	1.894	2.604	2.990	3.462	3.580	5.677	6.206	7.080	7.477	8.053	8.335	8.335	8.626	8.868	9.107
02. Mekong	1.000	1.000	1.000	0.831	0.826	0.907	0.864	0.882	0.890	0.931	0.938	0.938	0.928	0.931	0.943	0.921
03. Kok	1.000	0.823	0.937	0.806	0.950	1.978	2.702	2.948	2.918	3.079	3.208	3.356	3.664	3.675	3.686	3.646
04. Chi	1.000	0.857	1.002	0.905	1.048	1.143	1.254	1.374	1.425	1.519	1.525	1.525	1.525	1.525	1.525	1.525
05. Mun	1.000	0.999	1.297	1.258	1.607	1.672	2.025	2.029	2.136	2.286	2.324	2.331	2.350	2.367	2.397	2.393
06. Ping	1.000	0.628	0.708	0.810	0.822	0.554	1.000	1.000	1.000	1.000	0.938	0.936	0.939	0.944	0.935	0.924
07. Wang	1.000	2.201	2.637	4.018	4.943	6.030	6.615	7.746	8.722	9.603	9.978	9.958	10.067	14.890	15.038	14.557
08. Yom	1.000	1.474	1.965	1.684	2.479	3.894	3.688	3.747	3.938	4.020	4.069	4.073	3.922	3.989	3.997	3.881
09. Nan	1.000	1.604	2.202	2.244	3.162	3.639	3.487	3.598	4.055	4.071	4.079	4.137	4.033	4.069	4.098	4.020
10. Chao Phraya	1.000	1.214	1.539	1.499	2.066	2.066	2.066	2.066	2.043	2.068	2.068	2.068	2.068	2.068	2.068	2.031
11. Sakae Krang	1.000	1.634	3.121	3.133	3.788	3.841	4.053	4.235	4.303	5.004	5.770	6.174	6.062	6.335	6.411	7.976
12. Pasak	1.000	1.938	3.386	4.577	5.992	7.676	10.715	10.747	14.573	17.022	18.400	22.264	28.721	29.152	29.239	31.374
13. Tha Chin	1.000	1.199	2.051	1.961	7.933	7.560	7.016	9.359	17.979	17.979	17.709	17.603	16.688	16.654	16.638	17.969
14. Mae Klong	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
15. Prachinburi	1.000	1.173	1.376	1.376	1.361	1.432	1.526	1.892	1.970	2.031	2.057	2.074	1.987	2.136	2.264	2.243
16. Bang Pakong	1.000	10.416	9.572	9.524	13.058	13.959	29.802	31.263	32.795	34.795	36.605	42.022	40.593	129.087	129.216	124.693
17. Tonle Sap	1.000	0.920	1.066	0.865	0.895	0.868	0.841	0.845	0.824	0.822	0.853	0.844	0.835	0.842	0.986	1.005
18. East Coast Gulf	1.000	0.758	0.872	0.710	0.873	0.858	0.912	0.899	0.885	0.971	0.984	0.950	0.967	0.969	0.957	1.168
19. Phetchaburi	1.000	2.554	2.237	11.016	10.697	11.146	10.500	10.384	10.353	10.446	10.875	10.722	10.347	10.357	10.368	10.046
20. West Coast-Gulf	1.000	0.935	1.173	1.649	8.057	10.289	10.875	10.255	10.491	10.596	10.490	10.417	12.042	12.078	12.005	12.005
21. Peninsular-East Coast	1.000	2.307	2.254	9.275	9.062	8.645	7.996	7.924	7.750	7.866	7.851	8.471	8.047	8.055	8.104	7.901
22. Tapi	1.000	0.634	0.595	2.621	2.564	1.713	2.356	2.731	2.783	5.961	5.043	6.587	6.554	6.521	5.843	5.702
23. Thale Sap Songkhla	1.000	0.758	1.146	0.923	1.025	1.037	1.043	1.074	1.092	1.780	2.124	2.115	2.049	2.084	2.145	2.106
24. Pattani	1.000	0.739	0.940	65.254	63.232	62.220	57.740	58.144	58.202	58.086	56.982	55.558	54.224	54.767	55.040	54.160
25. Peninsular-West Coast	1.000	1.218	1.085	2.867	2.836	2.924	3.061	3.275	3.370	3.610	3.624	3.827	3.720	4.508	4.535	4.540

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-2
- Efficiency change refers to the movement of the basins towards the technology frontier

Table D-10 Efficiency change indices: Stage 1

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	10.227	10.391	10.433	10.495	10.642	10.876	10.637	10.850	11.067	11.166	12.864	12.889	13.392	13.874	14.152
02. Mekong	0.922	0.927	0.929	0.923	0.923	0.899	0.873	0.860	0.850	0.849	0.851	0.853	0.872	0.882	0.887
03. Kok	3.679	3.686	3.697	3.690	3.693	3.656	3.602	3.569	3.537	3.533	3.576	3.569	3.701	3.775	3.809
04. Chi	1.525	1.525	1.525	1.525	1.525	1.502	1.459	1.454	1.441	1.443	1.447	1.447	1.456	1.460	1.460
05. Mun	2.378	2.383	2.388	2.390	2.397	2.364	2.297	2.286	2.265	2.270	2.288	2.290	2.302	2.300	2.295
06. Ping	0.929	0.931	0.931	0.936	0.944	0.946	0.937	0.938	0.937	0.937	0.941	0.945	0.946	0.945	0.947
07. Wang	14.528	15.211	15.211	15.196	15.181	16.653	17.735	17.487	17.277	17.519	17.642	18.065	19.818	20.016	20.096
08. Yom	4.117	4.225	4.275	4.245	4.449	4.396	4.259	4.208	4.309	4.327	4.413	4.470	4.524	4.592	4.624
09. Nan	4.068	4.089	4.130	4.117	4.134	4.063	3.929	3.910	4.461	4.465	4.568	4.586	4.591	4.577	4.559
10. Chao Phraya	2.049	2.053	2.057	2.069	2.069	2.069	2.069	2.069	2.069	2.069	2.069	2.069	2.069	2.069	2.069
11. Sakae Krang	8.311	8.369	8.369	8.888	9.030	8.931	8.814	10.172	11.413	11.390	11.390	11.732	11.978	12.481	14.104
12. Pasak	31.405	31.657	32.068	31.908	32.003	31.491	44.844	45.472	45.881	48.037	48.133	48.085	49.047	49.243	49.341
13. Tha Chin	17.969	17.969	17.969	17.807	17.772	17.345	16.686	16.502	16.271	16.239	16.239	16.206	16.239	16.255	16.352
14. Mae Klong	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
15. Prachinburi	2.304	2.311	2.327	2.309	2.309	2.258	2.181	2.164	2.155	2.155	2.157	2.157	2.224	2.242	2.320
16. Bang Pakong	126.189	126.189	126.442	125.936	125.684	123.547	118.976	117.073	115.551	115.320	115.320	115.089	115.089	115.089	114.744
17. Tonle Sap	1.169	1.172	1.172	1.167	1.167	1.153	1.115	1.119	1.111	1.109	1.109	1.132	1.138	1.217	1.251
18. East Coast Gulf	1.278	1.357	1.355	1.792	1.794	1.772	1.719	1.698	1.687	1.690	1.687	1.708	1.755	1.781	1.781
19. Phetchaburi	10.026	10.026	10.056	9.996	10.286	10.111	10.061	10.362	10.311	10.362	10.393	10.456	12.191	12.728	13.008
20. West Coast-Gulf	13.890	13.890	17.543	18.894	19.197	19.024	18.891	19.627	19.647	19.726	19.765	19.844	21.332	22.079	22.830
21. Peninsular-East Coast	7.980	8.108	8.205	8.148	8.131	7.912	7.611	7.581	7.497	7.497	7.520	7.550	7.716	7.731	7.739
22. Tapi	6.723	6.656	6.616	6.636	6.636	6.629	6.629	6.649	6.676	6.736	6.466	6.479	6.615	6.424	6.417
23. Thale Sap Songkhla	2.180	2.228	2.362	2.378	2.409	2.686	2.632	2.698	2.682	3.012	3.012	3.012	3.289	3.295	3.289
24. Pattani	53.943	53.889	83.582	83.749	83.833	83.498	82.830	84.652	85.922	86.180	85.662	85.834	136.733	134.819	132.392
25. Peninsular-West Coast	5.275	5.492	6.090	6.096	6.102	6.347	6.220	6.363	6.394	6.465	6.639	6.686	7.328	7.474	7.527

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-2
- Efficiency change refers to the movement of the basins towards the technology frontier

Table D-11 Efficiency change indices: Stage 2 *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	1.000	1.782	1.755	4.862	3.121	4.869	6.048	3.562	5.001	4.226	6.081	5.370	5.160	7.808	10.845	12.136
02. Mekong	1.000	17.201	23.273	43.125	43.944	48.558	58.076	52.442	46.411	41.956	47.326	49.314	45.221	40.473	38.490	75.093
03. Kok	1.000	4.207	6.525	18.812	11.701	5.488	9.093	5.647	8.352	10.064	12.902	14.076	12.654	13.426	14.916	22.643
04. Chi	1.000	10.585	11.548	16.468	11.379	10.640	17.023	13.346	16.910	15.895	16.070	16.986	19.959	21.675	21.133	25.212
05. Mun	1.000	7.529	6.498	11.202	6.553	7.031	9.380	9.023	10.305	8.584	10.575	9.084	9.239	13.165	13.165	13.165
06. Ping	1.000	6.231	8.518	15.928	17.378	19.654	10.712	7.927	10.376	11.860	11.871	12.370	13.335	14.188	15.962	18.851
07. Wang	1.000	5.983	5.151	6.686	4.874	3.368	5.942	5.437	6.687	7.255	7.023	7.627	7.185	3.858	4.638	5.723
08. Yom	1.000	4.658	3.671	12.579	7.459	7.862	9.938	8.785	9.294	9.527	12.051	13.100	14.501	14.966	12.975	20.475
09. Nan	1.000	8.201	6.380	18.375	4.006	6.489	5.828	4.924	6.830	8.442	10.063	8.443	8.789	15.574	12.038	17.046
10. Chao Phraya	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11. Sakae Krang	1.000	7.411	12.769	13.752	13.752	13.752	13.752	13.752	13.752	13.752	13.752	13.752	13.752	13.752	13.752	13.752
12. Pasak	1.000	1.736	1.736	1.736	1.736	1.736	1.736	1.736	1.736	1.736	1.736	1.736	1.299	1.234	1.646	1.738
13. Tha Chin	1.000	1.000	1.000	1.000	1.000	0.899	1.000	1.000	0.862	0.712	0.729	0.708	0.995	0.728	0.574	0.914
14. Mae Klong	1.000	4.989	5.503	1.035	4.058	4.943	8.710	5.749	6.622	6.742	7.739	7.043	8.881	9.103	9.076	8.921
15. Prachinburi	1.000	18.146	29.596	26.015	43.913	82.162	84.544	81.501	62.919	65.373	64.850	72.631	67.838	49.115	48.378	84.710
16. Bang Pakong	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.276	0.309	0.583
17. Tonle Sap	1.000	4.898	5.055	12.015	14.058	19.695	26.194	28.683	135.668	145.029	145.029	145.029	145.029	145.029	130.236	144.953
18. East Coast Gulf	1.000	17.205	17.205	17.205	17.205	17.205	17.205	17.067	17.204	17.204	17.204	17.204	17.204	17.204	17.204	17.204
19. Phetchaburi	1.000	3.538	3.871	1.815	1.746	1.139	1.635	1.749	2.194	2.062	2.576	3.068	3.111	5.808	5.198	7.875
20. West Coast-Gulf	1.000	1.446	1.446	1.446	1.281	0.714	1.195	1.103	1.448	1.448	1.448	1.448	1.448	1.448	1.448	1.448
21. Peninsular-East Coast	1.000	1.127	1.459	2.986	2.643	2.986	2.986	2.986	2.986	1.407	1.183	0.771	0.818	1.217	1.196	1.194
22. Tapi	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
23. Thale Sap Songkhla	1.000	1.609	1.609	1.609	1.609	0.817	1.299	1.164	1.319	1.171	0.815	0.663	0.759	0.706	0.675	0.932
24. Pattani	1.000	1.000	1.000	0.402	0.458	0.159	0.210	0.294	0.294	0.293	0.267	0.293	0.321	0.356	0.341	0.322
25. Peninsular-West Coast	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-2
- Efficiency change refers to the movement of the basins towards the technology frontier

Table D-11 Efficiency change indices: Stage 2

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	12.330	11.356	10.652	11.163	11.163	11.464	12.129	10.625	11.858	12.510	11.884	11.314	11.099	11.155	10.731
02. Mekong	75.093	75.093	75.093	75.093	75.093	75.093	75.093	75.093	75.093	75.093	75.093	75.093	75.093	75.093	75.093
03. Kok	23.390	25.145	24.340	25.557	25.352	24.972	26.046	26.515	31.738	30.945	31.533	33.898	44.508	46.332	31.182
04. Chi	24.708	22.064	21.292	21.143	19.853	19.853	21.203	24.256	30.781	27.641	28.415	30.887	30.301	29.301	30.619
05. Mun	13.165	13.165	13.165	13.165	13.165	13.165	13.165	13.165	13.165	13.165	13.165	13.165	13.165	13.165	13.165
06. Ping	17.569	17.534	17.025	17.315	16.847	15.904	17.765	21.406	23.590	27.246	26.838	28.582	27.410	25.519	27.203
07. Wang	5.889	5.830	5.608	5.844	5.785	4.461	3.684	3.651	3.684	4.016	4.180	3.854	3.241	3.682	3.686
08. Yom	20.475	19.123	18.072	19.138	17.415	18.095	20.447	20.447	20.447	20.447	20.447	20.447	20.447	20.447	20.447
09. Nan	13.637	14.074	16.325	15.558	15.776	15.823	20.364	19.876	16.378	18.261	13.495	13.481	12.106	13.244	15.668
10. Chao Phraya	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11. Sakae Krang	13.752	13.752	13.752	13.752	13.752	13.752	13.752	13.752	13.752	13.752	13.752	13.752	13.752	13.752	13.752
12. Pasak	1.738	1.738	1.738	1.738	1.738	1.738	1.567	1.718	1.737	1.737	1.737	1.737	1.737	1.737	1.737
13. Tha Chin	0.886	0.775	0.803	0.809	0.794	0.911	1.000	0.870	0.999	0.999	0.999	0.999	0.999	0.999	0.999
14. Mae Klong	10.679	6.867	6.606	8.779	6.409	6.171	8.622	9.932	10.409	11.137	10.447	10.395	9.428	9.286	11.088
15. Prachinburi	84.710	84.710	84.710	84.710	84.710	84.710	84.710	84.710	84.710	84.710	82.761	84.748	84.748	84.748	55.171
16. Bang Pakong	0.519	0.533	0.451	0.442	0.472	0.460	0.469	0.492	0.718	0.605	0.657	0.726	0.792	1.002	0.710
17. Tonle Sap	144.953	144.953	144.953	144.953	144.953	144.953	144.953	144.953	144.953	144.953	144.953	144.953	144.953	144.953	144.953
18. East Coast Gulf	17.204	17.204	17.204	13.746	15.464	15.480	14.953	13.697	13.451	12.899	12.899	12.848	11.357	12.300	10.123
19. Phetchaburi	5.260	9.158	7.665	9.436	8.426	7.145	9.403	8.849	5.274	8.264	9.264	11.117	3.368	3.099	7.518
20. West Coast-Gulf	1.448	1.443	0.866	0.900	0.791	0.808	1.044	1.042	0.820	0.727	0.806	1.033	0.804	0.732	1.067
21. Peninsular-East Coast	1.048	1.039	1.132	1.225	1.234	1.409	1.454	1.612	1.561	1.518	1.541	1.566	1.608	1.644	1.696
22. Tapi	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
23. Thale Sap Songkhla	1.059	1.130	1.090	1.132	1.139	1.011	0.968	0.951	1.009	0.775	0.792	0.807	0.849	0.922	0.824
24. Pattani	0.393	0.406	0.473	0.459	0.453	0.483	0.529	0.500	0.506	0.522	0.533	0.545	0.424	0.417	0.425
25. Peninsular-West Coast	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-2
- Efficiency change refers to the movement of the basins towards the technology frontier

Table D-12 Efficiency change indices: Stage 3 *(continued next page)*

Basins	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
01. Salawin	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
02. Mekong	1.000	0.862	1.231	1.231	1.130	1.232	0.613	0.537	0.635	0.940	0.815	0.614	0.452	1.034	1.013	0.735
03. Kok	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
04. Chi	1.000	1.005	0.972	1.161	1.129	1.185	1.303	1.179	1.246	0.967	1.106	0.993	0.868	0.855	1.083	0.916
05. Mun	1.000	0.979	1.258	1.346	0.824	0.736	0.811	0.697	0.881	1.825	1.133	1.518	1.207	1.147	0.927	1.500
06. Ping	1.000	0.917	0.883	1.273	1.234	1.283	1.453	1.397	1.586	1.453	1.790	1.285	1.392	1.503	1.645	1.732
07. Wang	1.000	0.833	1.094	1.094	0.786	1.093	0.944	0.538	0.608	1.093	1.093	1.093	0.690	1.060	1.094	0.763
08. Yom	1.000	0.924	0.931	1.324	1.266	1.309	1.384	1.287	1.477	1.108	1.295	1.052	1.000	1.003	1.316	1.007
09. Nan	1.000	0.889	1.007	1.397	1.197	1.316	1.484	1.181	1.518	1.104	1.244	1.143	1.125	0.981	1.222	0.970
10. Chao Phraya	1.000	0.940	0.945	1.808	1.163	1.386	1.536	1.433	1.676	0.843	0.954	0.760	0.659	0.702	0.871	0.707
11. Sakae Krang	1.000	1.002	0.943	1.459	1.186	1.285	1.420	1.232	1.586	1.150	1.465	1.165	1.023	0.953	1.228	0.919
12. Pasak	1.000	1.085	1.023	1.780	1.179	1.633	1.779	1.249	1.553	1.089	1.808	1.589	1.446	1.560	1.713	1.460
13. Tha Chin	1.000	0.946	1.013	1.313	1.085	1.312	1.312	1.312	1.312	0.949	1.123	0.959	0.865	0.852	1.048	0.878
14. Mae Klong	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
15. Prachinburi	1.000	0.896	1.262	1.262	1.262	1.262	1.019	1.061	1.120	0.790	0.873	0.844	0.777	0.777	0.901	0.775
16. Bang Pakong	1.000	0.883	0.814	1.001	1.001	1.001	1.001	1.001	1.001	0.847	1.002	0.976	0.893	0.974	1.001	0.887
17. Tonle Sap	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
18. East Coast Gulf	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
19. Phetchaburi	1.000	0.818	0.990	1.060	1.167	1.181	1.239	1.258	1.456	1.456	1.456	1.083	0.992	1.065	1.455	1.270
20. West Coast-Gulf	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
21. Peninsular-East Coast	1.000	1.000	1.000	1.000	1.000	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
22. Tapi	1.000	0.991	1.046	1.007	1.065	1.484	1.484	1.258	1.052	0.933	1.007	1.074	1.080	1.007	1.079	1.126
23. Thale Sap Songkhla	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
24. Pattani	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
25. Peninsular-West Coast	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-2
- Efficiency change refers to the movement of the basins towards the technology frontier

Table D-12 Efficiency change indices: Stage 3

Basins	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
01. Salawin	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
02. Mekong	0.735	0.875	0.804	0.697	0.808	0.520	0.477	0.451	0.580	0.763	0.764	0.894	0.832	0.628	0.671
03. Kok	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
04. Chi	1.192	1.028	0.846	0.910	0.985	1.065	0.966	0.909	1.282	1.304	1.673	1.838	1.487	1.327	1.341
05. Mun	0.878	1.227	1.531	1.741	1.398	0.855	0.737	0.541	0.600	0.746	1.265	0.922	0.961	0.633	1.341
06. Ping	1.791	1.791	1.791	1.758	1.718	1.792	1.792	1.772	1.792	1.792	1.684	1.714	1.671	1.792	1.792
07. Wang	0.744	0.883	1.063	0.848	1.080	1.094	1.094	1.094	1.094	1.094	1.094	1.094	1.094	1.094	1.094
08. Yom	1.273	1.124	0.980	1.042	1.057	1.147	1.062	0.980	1.579	1.737	1.473	1.589	1.343	1.532	1.488
09. Nan	1.202	1.009	0.929	1.030	1.024	1.145	1.052	0.961	1.081	1.508	1.375	1.444	1.411	1.523	1.255
10. Chao Phraya	0.846	0.711	0.595	1.809	1.557	0.925	1.053	1.808	1.808	1.808	1.808	1.808	1.808	1.808	1.808
11. Sakae Krang	1.234	1.080	0.846	0.992	1.035	1.041	0.969	1.057	1.092	1.514	1.334	1.212	1.001	1.103	1.072
12. Pasak	1.784	1.616	1.501	1.561	1.611	1.690	1.582	1.577	1.451	1.480	1.523	1.553	1.465	1.614	1.695
13. Tha Chin	1.305	1.136	0.940	1.175	1.139	1.276	1.152	1.315	1.315	1.315	1.315	1.315	1.315	1.315	1.315
14. Mae Klong	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
15. Prachinburi	0.860	0.764	0.730	0.741	0.753	0.728	0.766	0.802	0.818	0.978	0.964	0.878	1.033	0.818	0.813
16. Bang Pakong	1.003	0.851	0.748	0.770	0.751	0.758	0.807	0.790	0.774	0.755	0.786	0.760	0.750	0.744	0.736
17. Tonle Sap	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
18. East Coast Gulf	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
19. Phetchaburi	1.455	1.455	1.323	1.439	1.428	1.414	1.302	1.454	1.454	1.454	1.454	1.454	1.454	1.454	1.454
20. West Coast-Gulf	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
21. Peninsular-East Coast	1.000	1.000	1.000	0.992	0.989	0.930	0.964	0.925	0.914	0.976	1.000	1.000	1.000	1.000	1.000
22. Tapi	1.193	1.120	0.932	0.884	0.866	0.868	0.788	0.797	1.482	1.482	1.482	1.482	1.482	1.482	1.482
23. Thale Sap Songkhla	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
24. Pattani	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
25. Peninsular-West Coast	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Notes: - The results are obtained from the application of DEAP software Version 2.1 – it is based on the application of Equation 4-2
- Efficiency change refers to the movement of the basins towards the technology frontier

APPENDIX E
RESULTS ON INTITUTION-PERFORMANCE LINKAGES

This appendix presents detailed results obtained from the application of EVIEWS software version 10. The methodology used to obtain these results are discussed in Section 5.3. It contains the following tables:

Table E-1 Correlation matrix: Stage 1

	ES1	OWN	PRO	ORG	ACC	BOUND	POL	CHK	DEM	BAR	WAT
OWN	0.31 (9.14)										
PRO	0.26 (7.35)	0.58 (20.00)									
ORG	0.21 (5.83)	0.51 (16.56)	0.14 (3.98)								
ACC	0.35 (10.48)	0.83 (40.74)	0.55 (18.19)	0.77 (33.41)							
BOUND	0.68 (25.79)	0.00 (0.00)	0.00 (0.00)	-0.00 (-0.00)	0.00 (0.00)						
POL	-0.05 (-1.34)	-0.02 (-0.61)	0.35 (10.23)	-0.19 (-5.26)	-0.19 (-5.40)	0.00 (0.00)					
CHK	-0.08 (-2.19)	0.28 (8.13)	0.01 (0.24)	0.25 (7.09)	0.37 (11.04)	-0.23 (-6.51)	-0.58 (-19.80)				
DEM	0.08 (2.23)	0.33 (9.58)	0.33 (9.57)	-0.44 (-13.68)	-0.02 (-0.51)	-0.00 (-0.00)	0.31 (9.17)	-0.13 (-3.71)			
BAR	0.02 (0.58)	0.00 (0.04)	0.01 (0.40)	-0.01 (-0.35)	-0.01 (-0.19)	0.14 (4.06)	0.03 (0.77)	-0.08 (-2.11)	0.01 (0.34)		
WAT	0.32 (9.24)	0.00 (0.00)	0.00 (0.00)	-0.00 (-0.00)	-0.00 (-0.00)	0.48 (15.15)	0.00 (0.00)	-0.03 (-0.70)	-0.00 (-0.00)	0.17 (4.93)	
LAND	0.55 (18.19)	-0.00 (-0.00)	-0.00 (-0.00)	0.00 (0.00)	0.00 (0.00)	0.78 (34.19)	0.00 (0.00)	-0.18 (-5.16)	0.00 (0.00)	0.20 (5.68)	0.40 (12.00)

Notes:
- The results are obtained from the application of EVIEWS software Version 10
- Correlation coefficient are estimated using the Spearman's rank method. Values in the bracket represent t-statistics
- Abbreviations and definitions of variables are provided in Section 5.4.1, Chapter 5

Table E-2 Causality matrix: Stage 1 *(continued next page)*

		ES1	OWN	PRO	ORG	ACC	BOUND	POL	CHK	DEM	BAR	WAT
OWN	→	9.68 (0.00)										
	←	4.95 (0.01)										
PRO	→	10.03 (0.00)	31.52 (0.00)									
	←	1.09 (0.34)	0.00 (1.00)									
ORG	→	2.87 (0.06)	NA NA	37.16 (0.00)								
	←	2.79 (0.06)	24.75 (0.00)	24.64 (0.00)								
ACC	→	9.81 (0.00)	33.23 (0.00)	6.89 (0.00)	71.56 (0.00)							
	←	0.25 (0.78)	39.51 (0.00)	12.82 (0.00)	7.49 (0.00)							
BOUND	→	NA NA	NA NA	NA NA	NA NA	NA NA						
	←	NA NA	NA NA	NA NA	NA NA	NA NA						
POL	→	0.24 (0.79)	6.58 (0.00)	42.86 (0.00)	131.54 (0.00)	37.87 (0.00)	NA NA					
	←	1.93 (0.15)	2.33 (0.10)	39.51 (0.00)	18.17 (0.00)	4.94 (0.01)	NA NA					

Table E-2 Causality matrix: Stage 1

		ES1	OWN	PRO	ORG	ACC	BOUND	POL	CHK	DEM	BAR	WAT
CHK	→	4.59	1.84	16.81	26.20	6.13	NA	4.95				
		(0.01)	(0.16)	(0.00)	(0.00)	(0.00)	NA	(0.01)				
	←	1.14	11.69	0.12	10.44	9.61	NA	38.71				
		(0.32)	(0.00)	(0.89)	(0.00)	(0.00)	NA	(0.00)				
DEM	→	1.11	370.29	23.08	18.11	12.10	NA	69.72	11.27			
		(0.33)	(0.00)	(0.00)	(0.00)	(0.00)	NA	(0.00)	(0.00)			
	←	0.52	16.14	0.62	10.04	35.85	NA	5.45	21.02			
		(0.60)	(0.00)	(0.54)	(0.00)	(0.00)	NA	(0.00)	(0.00)			
BAR	→	0.04	0.02	0.06	0.01	0.08	NA	0.01	0.38	0.00		
		(0.96)	(0.98)	(0.94)	(0.99)	(0.92)	NA	(0.99)	(0.69)	(1.00)		
	←	1.29	0.02	0.11	0.15	0.04	NA	0.06	0.97	0.04		
		(0.27)	(0.98)	(0.89)	(0.86)	(0.96)	NA	(0.94)	(0.38)	(0.96)		
WAT	→	1.13	NA	NA	NA	NA	NA	NA	NA	NA	NA	
		(0.33)	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	←	3.42	NA	NA	NA	NA	NA	NA	NA	NA	NA	
		(0.04)	NA	NA	NA	NA	NA	NA	NA	NA	NA	
LAND	→	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	←	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:
- The results are obtained from the application of EVIEWS software Version 10 – it is based on the application of equation 5-1 to 5-6
- '→' represents the test of hypothesis that variables in a row does not granger cause variables in a column; '←' represents the test of hypothesis that variables in a column does not granger cause variables in a row
- Test results are presented in terms of F-statistics. Values in the bracket represent the level of significance
- Abbreviations and definitions of variables are provided in Section 5.4.1, Chapter 5

Table E-3 3SLS model results: Stage 1 *(continued next page)*

System: STAGE1
Estimation Method: Three-Stage Least Squares
Date: 05/02/19 Time: 17:30
Sample: 1987 2017
Included observations: 775
Total system (balanced) observations 3875
Linear estimation after one-step weighting matrix
Instruments: C LAND BON GOV LEG PAR OWN PRO ORG ACC

	Coefficient	Std. Error	t-Statistic	Prob.
C(10)	0.1223	0.0396	3.0859	0.0020
C(11)	0.0000	0.0000	1.3777	0.1684
C(12)	0.2029	0.0466	4.3545	0.0000
C(13)	-0.0332	0.0200	-1.6591	0.0972
C(14)	-0.0400	0.0381	-1.0513	0.2932
C(15)	0.0397	0.0023	17.5200	0.0000
C(20)	-1.0992	0.0786	-13.9816	0.0000
C(21)	0.7042	0.0337	20.9214	0.0000
C(22)	0.3566	0.0173	20.6704	0.0000
C(23)	0.0131	0.0348	0.3770	0.7062
C(30)	-2.6053	0.3465	-7.5193	0.0000
C(31)	1.4095	0.1337	10.5401	0.0000
C(32)	-1.2022	0.0819	-14.6776	0.0000
C(33)	0.4832	0.0628	7.6923	0.0000
C(40)	-3.8816	0.6490	-5.9810	0.0000
C(41)	2.3510	0.3757	6.2580	0.0000
C(42)	-1.4873	0.2916	-5.1003	0.0000
C(43)	-0.5516	0.0392	-14.0835	0.0000
C(44)	-0.2510	0.0897	-2.7976	0.0052
C(50)	1.7775	0.0551	32.2391	0.0000
C(51)	0.2000	0.0983	2.0356	0.0419
C(52)	-0.6461	0.0732	-8.8221	0.0000
Determinant residual covariance		8.03E-06		

Notes:
- The results are obtained from the application of EVIEWS software Version 10 – it is based on the application of equation 5-7 and 5-8
- Abbreviations and definitions of variables are provided in Section 5.4.1, Chapter 5

Table E-3 3SLS model results: Stage 1

Equation: ES1 = C(10) + C(11)*LAND + C(12)*OWN + C(13)*PRO + C(14) *ORG + C(15)*BON			
R-squared	0.5184	Mean dependent var	0.5505
Adjusted R-squared	0.5152	S.D. dependent var	0.3207
S.E. of regression	0.2233	Sum squared resid	38.3337
Durbin-Watson stat	0.2363		
Equation: OWN = C(20) + C(21)*ACC + C(22)*LEG + C(23)*ES1			
R-squared	0.7933	Mean dependent var	0.6452
Adjusted R-squared	0.7925	S.D. dependent var	0.4788
S.E. of regression	0.2181	Sum squared resid	36.6708
Durbin-Watson stat	1.0426		
Equation: PRO = C(30) + C(31)*ACC + C(32)*GOV + C(33)*LEG			
R-squared	0.5265	Mean dependent var	1.7742
Adjusted R-squared	0.5247	S.D. dependent var	1.0994
S.E. of regression	0.7579	Sum squared resid	442.9294
Durbin-Watson stat	0.6860		
Equation: ORG = C(40) + C(41)*ACC + C(42)*PAR + C(43)*LEG + C(44) *ES1			
R-squared	-3.3897	Mean dependent var	0.3226
Adjusted R-squared	-3.4125	S.D. dependent var	0.4678
S.E. of regression	0.9826	Sum squared resid	743.4146
Durbin-Watson stat	0.4406		
Equation: ACC = C(50) + C(51)*OWN + C(52)*PAR			
R-squared	0.3399	Mean dependent var	2.3197
Adjusted R-squared	0.3382	S.D. dependent var	0.6113
S.E. of regression	0.4973	Sum squared resid	190.9377
Durbin-Watson stat	0.4057		
S.E. of regression	0.3477	Sum squared resid	93.3565
Durbin-Watson stat	0.5911		
Equation: PAR = C(200) + C(201)*GOV + C(202)*LEG			
R-squared	0.3373	Mean dependent var	0.6395
Adjusted R-squared	0.3356	S.D. dependent var	0.3047
S.E. of regression	0.2483	Sum squared resid	47.6068
Durbin-Watson stat	0.4185		

Notes:
- The results are obtained from the application of EVIEWS software Version 10 – it is based on the application of equation 5-7 and 5-8
- Abbreviations and definitions of variables are provided in Section 5.4.1, Chapter 5

Table E-4 OLS model results: Stage 1 *(continued next page)*

System: STAGE1
Estimation Method: Least Squares
Date: 05/02/19 Time: 17:40
Sample: 1987 2017
Included observations: 775
Total system (balanced) observations 3875

	Coefficient	Std. Error	t-Statistic	Prob.
C(10)	-0.0014	0.0207	-0.0652	0.9480
C(11)	0.0000	0.0000	1.3321	0.1829
C(12)	0.1262	0.0229	5.5022	0.0000
C(13)	0.0388	0.0087	4.4691	0.0000
C(14)	0.0617	0.0193	3.2066	0.0014
C(15)	0.0411	0.0024	17.2157	0.0000
C(20)	-0.9695	0.0310	-31.3045	0.0000
C(21)	0.6545	0.0135	48.3178	0.0000
C(22)	0.3604	0.0171	21.0566	0.0000
C(23)	-0.0150	0.0259	-0.5783	0.5631
C(30)	-1.8852	0.1283	-14.6888	0.0000
C(31)	1.1282	0.0443	25.4692	0.0000
C(32)	1.1076	0.0721	15.3579	0.0000
C(33)	0.5136	0.0616	8.3327	0.0000
C(40)	-0.8465	0.0321	-26.3914	0.0000
C(41)	0.6326	0.0151	42.0154	0.0000
C(42)	-0.1855	0.0286	-6.4981	0.0000
C(43)	-0.4504	0.0174	-25.9536	0.0000
C(44)	-0.0888	0.0268	-3.3120	0.0009
C(50)	1.4824	0.0295	50.3199	0.0000
C(51)	1.0012	0.0261	38.3525	0.0000
C(52)	0.2991	0.0410	7.2915	0.0000
Determinant residual covariance		2.18E-06		

Notes:
- The results are obtained from the application of EVIEWS software Version 10 – it is based on the application of equation 5-7 and 5-8
- Abbreviations and definitions of variables are provided in Section 5.4.1, Chapter 5

Table E-4 OLS model results: Stage 1

Equation: ES1 = C(10) + C(11)*LAND + C(12)*OWN + C(13)*PRO + C(14)*ORG + C(15)*BON			
Observations: 775			
R-squared	0.5748	Mean dependent var	0.5505
Adjusted R-squared	0.5721	S.D. dependent var	0.3207
S.E. of regression	0.2098	Sum squared resid	33.8395
Durbin-Watson stat	0.2143		
Equation: OWN = C(20) + C(21)*ACC + C(22)*LEG + C(23)*ES1			
Observations: 775			
R-squared	0.7985	Mean dependent var	0.6452
Adjusted R-squared	0.7978	S.D. dependent var	0.4788
S.E. of regression	0.2153	Sum squared resid	35.7419
Durbin-Watson stat	0.9971		
Equation: PRO = C(30) + C(31)*ACC + C(32)*GOV + C(33)*LEG			
Observations: 775			
R-squared	0.5501	Mean dependent var	1.7742
Adjusted R-squared	0.5483	S.D. dependent var	1.0994
S.E. of regression	0.7388	Sum squared resid	420.8865
Durbin-Watson stat	0.6532		
Equation: ORG = C(40) + C(41)*ACC + C(42)*PAR + C(43)*LEG + C(44)*ES1			
Observations: 775			
R-squared	0.7862	Mean dependent var	0.3226
Adjusted R-squared	0.7851	S.D. dependent var	0.4678
S.E. of regression	0.2168	Sum squared resid	36.2067
Durbin-Watson stat	0.9152		
Equation: ACC = C(50) + C(51)*OWN + C(52)*PAR			
Observations: 775			
R-squared	0.7027	Mean dependent var	2.3197
Adjusted R-squared	0.7019	S.D. dependent var	0.6113
S.E. of regression	0.3338	Sum squared resid	86.0022
Durbin-Watson stat	0.6025		

Notes:
- The results are obtained from the application of EVIEWS software Version 10 – it is based on the application of equation 5-7 and 5-8
- Abbreviations and definitions of variables are provided in Section 5.4.1, Chapter 5

Table E-5 Tobit model results: Stage 1

Dependent Variable: ES1
Method: ML - Censored Normal (TOBIT) (Newton-Raphson / Marquardt steps
Date: 05/02/19 Time: 17:48
Sample: 1987 2017
Included observations: 775
Truncated sample
Left censoring (value) at zero
Convergence achieved after 4 iterations
Coefficient covariance computed using observed Hessian
INDEX = C(10) + C(11)*LAND + C(12)*OWN + C(13)*PRO + C(14)*ORG + C(15)*BON

	Coefficient	Std. Error	z-Statistic	Prob.
C(10)	-0.0996	0.0280	-3.5568	0.0004
C(11)	0.0000	0.0000	0.9515	0.3413
C(12)	0.1542	0.0269	5.7315	0.0000
C(13)	0.0462	0.0102	4.5407	0.0000
C(14)	0.0688	0.0216	3.1879	0.0014
C(15)	0.0459	0.0027	16.8442	0.0000
C(1)	0.2249	0.0068	33.2624	0.0000

Mean dependent var	0.5505	S.D. dependent var	0.3207
S.E. of regression	0.2130	Akaike info criterion	-0.3745
Sum squared resid	34.8733	Schwarz criterion	-0.3325
Log likelihood	152.1157	Hannan-Quinn criter.	-0.3583
Avg. log likelihood	0.1963		

Left censored obs	0	censored obs	0
Uncensored obs	775	Total obs	775

Notes: - The results are obtained from the application of EVIEWS software Version 10 – it is based on the application of equation 5-7 and 5-8
- Abbreviations and definitions of variables are provided in Section 5.4.1, Chapter 5

Table E-6 Correlation matrix: Stage 2

	ES2	REG	ORG	INT	RIGHT	BOUND	POL	CHK	DEM	BAR	RIV	DEN	INC	RAIN
ES3	-0.12													
	(-3.47)													
REG	-0.01													
	(-0.21)													
ORG	-0.01	1.00												
	(-0.21)	NA												
INT	0.00	0.74	0.74											
	(0.06)	(30.89)	(30.89)											
RIGHT	-0.01	1.00	1.00	0.74										
	(-0.21)	NA	NA	(30.89)										
BOUND	-0.08	-0.00	-0.00	0.00	-0.00									
	(-2.19)	(-0.00)	(-0.00)	(0.00)	(-0.00)									
POL	0.02	-0.19	-0.19	-0.24	-0.19	0.00								
	(0.65)	(-5.26)	(-5.26)	(-6.83)	(-5.26)	(0.00)								
CHK	0.04	0.25	0.25	0.40	0.25	-0.23	-0.58							
	(2.02)	(7.09)	(7.09)	(12.11)	(7.09)	(-6.51)	(-19.80)							
DEM	0.02	-0.44	-0.44	-0.03	-0.44	-0.00	0.31	-0.13						
	(0.54)	(-13.68)	(-13.68)	(-0.94)	(-13.68)	(-0.00)	(9.17)	(-3.71)						
BAR	-0.08	-0.01	-0.01	-0.01	-0.01	0.14	0.03	-0.08	0.01					
	(-2.33)	(-0.35)	(-0.35)	(-0.21)	(-0.35)	(4.06)	(0.77)	(-2.11)	(0.34)					
RIV	-0.18	0.00	0.00	-0.00	0.00	0.60	0.00	-0.11	-0.00	0.30				
	(-5.18)	(0.00)	(0.00)	(-0.00)	(0.00)	(20.59)	(0.00)	(-3.08)	(-0.00)	(8.66)				
DEN	0.21	0.00	0.00	-0.00	0.00	-0.05	0.01	0.03	-0.01	-0.32	-0.08			
	(5.83)	(0.08)	(0.08)	(-0.03)	(0.08)	(-1.52)	(0.29)	(0.71)	(-0.34)	(-9.33)	(-2.22)			
INC	0.29	0.01	0.01	0.01	0.01	-0.14	-0.00	0.07	-0.01	-0.47	-0.19	0.72		
	(8.34)	(0.39)	(0.39)	(0.35)	(0.39)	(-3.98)	(-0.06)	(2.01)	(-0.31)	(-14.76)	(-5.44)	(28.49)		
RAIN	0.07	-0.06	-0.06	-0.03	-0.06	-0.05	0.15	0.13	0.14	-0.04	0.05	0.06	0.12	
	(1.83)	(-1.65)	(-1.65)	(-0.91)	(-1.65)	(-1.31)	(4.21)	(3.66)	(3.95)	(-1.20)	(1.35)	(1.60)	(3.26)	
LAND	-0.10	0.00	0.00	0.00	0.00	0.78	0.00	-0.18	0.00	0.20	0.78	-0.07	-0.16	-0.03
	(-2.89)	(0.00)	(0.00)	(0.00)	(0.00)	(34.19)	(0.00)	(-5.16)	(0.00)	(5.68)	(34.53)	(-1.82)	(-4.53)	(-0.88)

Notes:
- The results are obtained from the application of EVIEWS software Version 10
- Correlation coefficient are estimated using the Spearman's rank method. Values in the bracket represent t-statistics
- Abbreviations and definitions of variables are provided in Section 5.4.1, Chapter 5

Table E-7 Causality matrix: Stage 2 *(continued next page)*

		ES2	REG	ORG	INT	RIGHT	BOUND	POL	CHK	DEM	BAR	RIV	DEN	INC	RAIN
ES3	→	11.08													
		(0.00)													
	←	36.56													
		(0.00)													
REG	→	0.09													
		(0.91)													
	←	0.40													
		(0.67)													
ORG	→	0.09	NA												
		(0.91)	NA												
	←	0.40	NA												
		(0.67)	NA												
INT	→	0.02	95.46	95.46											
		(0.98)	(0.00)	(0.00)											
	←	0.03	14.18	14.18											
		(0.97)	(0.00)	(0.00)											
RIGHT	→	0.09	NA	NA	14.18										
		(0.91)	NA	NA	(0.00)										
	←	0.40	NA	NA	95.46										
		(0.67)	NA	NA	(0.00)										
BOUND	→	NA	NA	NA	NA	NA									
		NA	NA	NA	NA	NA									
	←	NA	NA	NA	NA	NA									
		NA	NA	NA	NA	NA									
POL	→	0.14	131.54	131.54	133.57	131.54	NA								
		(0.87)	(0.00)	(0.00)	(0.00)	(0.00)	NA								
	←	0.02	18.17	18.17	52.80	18.17	NA								
		(0.98)	(0.00)	(0.00)	(0.00)	(0.00)	NA								
CHK	→	1.69	26.20	26.20	30.45	26.20	NA	4.95							
		(0.19)	(0.00)	(0.00)	(0.00)	(0.00)	NA	(0.01)							
	←	0.36	10.44	10.44	12.85	10.44	NA	38.71							
		(0.70)	(0.00)	(0.00)	(0.00)	(0.00)	NA	(0.00)							

Table E-7 Causality matrix: Stage 2

		ES2	REG	ORG	INT	RIGHT	BOUND	POL	CHK	DEM	BAR	RIV	DEN	INC	RAIN
DEM	→	0.45	18.11	18.11	16.56	18.11	NA	69.72	11.27						
		(0.64)	(0.00)	(0.00)	(0.00)	(0.00)	NA	(0.00)	(0.00)						
	←	0.26	10.04	10.04	76.20	10.04	NA	5.45	21.02						
		(0.77)	(0.00)	(0.00)	(0.00)	(0.00)	NA	(0.00)	(0.00)						
BAR	→	16.93	0.01	0.01	0.06	0.01	NA	0.01	0.38	0.00					
		(0.00)	(0.99)	(0.99)	(0.94)	(0.99)	NA	(0.99)	(0.69)	(1.00)					
	←	7.41	0.15	0.15	0.04	0.15	NA	0.06	0.97	0.04					
		(0.00)	(0.86)	(0.86)	(0.96)	(0.86)	NA	(0.94)	(0.38)	(0.96)					
RIV	→	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA				
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA				
	←	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA				
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA				
DEN	→	20.65	0.09	0.09	0.05	0.09	NA	0.05	2.66	0.09	71.57	NA			
		(0.00)	(0.91)	(0.91)	(0.95)	(0.91)	NA	(0.95)	(0.07)	(0.91)	(0.00)	NA			
	←	5.20	0.01	0.01	0.01	0.01	NA	0.01	0.35	0.14	10.14	NA			
		(0.01)	(0.99)	(0.99)	(0.99)	(0.99)	NA	(0.99)	(0.71)	(0.87)	(0.00)	NA			
INC	→	29.98	0.15	0.15	0.04	0.15	NA	0.02	2.59	0.07	14.12	NA	10.88		
		(0.00)	(0.86)	(0.86)	(0.96)	(0.86)	NA	(0.98)	(0.08)	(0.94)	(0.00)	NA	(0.00)		
	←	12.78	0.09	0.09	0.06	0.09	NA	0.04	0.77	0.08	17.02	NA	43.75		
		(0.00)	(0.91)	(0.91)	(0.94)	(0.91)	NA	(0.96)	(0.46)	(0.93)	(0.00)	NA	(0.00)		
RAIN	→	2.15	11.70	11.70	7.24	11.70	NA	6.39	6.38	5.53	0.58	NA	3.12	4.91	
		(0.12)	(0.00)	(0.00)	(0.00)	(0.00)	NA	(0.00)	(0.00)	(0.00)	(0.56)	NA	(0.04)	(0.01)	
	←	1.58	5.86	5.86	10.96	5.86	NA	11.28	1.22	2.49	0.13	NA	1.04	0.57	
		(0.21)	(0.00)	(0.00)	(0.00)	(0.00)	NA	(0.00)	(0.30)	(0.08)	(0.88)	NA	(0.35)	(0.57)	
LAND	→	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	←	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:
- The results are obtained from the application of EVIEWS software Version 10 – it is based on the application of equation 5-1 to 5-6
- '→' represents the test of hypothesis that variables in a row does not granger cause variables in a column; '←' represents the test of hypothesis that variables in a column does not granger cause variables in a row
- Test results are presented in terms of F-statistics. Values in the bracket represent the level of significance
- Abbreviations and definitions of variables are provided in Section 5.4.1, Chapter 5

Table E-8 3SLS model results: Stage 2

System: STAGE2
Estimation Method: Three-Stage Least Squares
Date: 05/01/19 Time: 12:21
Sample: 1987 2017
Included observations: 775
Total system (balanced) observations 1550
Linear estimation after one-step weighting matrix

	Coefficient	Std. Error	t-Statistic	Prob.
C(100)	-2.6210	0.5618	-4.6654	0.0000
C(101)	-0.0069	0.0057	-1.2175	0.2236
C(102)	-0.0322	0.0478	-0.8210	0.4347
C(103)	0.0472	0.0075	6.3041	0.0000
C(104)	0.0171	0.0340	0.5040	0.6143
C(105)	-0.0079	0.0017	-4.7824	0.0000
C(106)	-0.0304	0.0259	-1.1734	0.2408
C(107)	0.2324	0.0287	8.1063	0.0000
C(109)	0.0800	0.0371	2.1548	0.0313
C(110)	-0.4507	0.0538	-8.3801	0.0000
C(200)	1.0000	0.0202	49.4852	0.0000
C(201)	-0.4601	0.0237	-19.4191	0.0000
C(202)	0.0364	0.0206	1.7683	0.0772

Determinant residual covariance 0.004331

Equation: ES2 = C(100) + C(101)*BON + C(102)*PAR + C(103)*BAR + C(104)*LOG(RAIN) + C(105)*RIV + C(106)*LOG(DEN) + C(107) *LOG(INC) + C(109)*LOG(LAND) + C(110)*ES3
Instruments: C BON GOV LEG BAR RAIN RIV DEN INC LAND ES3
Observations: 775

R-squared	0.2575	Mean dependent var	0.6911
Adjusted R-squared	0.2488	S.D. dependent var	0.3091
S.E. of regression	0.2679	Sum squared resid	54.9097
Durbin-Watson stat	2.0404		

Equation: PAR = C(200) + C(201)*GOV + C(202)*LEG
Instruments: C BON GOV LEG BAR RAIN RIV DEN INC LAND ES3
Observations: 775

R-squared	0.3392	Mean dependent var	0.6395
Adjusted R-squared	0.3375	S.D. dependent var	0.3047
S.E. of regression	0.2480	Sum squared resid	47.4739
Durbin-Watson stat	0.4176		

Notes: - The results are obtained from the application of EVIEWS software Version 10 – it is based on the application of equation 5-7 and 5-8
- Abbreviations and definitions of variables are provided in Section 5.4.1, Chapter 5

Table E-9 OLS model results: Stage 2

System: STAGE2
Estimation Method: Least Squares
Date: 05/01/19 Time: 12:27
Sample: 1987 2017
Included observations: 775
Total system (balanced) observations 1550

	Coefficient	Std. Error	t-Statistic	Prob.
C(100)	-2.9220	0.4161	-7.0217	0.0000
C(101)	-0.0054	0.0041	-1.3246	0.1855
C(102)	-0.0033	0.0325	-0.1007	0.9198
C(103)	0.0570	0.0070	8.0914	0.0000
C(104)	0.0087	0.0326	0.2680	0.7888
C(105)	-0.0073	0.0015	-4.8388	0.0000
C(106)	-0.0238	0.0203	-1.1738	0.2407
C(107)	0.2759	0.0228	12.1098	0.0000
C(109)	0.0691	0.0239	2.8909	0.0039
C(110)	-0.4981	0.0491	-10.1347	0.0000
C(200)	1.0000	0.0202	49.3887	0.0000
C(201)	-0.4602	0.0237	-19.3843	0.0000
C(202)	0.0367	0.0207	1.7779	0.0756

Determinant residual covariance 0.0043

Equation: ES2 = C(100) + C(101)*BON + C(102)*PAR + C(103)*BAR + C(104)*LOG(RAIN) + C(105)*RIV + C(106)*LOG(DEN) + C(107)*LOG(INC) + C(109)*LOG(LAND) + C(110)*ES3
Observations: 775

R-squared	0.2658	Mean dependent var	0.6911
Adjusted R-squared	0.2572	S.D. dependent var	0.3091
S.E. of regression	0.2664	Sum squared resid	54.2943
Durbin-Watson stat	2.0532		

Equation: PAR = C(200) + C(201)*GOV + C(202)*LEG
Observations: 775

R-squared	0.3392	Mean dependent var	0.6395
Adjusted R-squared	0.3375	S.D. dependent var	0.3047
S.E. of regression	0.2480	Sum squared resid	47.4738
Durbin-Watson stat	0.4177		

Notes: - The results are obtained from the application of EVIEWS software Version 10 – it is based on the application of equation 5-7 and 5-8
- Abbreviations and definitions of variables are provided in Section 5.4.1, Chapter 5

Table E-10 Tobit model results: Stage 2

Dependent Variable: ES2
Method: ML - Censored Normal (TOBIT) (Newton-Raphson / Marquardt steps)
Date: 05/01/19 Time: 12:34
Sample: 1987 2017
Included observations: 775
Truncated sample
Left censoring (value) at zero
Convergence achieved after 4 iterations
Coefficient covariance computed using observed Hessian
INDEX = C(100) + C(101)*BON + C(102)*PAR + C(103)*BAR + C(104)
*LOG(RAIN) + C(105)*RIV + C(106)*LOG(DEN) + C(107)*LOG(INC) +
C(109)*LOG(LAND) + C(110)*ES3

	Coefficient	Std. Error	z-Statistic	Prob.
C(100)	-3.1842	0.4496	-7.0828	0.0000
C(101)	-0.0059	0.0044	-1.3366	0.1814
C(102)	-0.0030	0.0349	-0.0873	0.9304
C(103)	0.0612	0.0076	8.0960	0.0000
C(104)	0.0107	0.0346	0.3090	0.7573
C(105)	-0.0081	0.0016	-4.9000	0.0000
C(106)	-0.0266	0.0219	-1.2135	0.2249
C(107)	0.2936	0.0248	11.8485	0.0000
C(109)	0.0748	0.0259	2.8937	0.0038
C(110)	-0.5316	0.0528	-10.0614	0.0000
C(1)	0.2748	0.0079	35.0008	0.0000

Mean dependent var	0.6911	S.D. dependent var	0.3091
S.E. of regression	0.2670	Akaike info criterion	0.1797
Sum squared resid	54.5349	Schwarz criterion	0.2458
Log likelihood	-58.6486	Hannan-Quinn criter.	0.2051
Avg. log likelihood	-0.0757		

Left censored obs	0	Right censored obs	0
Uncensored obs	775	Total obs	775

Notes: - The results are obtained from the application of EVIEWS software Version 10 – it is based on the application of equation 5-7 and 5-8
- Abbreviations and definitions of variables are provided in Section 5.4.1, Chapter 5

Table E-11 Correlation matrix: Stage 3

	ES3	COMP	REG	BOUND	POL	CHK	DEM	BAR	DEN
ES1	-0.06 (-1.70)								
ES2	-0.12 (-3.47)								
COMP	0.00 (0.05)	1.00 -----							
REG	-0.01 (-0.28)	0.76 (33.00)	1.00 -----						
BOUND	-0.05 (-1.48)	0.00 (0.00)	0.00 (0.00)	1.00 -----					
POL	0.02 (0.44)	-0.19 (-5.41)	-0.18 (-5.06)	0.00 (0.00)	1.00 -----				
CHK	-0.02 (-0.58)	0.37 (11.18)	0.39 (11.64)	-0.23 (-6.51)	-0.58 (-19.80)	1.00 -----			
DEM	0.01 (0.39)	0.06 (1.69)	-0.19 (-5.46)	-0.00 (-0.00)	0.31 (9.17)	-0.13 (-3.71)	1.00 -----		
BAR	0.11 (3.07)	-0.01 (-0.17)	-0.00 (-0.07)	0.14 (4.06)	0.03 (0.77)	-0.08 (-2.11)	0.01 (0.34)	1.00 -----	
DEN	-0.02 (-0.47)	-0.00 (-0.07)	-0.00 (-0.01)	-0.05 (-1.52)	0.01 (0.29)	0.03 (0.71)	-0.01 (-0.34)	-0.32 (-9.33)	1.00 -----
INC	0.21 (5.84)	0.01 (0.28)	0.02 (0.54)	-0.14 (-3.98)	-0.00 (-0.06)	0.07 (2.01)	-0.01 (-0.31)	-0.47 (-14.76)	0.72 (28.49)

Notes:
- The results are obtained from the application of EVIEWS software Version 10
- Correlation coefficient are estimated using the Spearman's rank method. Values in the bracket are t-statistics
- Abbreviations and definitions of variables are provided in Section 5.4.1, Chapter 5

Table E-12 Causality matrix: Stage 3

		ES3	COMP	REG	BOUND	POL	CHK	DEM	BAR	DEN
ES1	→	1.54 (0.21)								
	←	0.15 (0.86)								
ES2	→	36.56 (0.00)								
	←	11.08 (0.00)								
COMP	→	0.71 (0.49)								
	←	0.18 (0.84)								
REG	→	0.18 (0.83)	107.60 (0.00)							
	←	0.55 (0.58)	29.72 (0.00)							
BOUND	→	NA NA	NA NA	NA NA						
	←	NA NA	NA NA	NA NA						
POL	→	0.64 (0.53)	109.60 (0.00)	2.78 (0.06)	NA NA					
	←	0.02 (0.98)	23.46 (0.00)	13.32 (0.00)	NA NA					
CHK	→	1.02 (0.36)	32.57 (0.00)	1.15 (0.32)	NA NA	4.95 (0.01)				
	←	0.11 (0.89)	4.29 (0.01)	18.16 (0.00)	NA NA	38.71 (0.00)				
DEM	→	0.34 (0.71)	10.55 (0.00)	34.33 (0.00)	NA NA	69.72 (0.00)	11.27 (0.00)			
	←	0.35 (0.70)	59.12 (0.00)	60.47 (0.00)	NA NA	5.45 (0.00)	21.02 (0.00)			
BAR	→	11.25 (0.00)	0.07 (0.93)	0.08 (0.93)	NA NA	0.01 (0.99)	0.38 (0.69)	0.00 (1.00)		
	←	14.87 (0.00)	0.05 (0.95)	0.10 (0.91)	NA NA	0.06 (0.94)	0.97 (0.38)	0.04 (0.96)		
DEN	→	10.07 (0.00)	0.04 (0.96)	0.07 (0.93)	NA NA	0.05 (0.95)	2.66 (0.07)	0.09 (0.91)	71.57 (0.00)	
	←	34.33 (0.00)	0.01 (0.99)	0.09 (0.91)	NA NA	0.01 (0.99)	0.35 (0.71)	0.14 (0.87)	10.14 (0.00)	
INC	→	17.53 (0.00)	0.07 (0.93)	0.01 (0.99)	NA NA	0.02 (0.98)	2.59 (0.08)	0.07 (0.94)	14.12 (0.00)	10.88 (0.00)
	←	10.83 (0.00)	0.05 (0.95)	0.08 (0.93)	NA NA	0.04 (0.96)	0.77 (0.46)	0.08 (0.93)	17.02 (0.00)	43.75 (0.00)

Notes:
- The results are obtained from the application of EVIEWS software Version 10 – it is based on the application of equation 5-1 to 5-6
- '→' represents the test of hypothesis that variables in a row does not granger cause variables in a column; '←' represents the test of hypothesis that variables in a column does not granger cause variables in a row
- Test results are presented in terms of F-statistics. Values in the bracket represent the level of significance
- Abbreviations and definitions of variables are provided in Section 5.4.1, Chapter 5

Table E-13 3SLS model results: Stage 3

System: STAGE3
Estimation Method: Three-Stage Least Squares
Date: 05/01/19 Time: 13:33
Sample: 1987 2017
Included observations: 775
Total system (balanced) observations 2325
Linear estimation after one-step weighting matrix

	Coefficient	Std. Error	t-Statistic	Prob.
C(100)	-0.9324	0.2425	-3.8454	0.0001
C(101)	0.0445	0.0060	7.3880	0.0000
C(102)	-0.1275	0.0181	-7.0512	0.0000
C(103)	0.1980	0.0308	6.4284	0.0000
C(104)	0.0964	0.1626	0.5933	0.5530
C(200)	7.2296	35.8622	0.2016	0.8403
C(201)	-0.0095	0.1396	-0.0679	0.9459
C(202)	-0.0120	0.2363	-0.0507	0.9596
C(203)	-0.3864	1.1441	-0.3377	0.7356
C(204)	0.0074	0.1658	0.0448	0.9643
C(205)	-0.0013	0.0159	-0.0825	0.9342
C(206)	1.1259	3.0169	0.3732	0.7090
C(207)	-1.7182	5.1204	-0.3356	0.7372
C(208)	0.0570	0.9002	0.0633	0.9495
C(209)	8.7790	24.2794	0.3616	0.7177
C(300)	0.9999	0.0202	49.5332	0.0000
C(301)	-0.4600	0.0237	-19.4410	0.0000
C(302)	0.0367	0.0206	1.7812	0.0750

Determinant residual covariance 5.10E-06

Equation: ES3 = C(100) + C(101)*BAR + C(102)*LOG(DEN) + C(103)*LOG(INC) + C(104)*ES2
Instruments: C BAR BON GOV LEG DEN INC RAIN RIV LAND
Observations: 775

R-squared	0.2382	Mean dependent var	0.8088
Adjusted R-squared	0.2342	S.D. dependent var	0.2381
S.E. of regression	0.2084	Sum squared resid	33.4371
Durbin-Watson stat	1.7569		

Equation: ES2 = C(200) + C(201)*BON + C(202)*PAR + C(203)*BAR +C(204)*LOG(RAIN) +C(205)*RIV + C(206)*LOG(DEN) + C(207)*LOG(INC) + C(208)*LOG(LAND) + C(209)*ES
Instruments: C BAR BON GOV LEG DEN INC RAIN RIV LAND
Observations: 775

R-squared	-34.6772	Mean dependent var	0.6911
Adjusted R-squared	-35.0969	S.D. dependent var	0.3091
S.E. of regression	1.8572	Sum squared resid	2638.5120
Durbin-Watson stat	1.7558		

Equation: PAR = C(300) + C(301)*GOV + C(302)*LEG
Instruments: C BAR BON GOV LEG DEN INC RAIN RIV LAND
Observations: 775

R-squared	0.3392	Mean dependent var	0.6395
Adjusted R-squared	0.3375	S.D. dependent var	0.3047
S.E. of regression	0.2480	Sum squared resid	47.4738
Durbin-Watson stat	0.4176		

Notes: - The results are obtained from the application of EVIEWS software Version 10 – it is based on the application of equation 5-7 and 5-8
- Abbreviations and definitions of variables are provided in Section 5.4.1, Chapter 5

Table E-14 OLS model results: Stage 3

System: STAGE3
Estimation Method: Least Squares
Date: 05/01/19 Time: 13:38
Sample: 1987 2017
Included observations: 775
Total system (balanced) observations 2325

	Coefficient	Std. Error	t-Statistic	Prob.
C(100)	-1.7164	0.1290	-13.3028	0.0000
C(101)	0.0588	0.0045	13.1861	0.0000
C(102)	-0.1416	0.0130	-10.8525	0.0000
C(103)	0.2931	0.0134	21.9545	0.0000
C(104)	-0.2299	0.0232	-9.8916	0.0000
C(200)	-2.9220	0.4161	-7.0217	0.0000
C(201)	-0.0054	0.0041	-1.3246	0.1854
C(202)	-0.0033	0.0325	-0.1007	0.9198
C(203)	0.0570	0.0070	8.0914	0.0000
C(204)	0.0087	0.0326	0.2680	0.7888
C(205)	-0.0073	0.0015	-4.8388	0.0000
C(206)	-0.0238	0.0203	-1.1738	0.2406
C(207)	0.2759	0.0228	12.1098	0.0000
C(208)	0.0691	0.0239	2.8909	0.0039
C(209)	-0.4981	0.0491	-10.1347	0.0000
C(300)	1.0000	0.0202	49.3887	0.0000
C(301)	-0.4602	0.0237	-19.3843	0.0000
C(302)	0.0367	0.0207	1.7779	0.0755

Determinant residual covariance 0.000129

Equation: ES3 = C(100) + C(101)*BAR + C(102)*LOG(DEN) + C(103)*LOG(INC) + C(104)*ES2
Observations: 775

R-squared	0.4006	Mean dependent var	0.8088
Adjusted R-squared	0.3975	S.D. dependent var	0.2381
S.E. of regression	0.1848	Sum squared resid	26.3096
Durbin-Watson stat	1.7842		

Equation: ES2 = C(200) + C(201)*BON + C(202)*PAR + C(203)*BAR + C(204)*LOG(RAIN) + C(205)*RIV + C(206)*LOG(DEN) + C(207)*LOG(INC) + C(208)*LOG(LAND) + C(209)*ES3
Observations: 775

R-squared	0.2658	Mean dependent var	0.6911
Adjusted R-squared	0.2572	S.D. dependent var	0.3091
S.E. of regression	0.2664	Sum squared resid	54.2943
Durbin-Watson stat	2.0532		

Equation: PAR = C(300) + C(301)*GOV + C(302)*LEG
Observations: 775

R-squared	0.3392	Mean dependent var	0.6395
Adjusted R-squared	0.3375	S.D. dependent var	0.3047
S.E. of regression	0.2480	Sum squared resid	47.4738
Durbin-Watson stat	0.4177		

Notes:
- The results are obtained from the application of EVIEWS software Version 10 – it is based on the application of equation 5-7 and 5-8
- Abbreviations and definitions of variables are provided in Section 5.4.1, Chapter 5

Table E-15 Tobit model results: Stage 3

Dependent Variable: ES3
Method: ML - Censored Normal (TOBIT) (Newton-Raphson / Marquardt steps)
Date: 05/01/19 Time: 13:41
Sample: 1987 2017
Included observations: 775
Truncated sample
Left censoring (value) at zero
Convergence achieved after 2 iterations
Coefficient covariance computed using observed Hessian
INDEX = C(100) + C(101)*BAR + C(102)*LOG(DEN) + C(103)*LOG(INC) + C(104)*ES2

	Coefficient	Std. Error	z-Statistic	Prob.
C(100)	- 1.725	0.13	- 13.31	-
C(101)	0.059	0.00	13.22	-
C(102)	- 0.142	0.01	- 10.88	-
C(103)	0.294	0.01	21.89	-
C(104)	- 0.231	0.02	- 9.92	-
C(1)	0.185	0.00	39.08	-

Mean dependent var	0.808832	S.D. dependent var	0.238134
S.E. of regression	0.184759	Akaike info criterion	-0.530463
Sum squared resid	26.28453	Schwarz criterion	-0.494441
Log likelihood	211.5546	Hannan-Quinn criter.	-0.516605
Avg. log likelihood	0.272974		

Left censored obs	0	Right censored obs	0
Uncensored obs	775	Total obs	775

Notes:
- The results are obtained from the application of EVIEWS software Version 10 – it is based on the application of equation 5-7 and 5-8
- Abbreviations and definitions of variables are provided in Section 5.4.1, Chapter 5

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