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# Understanding water institutions and their impact on the performance of the water sector in India

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## Abstract

The water crisis in India is no more restricted to a few states or areas. It has started affecting all forms of life, industry, and livelihood, and therefore it emerges as one of the biggest challenges. The water crisis is a direct outcome of the governance and analysis of water institutions, playing a central role in understanding the state of water governance. This study aims to understand the water institutions and their ultimate impact on various aspects of water sector performance in India. A survey was administered to collect information on the perception of water experts on the role and importance of various institutional aspects including water law, policy, and administration in improving water sector performance in India. Factor analysis and multiple linear regression methods were used to find the significant factors of water institutions and their effect on the different aspects of water sector performance in India. The analysis shows that the most important factors for improving the water sector performance are (a) legal accountability provisions, (b) water transfer policies, and (c) use of science and technology application along with reliable data. The level of importance of these significant institutional variables also varies within various performance aspects.

*Keywords:* Factor analysis; India; Multi-linear regression; Water institutions; Water scarcity; Water sector performance

## Highlights

- Analytical analysis of water institutions in India is not widely studied.
- Relationship and impact of institution variables on water sector performance is not explored.
- Understanding of water institutions and water sector performance linkages in India is limited.
- Exploratory analysis and multi-linear regression to analyse and understand latent factors impacting performance of water sector in India.



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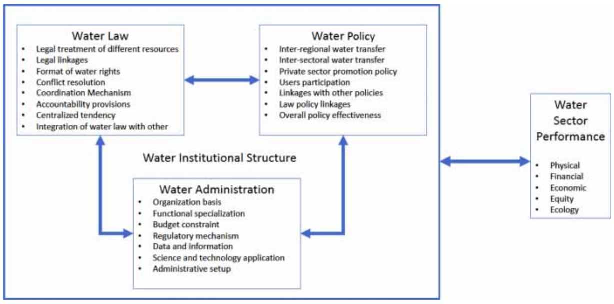
**Graphical Abstract**




## 1. Introduction

Water scarcity and other water-related problems are not hypothetical cases anymore, but are a reality of our time. Factors like burgeoning population, urbanization, pollution and industrialization, climate change, etc., have resulted in increased pressure on already stressed water resources all around the world (Griffin, 2016). As well, demand from different stakeholders is on the rise and has resulted in water conflicts in many parts of the world. Hence, water crises are emerging as a major development challenge for many countries.

In India, water demand is increasing due to the water needs of the growing population, food production, and industries for economic development. However, water supplies are restricted due to several constraints like low investment in the water sector from public and private entities, poor infrastructure, and political unwillingness (Amarasinghe *et al*., 2005; Gulati & Banerjee, 2016; Jain, 2019). This has resulted in an increased number of cases related to water conflicts all across the country (Aayog *et al*., 2018). Water institutions need to accommodate the physical, economic, institutional, and political constraints for a durable and holistic approach to improve the water sector performance (Saleth 2010). Therefore, it is critical to analyze and understand the role of water institutions and their impact on the water sector performance in India.

The comprehensive review of water governance by Araral & Wang (2013) shows the lack of focus on (a) water governance as a multi- and inter-disciplinary agenda, (b) no consensus on scope, definition, and quantification of water governance, and (c) study of incentive structures and clear policy implications of water governance as a matter of concern. It is evident from the literature that the water crisis is a direct outcome of the 'governance crisis' (Saleth, 2018). Also, the UN World Water Report (2016), cited in Ahmed & Araral (2019), assessed the water crisis is mainly due to the water governance failure and thus it is critical to prioritize the improvement of water governance for improved water sector performance.

There is need for an institutional framework that shifts from reforms in water policy and law to effective implementation of water governance (Neto, 2016). In recent past years, United Nations organizations, the World Bank, the Global Environmental Facility, the Organization for Economic Co-operation and Development (OECD), and many others have collaborated with governments, stakeholders, civil groups, private and public organizations, and academic representatives to explore the efforts to improve water governance (Megdal *et al*., 2017). Countries worldwide have evolved diverse water governance regimes to regulate the development and management of water resources (Ozerol *et al*., 2018). However, there is no internationally agreed upon definition for water governance as the concept of water governance is still evolving (Tortajada, 2010).

Water governance, as defined by Global Water Partnership is 'the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and delivery of water services, at different levels of society' (Biswas & Tortajada, 2010). Developing and analyzing water governance for the challenges of integrated water resource management, efficient allocation, water pricing reforms, and public–private partnerships in the water sector requires theories drawn from public economics, new institutional economics, political economy, and public administration (Araral & Wang, 2013).

Water management can be defined as a 'decision process in the development and management of water resources for the various uses, taking into account the needs and aspirations of different users and stakeholders' Neto (2016). Water governance encompasses water management as highlighted by Lautze *et al*. (2011),

> '*Water governance is a set of processes and institutions through which management goals are identified, and water management is charged with practical measures to achieve those goals. More simply, water management aims to improve outcomes directly, whereas water governance seeks to define those outcomes and align water management to achieve those goals*.'

Pahl-Wostl *et al*. (2012) differentiated the governance from management as 'Governance sets the rules under which management operates'.

The water governance mechanisms (WGM) which include institutions, formal or informal rules, stakeholders, network and systems is the mechanism through which water governance is translated into water management (Ahmed & Araral, 2019). To evaluate and study water governance, analysis of water institutions plays a central role. Also, water institutional arrangements governing water resource development, allocation, and management are receiving attention worldwide as we are entering into the era of scarcity from the era of plenty (Saleth, 2004). The OCED has developed a Water Governance Indicator framework to assess water governance at various scales and capture different water management goals (Akhmouch & Correia, 2016).

Literature also emphasizes that the right kind of water institutions encourage sustainable use, allocation, and management of water at different levels (Saleth & Dinar, 2008). Especially for a developing country, water institutional analysis plays a significant key role (Saleth, 2004; Pahl-Wostl *et al*., 2012; Akhmouch & Correia, 2016). Regardless of the importance and acceptance of indicator-based water governance frameworks, development and selection of these indicators are considered challenging tasks (Ahmed & Araral, 2019). As per the OECD assessment, key difficulties in water governance indicators are related to data collection, comparability across different space and time, and drawing casual linkages between policies and outcomes (Akhmouch & Correia, 2016).

It has been noticed that improved water sector performance results in improved public health outcomes and contributes positively to per capita GDP (Bromley & Anderson, 2018). Literature also suggests that water scarcity results from inefficient use and poor management of the water sector (Saleth & Dinar, 2004). The number of empirical studies related to water governance and its effect on water sector performance is few (Saleth, 2004; Araral & Ratra, 2016). We adopt the interdisciplinary approach for water institutional analysis developed and proposed by Saleth & Dinar (2004), in which they did a cross-country analysis of water governance and water institutional-performance linkages using data collected through the perception of water experts. They also highlighted the importance of water law, policy, and administration in managing the water sector and its related sectors.

A similar methodology was used by Araral & Wang (2013), in which they highlighted the importance of comparative water governance to study the challenges and opportunities for countries having similar or different institutional, economic, and political structures. Also, the level of economic development of a country affects the evolvement of water institutions and water sector performance (Saleth, 2004; Saleth & Dinar, 2004). Araral & Yu (2013) concluded that water laws, policies, and administration vary significantly among high-, middle-, and low-income countries as well as within countries over time.

A study by Araral & Wang (2015) also analyzes the effect of water institutions on a different aspect of water sector performance. They surveyed water experts of China considering 17 indicators of water laws, policies, and administration. They concluded that the interpretation and implementation of guidelines of water laws, policies, and administration vary considerably between the provinces. As well, in the absence of storage capacity, there can be very little improvement in water sector performance with improvement in water governance. It is extremely critical to analyze and assess whether the current water institutional structure and practices can solve the present problem of a water crisis of the nation or not (Saleth & Dinar, 2006; De Stefano *et al*., 2014).

In the Indian context, very few studies have been carried out to understand the role of water institutions and their role in various performance aspects. A study by Saleth (2004) gives the theoretical and analytical perspective of macro- and micro-level water institutions and their role in the overall water sector performance. There are few empirical studies on water governance in India. A study by Araral & Ratra (2016) compared the water governance in India and China by comparing 17 indicators of water governance. They found that the water governance in India is weak and results from the difference in the political, legal, and administrative system. The latest study by Ahmed & Araral (2019) argues that the water governance in eight Indian states have improved after the announcement of SDGs. In that study they also calculated the water governance index of eight Indian states using 17 indicators related to water law, policy, and administration. A different approach was used by Saravanan (2008) to understand the socio-political process of water management and the role of different actors, rules, and negotiations in making water-related decisions. A study by Bhatt & Bhatt (2017) places emphasis on the effect of change of constitutional status of water on overall water governance in India. Bandyopadhyay (2016) also highlights the need for a new interdisciplinary water institutional structure for improving water security in India.

Considering the limitation and gaps in the literature on the subject under study, the main objective of this study is to understand the water institutions and their impact on the different aspects of water sector performance in India. In this study, a survey questionnaire was used to collect the perception of water experts (engineers, academicians/researchers, legal experts, government officers, civil society/user groups) to understand the interaction of water institutions and water sector performance in India. This study contributes to the empirical literature on the understanding of water institutions of India, as most of the previous work in the Indian context derived their results from theoretical understanding and less from empirical analysis. The first step in the analysis is to explore the underlying factors of water institutions. The next step is to examine the significance of those latent factors on various aspects of water sector performance.

The paper is organized as follows: the first section discusses the need for institutional analysis in India. The second section gives details about the theoretical framework, methodology, and data used for this analysis. The third section covers the results obtained from the analysis. The last section talks about the policy implication and conclusions of this study.

## 2. Theoretical framework, methodology, and data

This study adopts the institutional decomposition and analysis (IDA) framework developed by Saleth & Dinar (2004). In this approach, water sector, water institutions, and their performance are conceived and analyzed at macro-level of a country or region. Saleth & Dinar (2004) argue that such a perspective is important to study the evaluation of the process of institution-performance interaction within the water sector. The water institutions also have their own institutional structure as well as their institutional environment like all other institutions (Saleth, 2004; Saleth & Dinar, 2004). The water institutions refer to the formal and informal rules of the game and their enforcement mechanism including water laws, policies, and administration (Araral & Wu, 2016) (for detailed discussion, see Saleth & Dinar (2004)).

### *2.1. Theoretical framework*

IDA can be used as a tool for eliciting the subjective and *ex ante* evaluation of macro institutions by stakeholders experiencing different conditions. It is important to consider all the major institutional aspects to cover all the relevant and policy-related factors for focused and meaningful evaluation of water institutions and water sector performance.

The IDA framework used in this study is illustrated in Figure 1. The IDA framework is a two-stage analytical decomposition where, in the first stage, water institution is decomposed into its main three components, i.e., water law, water policy, and water administration. In the second stage, water institution

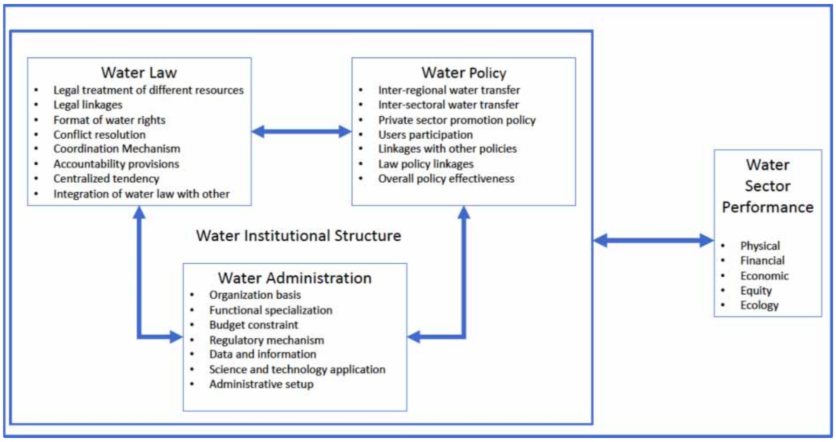



Fig. 1. Decomposition of water institutional structure and its linkage with water sector performance (adapted from Saleth & Dinar (2004)).

components and water sector performance are further decomposed to identify their major subcomponents to capture institutional aspects. The water institutional structure is defined collectively by these three institutional components, namely, water law, water policy, and water administration. It constitutes all the formal and informal arrangements within which the water sector functions (for details see Saleth & Dinar (2004)).

In water institutions, water law, policy, and administration play a key role in defining the legal framework, enforcing powers, approaches, and solutions to the sectoral challenges and financial and organizational structure related to the water sector (Saleth, 2004). As discussed in Saleth & Dinar (2004), it is difficult to differentiate between water law and policy based on what precedes or succeeds between the two. The water law and policy need mutual adjustment and improve with time for their effective implementation. The role of water administration is to implement water law and policies at the ground level within the framework and capacity defined by water law and policy. In the second stage, although there are several institutional aspects involved in each of these three institutional components, for a meaningful and focused evaluation only major institutional aspects are selected. The selected components of water law, water policy, and water administration included in this study are discussed below along with water sector performance aspects.

*2.1.1. Water law*. Water law includes major institutional aspects like legal linkages, provisions for conflict resolution, coordination mechanism, accountability, laws protecting water quality, centralization tendency, and integration of water law with other laws are included in the water law components. In this study we have considered seven (ordinal) subcomponents in water law as given in Table 1.

*2.1.2. Water policy*. Water policy component includes institutional aspects like inter-regional and inter-sectoral water transfer polices, private sector promotion and user participation, law-policy linkages, and linkages with other policies. A total of seven (ordinal) subcomponents have been used in water policy, as given in Table 1.

*2.1.3. Water administration*. The major institutional aspects included in water administration are the organizational basis, functional specialization, budget constraints, regulatory mechanism, data and information adequacy, science and technology capabilities, and administrative setup. Table 1 gives the details of seven (ordinal) subcomponents used in water administration.

*2.1.4. Water sector performance*. Similar to water institutions, water sector performance evaluation can also be done by decomposing it into its main dimensions, i.e., physical, financial, economic, equity, and ecology. The physical performance (OPP) covers the institutional aspects of the demand–supply gap, infrastructure health, conflict resolution efficiency, and smoothness of water transfers. The financial performance (OFP) is evaluated by comparing (a) actual and required investment and (b) expenditure and cost recovery. The economic performance (OEP) is evaluated in terms of the pricing and incentive gap. The equity performance (OEQP) covers the institutional aspects of equity between regions, sectors, and groups. The ecological performance (OECP) is evaluated considering the importance given to the ecological and environmental health of the water system. Figure 1 depicts the water institutional structure and its ultimate effect on the water sector performance, which is the focus of this study.

Table 1. Descriptive statistics of various institutional and performance variables/items of water sector.

| S. No. | Variable/item | Min. | Max. | Mean | Median | SD |
|---|---|---|---|---|---|---|
| WL | Water law | | | | | |
| 1. | How strong are the legal linkages | | | | | |
| 1.1 | Between land and groundwater (WL_LG) | 1 | 10 | 5.00 | 5.00 | 2.96 |
| 1.2 | Between land and surface water (WL_LS) | 1 | 10 | 5.97 | 6.00 | 2.60 |
| 1.3 | Between forest, environment and water (WL_FEW) | 1 | 10 | 5.21 | 5.00 | 2.63 |
| 2. | How effective are the legal provisions for conflict-resolution | | | | | |
| 2.1 | Local level (among users) (WL_CRL) | 1 | 10 | 3.67 | 3.00 | 2.63 |
| 2.2 | State level (among regions and sectors) (WL_CRS) | 1 | 9 | 3.74 | 3.00 | 2.14 |
| 2.3 | National level (among states and sector) (WL_CRN) | 1 | 10 | 4.26 | 5.00 | 2.47 |
| 3. | How effective are the legal provisions for coordination mechanism between | | | | | |
| 3.1 | Local level (among users) (WL_CML) | 1 | 9 | 2.95 | 3.00 | 2.00 |
| 3.2 | State level (among regions and sectors) (WL_CMS) | 1 | 9 | 3.53 | 3.00 | 1.81 |
| 3.3 | National level (among states and sector) (WL_CMN) | 1 | 10 | 4.10 | 4.00 | 2.30 |
| 4. | How effective are the accountability provisions | | | | | |
| 4.1 | For officials (WL_AO) | 1 | 8 | 2.85 | 2.00 | 1.92 |
| 4.2 | For users (WL_AU) | 1 | 8 | 2.83 | 2.00 | 1.89 |
| 5. | How effective are the overall legal provisions in protecting water quality (WL_WQ) | 1 | 9 | 3.75 | 3.00 | 2.12 |
| 6. | How strong is the tendency toward centralization (WL_CN) | 1 | 10 | 5.92 | 6.00 | 2.72 |
| 7. | How integrated are water law with other laws related to land, forest and environment (WL_WLFE) | 1 | 8 | 3.44 | 3.00 | 2.08 |
| WP | Water policy | | | | | |
| 1. | How effective are the water transfer policies | | | | | |
| 1.1 | Inter-regional (WP_IR) | 1 | 10 | 4.14 | 4.00 | 2.54 |
| 1.2 | inter-sectoral (WP_IS) | 1 | 9 | 3.83 | 2.50 | 2.56 |
| 2. | Impact of private sector promotion policy (WP_PS) | 1 | 8 | 4.36 | 4.00 | 1.89 |
| 3. | Impact of policy for promoting users' participation (WP_UP) | 1 | 9 | 4.92 | 5.00 | 2.47 |
| 4. | Extent of influence of other policies on water development/use | | | | | |
| 4.1 | Agricultural policies (WP_AG) | 1 | 10 | 6.05 | 6.00 | 2.66 |
| 4.2 | Energy and power policies (WP_EP) | 1 | 10 | 5.82 | 6.00 | 2.44 |
| 4.3 | Pollution control and environmental policies (WP_PC) | 1 | 10 | 4.33 | 4.00 | 2.20 |
| 4.4 | Fiscal policies (WP_FP) | 1 | 9 | 4.15 | 5.00 | 2.39 |
| 5. | Extent of linkage between water law and water policy (WP_WLP) | 1 | 8 | 3.78 | 4.00 | 1.79 |
| 6. | How well does water policy reflect water law (WP_PRL) | 1 | 8 | 3.72 | 3.50 | 1.83 |
| 7. | How effective is the overall water policy in addressing sectoral challenges (WP_OP) | 1 | 9 | 3.87 | 3.00 | 1.99 |
| WA | Water administration | | | | | |
| 1. | How effective is the organization basis (WA_OB) | 1 | 9 | 4.05 | 4.00 | 1.99 |
| 2. | How balanced is the functional specialization within the water administration (WA_FS) | 1 | 9 | 4.00 | 4.00 | 1.85 |
| 3. | How serious is the budget constraint in order to meet the modernization and strengthening objective (WA_BC) | 1 | 8 | 4.03 | 4.00 | 2.40 |
| 4. | How effective are the regulatory mechanisms (WA_RM) | 1 | 6 | 3.28 | 3.00 | 1.56 |
| 5. | Adequacy and relevance of the information base (WA_IF) | 1 | 8 | 3.79 | 3.00 | 1.85 |
| 6. | Extent of science and technology application within water administration (WA_ST) | 1 | 9 | 3.93 | 3.50 | 1.99 |

(*Continued.*)

Table 1. (*Continued.*)

| S. No. | Variable/item | Min. | Max. | Mean | Median | SD |
|---|---|---|---|---|---|---|
| 7. | How adequate is the administrative setup to operationalize water policy and water law (WA_OPL) | 1 | 9 | 3.53 | 3.00 | 1.64 |
| WSP | Water sector performance | | | | | |
| 1. | How effective is the physical performance (OPP) | 1 | 9 | 3.78 | 3.50 | 1.76 |
| 2. | How effective is the financial performance (OFP) | | | | | |
| 2.1 | Actual investment vs investment requirements | 1 | 7 | 3.11 | 3.00 | 1.60 |
| 2.2 | Cost recovery vs expenditure | 1 | 6 | 2.51 | 2.00 | 1.30 |
| 3. | How effective is the economic efficiency (OEP) | | | | | |
| 3.1 | Extent water prices cover supply cost | 1 | 7 | 2.82 | 2.00 | 1.57 |
| 3.2 | Extent water prices cover scarcity value | 1 | 7 | 2.44 | 2.00 | 1.65 |
| 4. | How effective is the equity performance (OEQP) | 1 | 8 | 2.97 | 3.00 | 1.84 |
| 5. | How effective is the ecological performance (OECP) | 1 | 7 | 2.85 | 3.00 | 1.70 |

## *2.2. Methodology*

At present, most of the issues that exist in the Indian water sector are related to water transfer, conflict resolution, financial and economic policies, integrated water resource management, accountability, decentralization, and investment (Jain, 2019; Pandit & Biswas, 2019). Different institutional aspects selected for water law, policy, and administration are trying to cover most of these policy issues of the water sector and hence are adequate to capture the role of these subcomponents on water institutions and water sector performance. As already stated, we adopt the methodology developed by Saleth & Dinar (2004). However, in this study, we have added granularity by further decomposing six of the second-stage subcomponents (ordinal) to understand the sectoral challenges, stakeholder responsibilities, and role of institutional division in the water sector (as given in Table 1). The basis of further subdivision of these six subcomponents is as follows: conflict resolution and coordination mechanism are further subdivided into local, state, and national levels (i.e., institutional division). Subcomponent accountability is further subdivided based on stakeholders involved, i.e., officials and users of the water sector. Subcomponents legal linkages, water transfer and linkages with other policies are subdivided based on sectoral and regional division.

The factors which affect the performance of the water sector and water institutions can be categorized into exogenous factor (outside of water sector) and endogenous factor (within the water sector) (Saleth & Dinar, 2004). The focus of this study is on the understanding of the linkage between water institutions' components (institutional linkages) and their impact on water sector performance (institution-performance linkages). Therefore, we are not considering exogenous factors like the political arrangement, economic development, social equity, cultural beliefs, demographic factors, etc., which defines the environment within which water institutions and water sector work.

The institutional subcomponents included in this study are of two types, (a) categorical variables which are factual, i.e., nominal scale, and (b) perceptional variables involving judgmental considerations (cannot be observed), i.e., ordinal scale. The perceptional variable has a bounded scale in the range of 1–10, where 1 and 10 indicate the worst and ideal situation, respectively, while categorical variables have different options based on their theoretical and practical importance. This analytical framework is useful in capturing most of the current institutional issues present globally or locally, and also, enables tracing of linkages among institutional components and performance aspects.

Also, these institutional linkages are very critical determinants of water sector performance, as the stronger the linkages within and between institutional components, the more effective will be water institutional structure (Garrido & Shechter, 2014). The degree of integration among different components of institutional structure also affects the overall performance of water institution and its ultimate impact on water sector performance. Hence, it is important to analyze and understand the linkages between water law, policy, and administration (institutional linkages) and between water institutions and sector performance (institution-performance linkages).

To derive insights on inter-linkages among factors of water law, policy, and administration and to examine the underlying latent factors exploratory factor analysis (EFA) is used. EFA is a multivariate statistical method used to examine the multi-dimensionality of the underlying structure of a reasonably large set of variables (Hair *et al*., 1998). It determines the underlying structure by identifying the dimensions which are called factors, enabling us to measure the underlying latent attributes. The quantification of latent factors is done through the computation of factor scores. The resulting factor scores can be directly used to carry out further statistical analysis. The extraction of latent factors is done using the principal component method.

The selection of extracted components can be done based on different criteria, the most commonly used one being an eigenvalue, i.e., components having eigenvalue greater than 1 will be retained, second, based on total variance explained, and lastly using scree plot (Budaev, 2010). In this analysis, we have used the Kaiser-1 (i.e., eigenvalue $>1$) criterion to extract the principal components. The next step is to find out the significance and effect of these extracted factors on various aspects of the water sector performance. For this, we have used multiple linear regression models as they allow a dependent variable (various performance aspects) to be modeled as a linear function of multiple predictor variables.

Considering the importance and role of water institutions and using the available literature on the subject, this study aims to evaluate the effectiveness of different aspects of water institutions and their impact on the water sector performance in India using the perception-based data from a sample of 40 water experts. In India, water is a state subject and many factors play a critical role in decision-making, therefore, this analysis will help to shed some light on the role and effect of these factors on institutional-performance linkages in the Indian water sector.

### *2.3. Data*

In this study, data from water experts in India were collected using an online survey questionnaire. We used purposeful sampling and contacted close to 200 water experts (engineers, academicians/researchers, legal experts, government officers, civil society/user groups) from different parts of India. Although a large number of people are engaged and quality research is being carried out in different parts of India, most of the work is related to technical and quality aspects of the water sector. As the focus of our study is more on the effect of water institutions, policy, and management in the water sector, our population is constrained. We received a total of 40 responses in 8–9 months through the online survey questionnaire. In this study, close to 82% of the respondents are academicians/researchers, 10% from civil society/user groups, and the remaining 8% are engineers. Considering the sample size, our study and results on the factor analysis are based on a small sample. The study by Arrindell & Van der Ende (1985) concluded that neither the observations to variables ratio nor an absolute minimum of observations had any influence on factor stability. A small sample study may be perfectly adequate if all communalities are above 0.6 (MacCallum *et al*., 1999). Also, the literature on small sample studies suggests that small sample data can also produce reliable actor solutions (Velicer & Fava, 1998; MacCallum *et al.*, 1999; Preacher & MacCallum, 2002; Bandalos & Boehm-Kaufman, 2009).

The communality value for all the items considered in factor analysis is well above 0.6 for our sample. Also, the value of the measure of sampling adequacy of the correlation matrix of factor analysis, i.e., KMO (0.757) and Bartlett's test of sphericity ($\chi_2 = 491$ with $p = 0.000$) are in the acceptable range for our data. Therefore, factor extraction using the items under study is meaningful. Given the population of water experts in India, to the best of our knowledge, this sample is adequate to elicit the effect of water institutions on various aspects of water sector performance in India.

## 3. Results and discussion

Details about descriptive statistics (i.e., minimum, maximum, mean, median, and standard deviation (SD) value) of institutional aspects (only ordinal) of water law, policy, administration, and water sector performance variables are given in Table 1. As already discussed, six of the second-stage subcomponents (ordinal) are further decomposed based on various criteria. All these ordinal items/variables vary in the range of 1 to 10. The value indicates the judgmental perception of water experts of India on these variables, hence can be used to analyze the status quo. There is a high degree of variation in the opinions of water experts on these institutional and performance aspects of the water sector in India. These variations may result from the unclear and underdeveloped water law, policies, and administration set up in the water sector of India. For comparing the effectiveness of different aspects, the mean value of these variables can be used as a meaningful indicator along with standard deviation.

### *3.1. State of water law variables*

Most of the water experts are of the view that there is a high tendency towards centralization (mean = 5.92). The legal provision of accountability has the lowest mean value, i.e., 2.85, which points towards one of the many reasons for inefficient use and weak conservation mechanism in India. There is variation in the effectiveness of legal provisions for conflict resolution and coordination mechanisms at the local, state, and national levels. While the linkages between water and land, forest, environment are strong (mean = 5.974), there is a low integration of water law with other laws (mean = 3.43). To promote conservation and effective management of water resources, there is a need to strengthen all these variables as water law provides legal backing to different policies of the water sector.

### *3.2. State of water policy variables*

In the case of water policy, the high mean value of policies related to the agriculture sector (mean = 6.05) and energy and power sector (mean = 5.82), which highlights the high influence of these policies on water sector policies. Integration of water law and water policy is perceived to be low (mean = 3.778), so is the overall water policy in addressing challenges faced by the water sector (mean = 3.868). Especially water policies for inter-sectoral water transfer (mean = 3.833) are believed to be ineffective. Policies related to the promotion of the private sector (mean = 4.359) and user's participation (mean = 4.917) policies in the water sector have a moderate impact.

### 3.3. State of water administration variables

The low mean value of most of the items of water administration indicates the inefficient working of water administration in India. Specifically, ineffective regulatory mechanism (mean = 3.28), poorly managed database (mean = 3.78), and low use of science and technology application (mean = 3.92) are believed to be major concerns for the ineffective working of water administration. Also, there is a need to improve the administrative setup to effectively operationalize the water law and policy in the water sector of India.

### 3.4. State of water sector performance variables

Overall water sector performance (OWSP) of the water sector in India is evaluated by capturing physical, financial, economic, equity, and ecological performance variables. As per the perception of water experts, all these performance variables are dysfunctional. The mean of these variables varies in the range of 2.436 to 3.775, pointing towards the poor state of different performance aspects of the water sector in India. Economic and ecological performance variables are the least effective ones. The poor state of these performance variables also highlights the ineffective, weak, and unclear institutional aspects of the water sector in India.

Most previous works have concluded their findings and suggestions on the impact of these different items on water institutional structure and water sector performance only based on descriptive statistics which is not sufficient (Araral & Wang, 2013; Araral & Ratra, 2016). However, to draw meaningful and informative conclusions it is important to analyze the inter-institutional linkages and impact of these institutional factors on various aspects of water sector performance. Therefore, in this study, we have used the factor extraction technique and the multiple linear regression method for analysis and policy recommendations.

### 3.5. Factor extraction

Data analyses on the primary data were performed using different statistical methods like factor analysis and multi-linear regression in SPSS (version 21.0). Only ordinal variables/items have been considered for factor extraction and regression. The mean imputation method was used for missing responses for the selected variables as these values account for less than 10% of the total responses in the sample (Schumacker, 2014). Initially, primary data on 32 ordinal items were used to understand inter-linkages between various subcomponents of water law, policy, and administration in India. A total of 19 ordinal items are used for this analysis, after eliminating 13 items out of a total 32 based on criteria such as missing data, low sampling adequacy, and high correlation. The first step is to explore and understand the dimensionality of water institutional structure. We also examine a few of the subcomponents at different levels, to analyze the micro-level effect and inter-linkages between these subcomponents.

Considering our small sample size and the large number of independent variables on which water experts have provided their inputs, it becomes necessary to reduce the number of dimensions. Hence, to proceed with dimension reduction we checked for factorability and sampling adequacy criteria. For the factorability check, the bivariate correlation was performed on these 19 items and was significant, indicating that the relationship among these variables is not merely due to chance. Also, Bartlett's test of sphericity ($\chi^2 = 461.8$, $p = 0.005$), and Kaiser-Meyer-Olklin (KMO) value (0.76) both satisfy the minimum threshold value of sampling adequacy. These results suggest that factor extraction can be meaningful. Factor extraction on 19 items was done based on principal component analysis as the extraction method and varimax rotation. There is support for using varimax rotation for small sample studies (Budaev, 2010). Also, the interpretable factor loadings in the case of a small sample should be $>0{:}5$ (Budaev, 2010). Thus, in this study, we suppressed all the factor loadings less than 0.5. The results showing the extracted factor along with their factor loading, variance, and communality value are given in Table 2. We have extracted a total of six factors, each with eigenvalue >1 and together explaining close to 81% of the variance. These extracted factors constitute different institutional aspects of water law, policy, and administration and are therefore named accordingly.

**Factor 1** consists of items from water law and administration and has an eigenvalue of 9.308 and explains about 47.57% of the variability in data. Items which loaded on factor 1, mainly deal with legal provision for conflict resolution and coordination mechanism at the state level (among regions and sectors) along with the integration of water law with other laws. It also has an item that reflects the effectiveness of water administration in the regulatory mechanism. For smooth governance of water resources and allocation, knowledge, and effectiveness of the integration of water law with other laws of the land, forest, and environment are very critical. All these points justify the integration

Table 2. Factor loading and communalities with varimax rotation.

| | Name of extracted factors | | | | | | |
|---|---|---|---|---|---|---|---|
| Items | CS_IWL F1 | WT_SD F2 | AC_WP F3 | L_CA F4 | N_CA F5 | BC_WQ F6 | Communality |
| WL_CMS | 0.882 | | | | | | 0.887 |
| WL_CRS | 0.756 | | | | | | 0.753 |
| WL_WLFE | 0.646 | | | | | | 0.713 |
| WA_RM | 0.554 | | | | | | 0.726 |
| WA_ST | | 0.834 | | | | | 0.812 |
| WP_IS | | 0.673 | | | | | 0.828 |
| WA_IF | | 0.649 | | | | | 0.776 |
| WP_IR | | 0.619 | | | | | 0.831 |
| WA_OPL | | 0.511 | | | | | 0.799 |
| WP_OP | | | 0.836 | | | | 0.801 |
| WL_AU | | | 0.65 | | | | 0.716 |
| WP_PRL | | | 0.586 | | | | 0.812 |
| WL_AO | | | 0.558 | | | | 0.785 |
| WL_CML | | | | 0.853 | | | 0.836 |
| WL_CRL | | | | 0.831 | | | 0.867 |
| WL_CRN | | | | | 0.886 | | 0.945 |
| WL_CMN | | | | | 0.815 | | 0.904 |
| WA_BC | | | | | | 0.903 | 0.855 |
| WL_WQ | | | | | | 0.699 | 0.831 |
| Initial eigen values | 9.038 | 1.654 | 1.463 | 1.231 | 1.052 | 1.038 | |
| % of variance explained | 47.57 | 8.707 | 7.702 | 6.477 | 5.538 | 5.462 | |
| Cumulative % of variance explained | 47.57 | 56.277 | 63.979 | 70.456 | 75.994 | 81.456 | |

*Note*: Factor loadings <0.5 are suppressed.

of these items into one factor. Two major themes for this factor are coordination and integration of water law with other laws, so we have named this factor coordination system (state level) and integration of other laws with water law (CS_IWL).

**Factor 2** integrates the items from water policy and water administration and has an eigenvalue of 1.654 and explains 8% of the variability in data. It covers the items related to the effectiveness of inter-sectoral and inter-regional water transfer policies, along with items which account for measuring the extent of the use of science and technology, adequacy and relevance of data and information in water administration. It also integrates the item which reflects the effectiveness of water administration setup in operationalizing water policy and water law. Integration of these different items indicates that judgmental perception of water experts in India believe science and technology, past data and information and administration setup play a very important role in effective and sustainable water transfer. As the main focus of this factor is on water transfer policy and use of science and data, we have named it water transfer policy and use of science and data (WT_SD).

**Factor 3** has items from water law and policy and has an eigenvalue of 1.463 and explains 7.702% of the variability in data. Items loaded into factor 3 mainly deal with the effectiveness of legal provisions for accountability and water policy in addressing sectoral challenges. The integration of these items highlights the importance of legal provisions for the accountability of users and officials along with the integration of water law and policy for effective management of the water sector. To cover all the sectoral challenges, the role of water policy is very important, as it acts as a regulatory document defining rules, responsibility, and mechanism in the water sector. We have named this factor legal accountability and overall water policy (AC_WP).

**Factor 4** has an eigenvalue of 1.231 and explains 6.477% of the variability in data. This factor has items evaluating the legal provision for conflict resolution and coordination mechanisms at the local level (i.e., among users). We have named this factor local coordination arrangement (L_CA).

**Factor 5** has an eigenvalue of 1.052 and explains 5.538% of the variability in data. It also has items related to the effectiveness of legal provisions for conflict resolution and coordination mechanism but at the national level (i.e., between states and sectors). We have named this factor national coordination arrangement (N_CA).

**Factor 6** has an eigenvalue of 1.038 and explains 5.462% of the variability in the data. The items in this factor mainly deal with the effectiveness of legal provisions on protecting water quality and the seriousness of budget constraints. To ensure and check the quality of the water being supplied, modernization of the water sector is required, which requires high investment from the government or private entities, hence justifying the integration of these two items into one factor. We have named this factor budget constraint and water quality (BC_WQ).

We have also checked the reliability of these six extracted factors using Cronbach's alpha. Cronbach's alpha values were well above the threshold value of 0.7 for all these factors. In the next step, we calculated the factor scores for these six extracted factors using the regression method. These six factor scores are used as an independent variable for further analysis, where we aim to check the significance of these factors on different aspects of water sector performance. As already stated, water sector performance can be assessed in terms of physical, financial, economic, ecological, and environmental performances. We have also analyzed the effect of these extracted factors on the overall water sector performance which is defined as an average score of its various aspects. Therefore, in total, we have six dependent (performance variables) and six independent variables (extracted factors) for further analysis.

A multiple linear regression method with forced entry was used for this analysis. A total of six models were generated to evaluate the impact of the set of independent variables on six different performance aspects of the water sector in India. The multiple linear regression results of these six models are summarized in Table 3. In the first step, all the predictor variables were added and then we ran the regression model. In the next step, we removed independent variables one by one sequentially to see the change in variance captured by the model. The difference in variance explained is accounted for by that individual factor in the presence of other factors in the model. We discuss only the large and moderate effects in these models by the variance explained by these factors and which is tabulated in Table 4. The general model form is given by Equation (1). The detail discussion of these six models are given below.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 \tag{1}$$

*3.5.1. Model 1: overall physical performance of water sector (OPP).* In this model, multiple linear regression was conducted with OPP as the dependent variable and CS_IWL, WT_SD, AC_WP, L_CA, N_CA, and BC_WQ as six independent variables. The model was able to explain 66.2% of the variance and was statistically significant. Out of these six predictor variables, state-level coordination system (CS_IWL), water transfer policy (WT_SD), legal accountability (AC_WP), local coordination arrangement (L_CA), and budget constraint (BC_WQ) are significant and positively related to the overall physical performance of the water sector except for the national coordination arrangement (N_CA) variable. The standardized $\beta$ coefficient of these factors along with model statistics is given in Table 3. The relative contribution of the total variance explained by these significant factors in Model 1 is analyzed and tabulated in Table 4. Out of these significant factors, legal accountability (AC_WP), which explains 26.4% of the variance alone, is the most significant factor, followed by water transfer policy (WT_SD), coordination system (CS_IWL), local coordination (L_CA), and budget constraint (BC_WQ) explaining 17.1%, 12.2%, 11.0%, and 4.2% of the variance, respectively. These results indicate that improving legal accountability provisions along with better water transfer policies will positively affect the physical performance of the water sector in India. The final model for OPP is given by Equation (2):

$$\text{OPP} = 3.775 + .615(\text{CS\_IWL}) + .727(\text{WT\_SD}) + .904(\text{AC\_WP}) + .585(\text{L\_CA}) + .361(\text{BC\_WQ}) \tag{2}$$

*3.5.2. Model 2: overall financial performance of water sector (OFP).* The multiple linear regression with OFP as the dependent variable and six independent variables explains 57.6% of the variance, and the model was found to be statistically significant. Table 3 gives details about the different standardized $\beta$ coefficients and model statistics. All these variables are positively related to the overall financial performance aspect of the water sector. Other than local and national coordination arrangement variables, other variables turn out to be significant. In this model also, legal accountability (AC_WP) is the most significant variable explaining 24.4% of the variance followed by state coordination system (CS_IWL) with 10.8%, budget constraint (BC_WQ) with 11.1%, and water transfer policy (WT_SD) with 6.1% of the variance explained. The relative contribution of the total variance explained by these significant factors in Model 2 is analyzed and tabulated in Table 4. This model highlights the importance of improving

Table 3. Multi-linear regression results for Models 1 to 6.

| Model variables | Dependent variables | | | | | |
|---|---|---|---|---|---|---|
| | Model 1: Overall physical performance (OPP) | Model 2: Overall financial performance (OFP) | Model 3: Overall economic performance (OEP) | Model 4: Overall equity performance (OEQP) | Model 5: Overall ecological performance (OECP) | Model 6: Overall water sector performance (OWSP) |
| Standardized model coefficients (*p*-value) | | | | | | |
| Constant | 0 | 0 | 0 | 0 | 0 | 0 |
| CS_IWL (F1) | 0.349 (0.001***) | 0.344 (0.004***) | 0.280 (0.032**) | 0.140. (0.335) | 0.346 (0.007***) | 0.355 (0.001***) |
| WT_SD (F2) | 0.413 (0.000***) | 0.259 (0.020**) | 0.306 (0.020**) | 0.455 (0.006***) | 0.491 (0.000***) | 0.470 (0.000***) |
| AC_WP (F3) | 0.513 (0.000***) | 0.514 (0.000***) | 0.480 (0.001***) | 0.414 (0.012**) | 0.311 (0.014**) | 0.515 (0.000***) |
| L_CA (F4) | 0.332 (0.001***) | 0.082 (0.461) | 0.132 (0.305) | 0.287 (0.067*) | 0.239 (0.055*) | 0.261 (0.01***) |
| N_CA (F5) | 0.073 (0.436) | 0.034 (0.755) | 0.027 (0.834) | 0.006 (0.965) | 0.076 (0.533) | 0.029 (0.760) |
| BC_WQ (F6) | 0.205 (0.035**) | 0.342 (0.004***) | 0.260. (0.045**) | 0.052 (0.722) | 0.013 (0.917) | 0.152 (0.117) |
| Model statistics | | | | | | |
| Number of observations | 40 | 37# | 39# | 39# | 40 | 40 |
| $R^2$ | 0.714 | 0.647 | 0.488 | 0.393 | 0.521 | 0.705 |
| Adjusted $R^2$ | 0.662 | 0.576 | 0.392 | 0.279 | 0.434 | 0.651 |
| F-statistics (df), (*p*-value) | 13.703 (6), (0.000) | 9.163 (6), (0.000) | 5.080 (6), (0.001) | 3.451 (6), (0.000) | 5.992 (6), (0.000) | 13.126 (6), (0.000) |
| # Missing responses | | 3 | 1 | 1 | | |

$*p < 0.1$, $**p < 0.05$, $***p < 0.01$.

Table 4. Relative contribution of total variance explained by significant factors.

| Model variables | Dependent variable: Model 1: Overall physical performance (OPP) | Model 2: Overall financial performance (OFP) | Model 3: Overall economic performance (OEP) | Model 4: Overall equity performance (OEQP) | Model 5: Overall ecological performance (OECP) | Model 6: Overall water sector performance (OWSP) |
|---|---|---|---|---|---|---|
| Variance explained (in %) | | | | | | |
| CS_IWL (F1) | 12.2 | 10.8 | 7.9 | 1.8 | 12.1 | 12.6 |
| WT_SD (F2) | 17.1 | 6.1 | 9.4 | 18.3 | 24.1 | 22.1 |
| AC_WP (F3) | 26.4 | 24.4 | 23.1 | 15.4 | 9.7 | 26.6 |
| L_CA (F4) | 11 | – | – | – | – | 6.8 |
| N_CA (F5) | – | – | – | – | – | – |
| BC_WQ (F6) | 4.2 | 11.1 | 6.7 | – | – | – |

legal provisions of accountability, along with the use of science and technology, data and improving budget allocation, as all these factors positively impact the financial performance, i.e., help in bridging the gap between actual investment vs investment required and cost recovery vs expenditure in the water sector. The final model for OFP is given by Equation (3):

$$OFP = 2.832 + .516(CS\_IWL) + .360(WT\_SD) + .7(AC\_WP) + .453(BC\_WQ) \quad (3)$$

*3.5.3. Model 3: overall economic performance of water sector (OEP).* The multiple linear regression with OEP as the dependent variable yields a model that explains 39.2% of the variance and was statistically significant. Detail about standardized $\beta$ coefficients and different model statistics is given in Table 3. In total, four variables, i.e., legal accountability (AC_WP), water transfer policies (WT_SD), state coordination system (CS_IWL), and budget constraint (BC_WQ) were found to be significant. The relative contribution of the total variance explained by these significant factors in Model 3 is analyzed and tabulated in Table 4. The legal accountability (AC_WP) variable turns out to be the most significant, alone explaining 23.1% of the variance, followed by water transfer polices (WT_SD), state coordination system (CS_IWL), and budget constraint (BC_WQ) explaining 9.4%, 7.9%, and 6.7% of the variance, respectively, as tabulated in Table 4. This analysis also indicates that improving water transfer policy, legal accountability provisions, and the use of science and technology applications along with adequate data and information impacts the overall economic performance positively. For example, by improving water pricing to cover supply cost and reflecting true scarcity value people intend to use this scarce resource carefully, hence all these variables are very critical to enhance the economic performance. The final model for OEP is given by Equation (4):

$$OEP = 2.611 + .423(CS\_IWL) + .462(WT\_SD) + .731(AC\_WP) + .393(BC\_WQ) \quad (4)$$

*3.5.4. Model 4: overall equity performance of water sector (OEQP).* In this multiple linear regression model, OEQP as a dependable variable explains 27.9% of the variance and was statistically significant. Table 3 gives the detail of various standardized $\beta$ coefficients and model statistics. These variables are positively related to overall equity performance. These results show that out of six variables only two variables, i.e., water transfer policy (WT_SD) and legal accountability (AC_WP) are significant variables in this model. The relative contribution of the total variance explained by these significant factors in Model 4 is analyzed and tabulated in Table 4. Water transfer policy (WT_SD) explains 18.3% of the variance while legal accountability (AC_WP) explains 15.4% of the total variance. It shows the importance of the effectiveness of water transfer policies, along with the adequacy and relevance of information base in improving equity performance considering equity across regions, sectors, and among social groups. The overall effectiveness of water policy for sectoral challenge and accountability provision should also consider equity as an important criterion and thus can improve the equity performance of the water sector. Also, effective legal provision for conflict resolution and coordination mechanism at the local level (among users) can affect the equity performance by considering the rights and uses of local users. The final model for OEQP is given by Equation (5):

$$\text{OEQP} = 3.089 + .876(\text{WT\_SD}) + .790(\text{AC\_WP}) \quad (5)$$

*3.5.5. Model 5: overall ecological performance of water sector (OECP).* The multiple linear regression model, with OECP as a dependent variable, explains 43.4% of the variance and was statistically significant. Out of six independent variables, four are significant and all are positively related to the dependent variable. Table 3 gives details of standardized $\beta$ coefficients and different model statistics. The water transfer policy (WT_ SD) has the highest positive impact as it explains 24.1% of the variance alone followed by state coordination system (CS_IWL) and legal accountability (AC_WP) explaining 12.0% and 9.7% of the variance, respectively. The relative contribution of the total variance explained by these significant factors in Model 5 is analyzed and tabulated in Table 4. It implies the ecological and environmental health of the water system is greatly affected by the effectiveness of the regulatory mechanism, water transfer policy, and use of science and technology application along with relevant information base. For the protection of water health, the role of accountability provisions and state and local-level legal provisions for conflict resolution and coordination mechanisms are also critical. The final model for OECP is given by Equation (6):

$$\text{OECP} = 2.850 + .590(\text{CS\_IWL}) + .837(\text{WT\_SD}) + .530(\text{AC\_WP}) \quad (6)$$

*3.5.6. Model 6: overall water sector performance (OWSP).* In this multiple regression model, OWSP as a dependent variable (calculated as an average of all the five aspects of water sector performance) yields a model that explains 65.1% of the variance. The details about standardized $\beta$ coefficients and model statistics are given in Table 3. All variables positively impact the OWSP and four variables prove to be significant. The relative contribution of the total variance explained by these significant factors in Model 6 is analyzed and tabulated in Table 4. The most significant variable is legal accountability (AC_WP) as it explains 26.6% of the variance followed by water transfer policy (WT_SD), state coordination system (CS_IWL), and local coordination arrangements (L_CA) explaining 22.91%, 12.6%, and 6.8% of the variance, respectively. The final model for OWSP is given by Equation (7):

$$\text{OWSP} = 3.035 + .492(\text{CS\_IWL}) + .651(\text{WT\_SD}) + .714(\text{AC\_WP}) + .362(\text{L\_CA}) \quad (7)$$

| | CS_IWL | WT_SD | AC_WP | L_CA | N_CA | BC_WQ |
|---|---|---|---|---|---|---|
| OPP | 0.349 | 0.413 | 0.513 | 0.332 | 0.073 | 0.205 |
| OFP | 0.344 | 0.259 | 0.514 | 0.082 | 0.034 | 0.342 |
| OEP | 0.28 | 0.306 | 0.48 | 0.132 | 0.027 | 0.26 |
| OEQP | 0.14 | 0.455 | 0.414 | 0.287 | 0.006 | 0.052 |
| OECP | 0.346 | 0.491 | 0.311 | 0.239 | 0.076 | 0.013 |
| OWSP | 0.355 | 0.47 | 0.515 | 0.261 | 0.029 | 0.152 |

**Dark box indicates the high significance of the factor whereas the light box indicates no or low level of significance.*

Fig. 2. Variation of standardized $\beta$ value of predictor factors within various performance aspects of water sector.

The standardized $\beta$ values of predictor variables for models 1 to 6 are given in Figure 2. Comparing the individual standardized $\beta$ values of these factors for all the six models can be used to highlight the importance of these factors. The standardized $\beta$ values are easy to interpret, as they tell us the number of standard deviations that the dependent variable change as a result of one standard deviation change in the predictor keeping the effect of other $\beta$ constant. Accountability factor (AC_WP) emerges as the most important predictor for most of the models where its standardized $\beta$ values vary in the range of 0.311 to 0.515. The water transfer policy factor (WT_SD) is the second most important predictor affecting positively the various performance aspects of the water sector in India except for financial performance where it has a low $\beta$ (0.259) value. The third important predictor turns out to be a factor related to the state-level coordination system (CS_IWL) where its standardized $\beta$ range is between 0.140 and 0.355, but it has no impact on the overall equity performance. The next significant factor is a budget constraint (BC_WQ) which turns out to be an important predictor for overall physical, financial, and economic performance variables. It has a positive impact on these variables and has $\beta$ in the range of 0.013 to 0.342. Improving the local-level coordination arrangement (L_CA) will improve the overall physical and overall water sector performance, whereas it is an insignificant predictor for other aspects of water sector performance, while national-level coordination arrangement (N_CA) is the most insignificant factor as per the analysis. The results from this analysis are in line with the literature, as many researchers recommend the strengthening of legal laws related to accountability provisions and development of water policies, keeping in mind the dynamic nature of the water sector to improve the various performance aspects (Araral & Yu, 2013; Araral & Wang, 2013; Bromley & Anderson, 2018). Also, the use of science and technology applications along with the use of reliable data can improve the decision-making and water policies for water transfer more effectively and ultimately result in improving the water sector performance.

## 4. Conclusions

There is a dearth of empirical studies on water institutions and how they interact with water sector performance, especially in the Indian context. This paper is an attempt to fill this gap by contributing to the literature on empirical analysis of inter-institutional linkages and their impact on water sector performance in India. Although the results obtained from this study are drawn from small sample data, at the same time, the respondents of this study were experienced, knowledgeable, and know the water sector well. Therefore, the insights from this study should be treated as a starting point to analyze, improve, and understand the water institutions and their impact on various variables of water sector performance in India. Also, our sample data satisfied all the feasibility criteria and sampling adequacy, therefore, factor extraction is meaningful.

We used a total of 19 different institutional aspects of water law, policy, and administration in this analysis. In the first stage, the factor analysis was used to reduce the dimensionality of the data. We used the most common extraction method, i.e., principal component with varimax rotation to find meaningful factors. In total, we had six factors, each with eigenvalue $>1$ and together explaining close to 81% of the variance. Further, these extracted factors were used as independent variables in multiple-linear regression to analyze the importance of these variables on various aspects of water sector performance.

The analysis shows that factors like accountability (AC_WP), water transfer policies (WT_SD), and coordination mechanism (CS_IWL) are the most important and significant predictors for various aspects of water sector performance in India. These predictors affect positively the various performance aspects. Hence, improving the effectiveness of these different institutional aspects will improve the water sector performance in India. These factors contain the items capturing the effectiveness of legal provisions of accountability, inter-regional and inter-sectoral water transfer policies, the importance of the use of science and technology application along with the relevant database, legal provisions for coordination mechanism, and the extent of integration of water laws with other laws. Factors like budget constraint (BC_WQ) and coordination arrangements at the local level (L_CA) moderately affect a few of the performance variables. These factors contain items related to the seriousness of budget constraint, legal provisions for the protection of water quality, and local-level coordination arrangement. The factor having items related to national-level coordination arrangement (N_CA) seems not to affect any performance variable in this analysis. This may be because in India water is a state subject and is mostly governed and controlled by state governments. Therefore, national-level coordination arrangement has no impact on different performance aspects.

At present, water institutional aspects like weaker legal provisions for accountability, conflict resolution mechanism, and water transfer policies have failed to effectively protect and manage the water sector in India. Also, lack of integrated approach, overlapping in policies of various sectors, and political agendas are acting as a catalyst in this problem. Therefore, by no means, are people motivated enough to conserve this precious resource. At the same time, the number of problems and conflicts related to the water sector in India is on the rise. We need some robust solutions to incentivize and motivate people. For better management and effective use of water resources, institutional changes are required. Many other countries have opted for institutional changes as a solution to the water crisis, e.g., Australia has introduced water markets as an incentive-based mechanism which has proved to improve the water sector performance (Tisdell, 2011).

This study shows the importance of various institutional aspects of water law, policy, and administration and how these factors are related to various performance measures of the water sector in India. The future water laws and policies should include a measure that will result in improving the effectiveness of different institutional aspects and water sector performance. Hence, it is high time for policymakers in India to consider and strengthen various institutional aspects of the water sector to effectively manage this scarce resource.

## Data availability statement

All relevant data are included in the paper or its Supplementary Information.

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