water

MDPI

Article

Measuring the Transaction Costs of Historical Shifts to Informal Drought Management Institutions in Italy

Adam Loch [1], Silvia Santato [2,3], C. Dionisio Pérez-Blanco [4,*] and Jaroslav Mysiak [2,3]

[1] Centre for Global Food and Resources, University of Adelaide, Adelaide, South Australia 5005, Australia; adam.loch@adelaide.edu.au
[2] Centro Euro-Mediterraneo sui Cambiamenti Climatici, 30175 Venezia Marghera, Italy; silvia.santato@cmcc.it (S.S.); jaroslav.mysiak@cmcc.it (J.M.)
[3] Università Ca' Foscari Venezia, 30123 Venezia, Italy
[4] Departamento de Economía e Historia Económica, Universidad de Salamanca, 37007 Salamanca, Spain
* Correspondence: Dionisio.perez@usal.es

Received: 6 May 2020; Accepted: 26 June 2020; Published: 29 June 2020

Abstract: Coase shows how costly resources are (re)allocated via costly institutions, and that transaction costs must therefore be positive. However, Coase did not elaborate on transitions between institutions which incur positive transaction costs that are characterized by numerous institutional complementarities; that is, feedback loops that inform the need for, and pathways toward, institutional change. Economic investigations of complementary modes of (re)allocation are rarely undertaken, let alone studies of transitions between modes. However, modes of (re)allocation that achieve similar results at less cost are generally viewed as having production-raising value. This paper measures the costs of transitioning drought management institutions in Italy toward informal, participatory, and consensus-based approaches during several recent drought events. The chosen model is Drought Steering Committees, which offer a substitute for current formal (less flexible) planning approaches, and where lower transaction costs that are associated with the transition are inferred. Our results highlight the relevance of empirical assessments of 'costly' transitions based on a historical study of transaction costs, as well as supporting previous works that highlight the value of contextual analysis in economic studies, in order to identify the benefits of institutional investment.

Keywords: Po River Basin; institutional economics; climate change adaptation; cost of adaptation

1. Introduction

Water, an essential resource, is becoming increasingly scarce and costly worldwide [1]. As water scarcity increases, existing institutions that are reliant on inflexible water governance arrangements will constrain corrective action leading to a crisis of governance [2,3]. Identifying or transitioning toward good governance practices and institutions delivering effective, fair and sustainable management of water resources is thus increasingly urgent especially in institutions capable of (re)allocating costly water resources during extreme scarcity events, such as drought.

Generally, institutions can be defined as 'the rules of the game' within which political, social and economic realities operate [4]. Two overarching institutional categories coexist in water resources management: (1) formal institutions, which are established and communicated through channels that are widely accepted as official, such as laws and regulations enforced by authorities and (2) informal institutions, where the social rules, customs, traditions, or codes of conduct are part of the culture and ideology [5]. In both cases, these institution types distribute power to differentially constrain and enable actors and facilitate or limit the response(s) of individuals and communities to climate hazards, such as drought [6]. Further, these institutional approaches may complement and/or substitute for one another depending on governance requirements and choices.

Coase [7] introduced institutional choice to economic investigation, extending a notion proposed by Robbins [8] that transitions between institutions occur within costly frameworks characterized by institutional complementarities. However, although Coase explained that costless bargaining (i.e., zero transaction cost institutions) were unrealistic, the concept of positive transaction costs with respect to institutional substitution was not considered [9]. Ostrom [10], among others, outline ways by which institutional change may be analyzed and selected. However, with respect to transaction cost specifically, while earlier works [11,12] affirm multiple options for dealing with transactions, they do not elaborate upon the role that economic investigation should take in clarifying the function of different modes of resource (re)allocation or organisation. Williamson [13] offers useful insights into governance modes and their selection with respect to economizing objectives (e.g., first order issues to get the institutional environment right, while third order economizing is better aimed at adapting to continuous uncertainty, such as drought). However, Coase typically framed an answer to the comparative institutional analysis problem as one of identifying alternative modes of organisation that achieve similar results at lower costs, which would enable the value of production to increase [11]. An appreciation of these issues by Pagano and Vatiero [9] led them to two hypotheses that we are keen to explore in this paper. The first is that institutional change (i.e., from formal to informal organisation) involves transition and transaction costs, both of which can be empirically measured in order to identify improved (i.e., low(er) costly) governance arrangements (H_1). The second is that costly institutions imply complex complementarities (e.g., feedback loops akin to those discussed by Ostrom [10]), which may limit (promote) substitution. Thus, a historical analysis of the complementary institutional factors framing governance choices will be needed to understand equilibria outcomes (H_2). To test these hypotheses using an applied case study we focus deeply on a set of historical transaction costs and institutional outcomes, which are a key premise of institutional economics.

1.1. The study of Transaction Costs

Transaction costs are defined as the costs of resources used to define, establish, maintain, administer, and change institutions and organizations, as well as those that are needed to define the problems that these institutions and organizations are intended to solve [14]. In the larger context of institutional evolution, they are all of the costs involved in human interaction over time. The arguments for measuring transaction costs represent an increasingly relevant feature in investigations of environmental or common property policy design and analysis, along with their budgets and benefits [15,16].

From an economic perspective, appropriate formal and informal institutional choices include options that minimise/lower all transaction and abatement costs [14]. In the context of complex multiscale problems, such as water management, the measurement of transaction costs usually focuses on markets and other formal institutions [17,18], with little research being conducted on the transaction costs of informal institutions [19]. The latter are frequently used for water resource management in several areas worldwide, particularly to mitigate the adverse effects of droughts, e.g., through informal water markets [20], quota-based water reallocation [21], or risk sharing [22]. Reasons for reliance on informal institutions include trust, networking, shared norms, and reciprocal arrangements, which may help to lower total transaction costs [23].

Measuring transaction costs is challenging, leading Quiggin [24] to describe them as generally being treated by economists as "something of a black box, the contents of which are inaccessible". Most water management institutions do not empirically quantify institutional transaction costs such that they can be easily distinguished from other cost categories. Researchers also report a number of difficulties that are related to the measurement of transaction costs, often suggesting that data are partial and indirect and/or derived from limited cost typologies or proxies to represent transaction costs [25]. Further, there is no broad agreement on a standard terminology about the definition of transaction costs [26]. For this reason, it seems unclear how to identify the peculiarities of a transaction, and which expenses/investment should be regarded as transaction costs. All of the above is even more challenging where informal institutions may amplify accounting data gaps. Consequently, economic investigations of complementary institutional modes of (re)allocation are rarely undertaken while using empirical transaction cost measures, let alone historical studies of transitions between modes.

However, a relatively common feature of transaction cost measurement is the distinction between ex-ante and ex-post costs; that is, those occurring before and after the transaction. The sum of ex-ante and ex-post transaction costs yields total transaction costs. Total transaction costs can be further divided into: (1) administering, monitoring, contracting, and enforcing current policy arrangements (termed *static transaction costs*) and (2) periodically designing, enabling, implementing new, and/or transitioning existing management arrangements to new systems (termed *institutional transition costs*). In addition to these costs, the total transaction costs may be increased when subsequent adaptation requirements are triggered by policy shocks or surprises (termed *institutional lock-in* costs) [14]. Table 1 references the typical transaction costs categories and examples, sub-divided between ex-ante and ex-post transaction costs, which we will focus on later in the analysis section.

Table 1. Categorisation examples of transaction costs, adapted from Garrick [27] and Marshall [14].

Classes	Sub-Classes	Typology of Transaction Costs	Water Market Arrangement Examples
Ex-ante	Institutional transition costs	Research and information	River Basin development planning and closure (cap on water diversion) Hydrologic and socio-economic studies
		Enactment or litigation	Water rights reform (adjudication, conflict resolution, rules)
		Design and implementation	Modification to storage and distribution, licensing systems and trading rules Water accounting systems
Ex-post	Static transaction costs	Support and administration	Transaction planning, identification of buyers and sellers, administrative reviews
		Contracting	Water rights due diligence
		Monitoring and detection	Water use accounting
		Prosecution and enforcement	Compliance monitoring and enforcement Dispute resolution
	Institutional lock-in costs	Adaptation or replacement	Revised caps on water diversion Adapted water rights and water user association rules Acquiring water rights for the environment if cap on water diversion is revised downward
Source: [28]	Source: [29]	Sources: [14,18,30]	Source: [17,18]

1.2. The Contribution of this Study

The goal of this paper is to evaluate whether, via a case study of informal drought management arrangements in northern Italy, less costly—and ideally improved—governance arrangements have been achieved (H_1). This evaluation will entail a historical examination of the evolution of water governance institutions for Italy, in general, and Po River Basin (PRB) drought management systems in particular (H_2). We will then measure and track transaction costs with respect to transitioning drought management institutions toward informal, participatory, and consensus-based approaches during several recent drought events, with a view to identifying any evidence of low(er) transaction costs coupled to similar—or improved—drought management outcomes. Ultimately, this approach will enable an assessment of the hypothetical propositions and their value for further study to develop the assessment process. The paper is structured as follows: in Section 2, we assess the historical context of the case study area, the PRB in northern Italy; in Section 3, we present methods and data; in Section 4, we conduct an empirical transaction cost analysis of the institutional transition in the PRB; Section 5 discusses the results; and, Section 6 concludes.

2. Historical Institutional Analysis

The PRB is located in northern Italy and extends, with five per cent of its total area (~74,000 km²), to portions of French and Swiss territory (Figure 1b). In terms of average annual water discharge, the PRB is one of the largest in Europe with an outflow at the mouth of the Po River in Pontelagoscuro of 1470 m³/s. Po River flow rates depend on the water captured and stored in artificial reservoirs in the mountains, principally in five lakes (Maggiore, Como, Iseo, Idro, and Garda) located at the foot of the Alps. Demand for water is high: the PRB supplies water for hydropower generation in upstream lakes and reservoirs, and potable water to some 3700 municipalities within seven administrative regions with a thriving industry that accounts for 40% of national GDP.

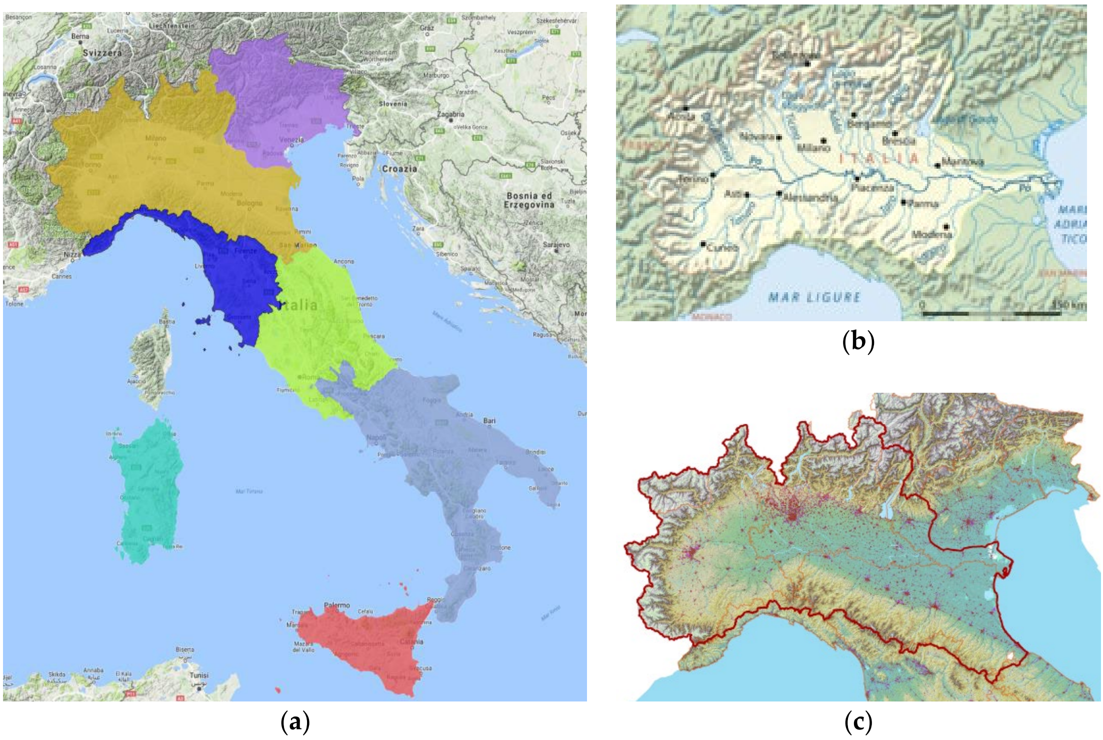

Figure 1. (**a**) the seven river basin districts in Italy; (**b**) the area of the PRB; and, (**c**) the boundaries of the territory managed by the Po River Basin Authority(red outline).

The system also supplies irrigation water to Italy's largest contiguous agricultural region, which comprises 21.5% of total Italian agricultural land, contributes 30% of national agricultural value-added production [31], and represents around 80% of total water extractions [32]. Water is also needed in the lower reaches of the river to mitigate salinity intrusion during low flow or drought periods—as the area is located below sea-level—and to support fisheries and aquaculture demand.

Average precipitation ranges from a maximum of 2000 mm in the Alpine regions of the PRB to less than 700 mm on the eastern plains, with an annual average of 1100 mm. Under future climate change temperatures will increase, while summer precipitation will likely decrease [33]. Po River discharge is expected to decline during the summer months—when the demand is typically at its peak—and shift to higher levels of discharge in the winter (Figures 2 and 3).

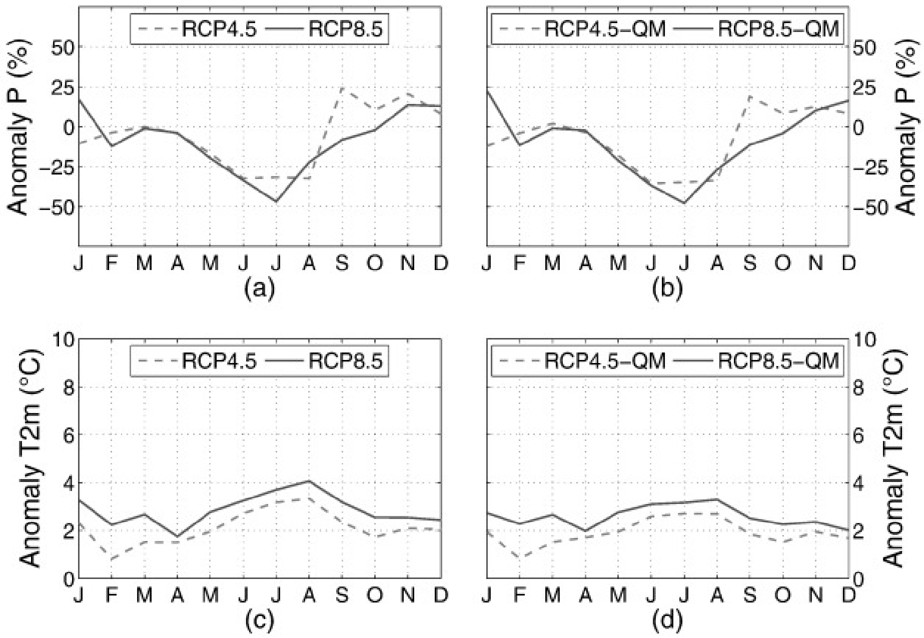

Figure 2. Anomalies in (**a**,**b**) seasonal precipitation in % and (**c**,**d**) two meter mean temperature in °C for the PRB, 2041–2070, versus a 1981–2010 benchmark period. Left side (**a**,**c**) refers to raw CMCC-CM/COSMO-CLM outputs, while the right side (**b**,**d**) indicates the bias-corrected climate projections [33].

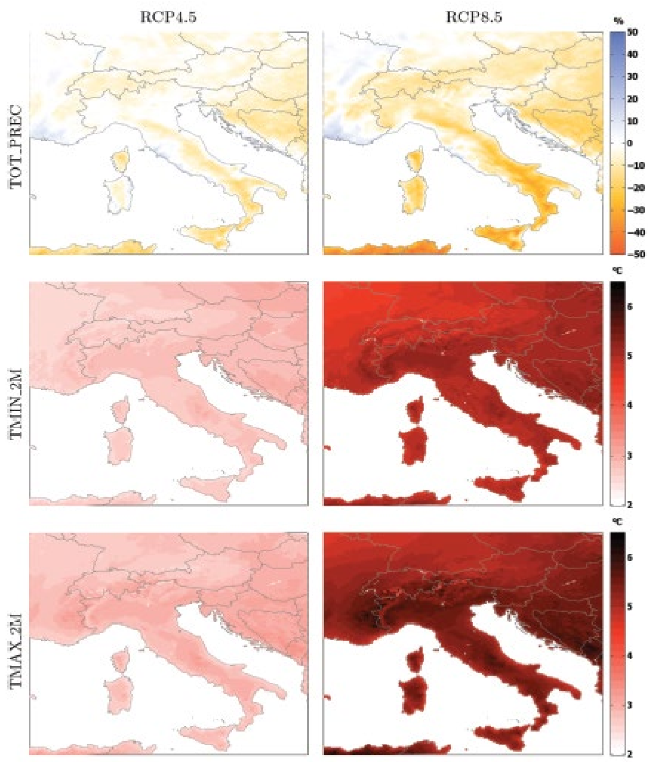

Figure 3. Climate change signal for the period 2071–2100 versus 1981–2010 for mean precipitation, maximum, and minimum temperature [34].

Thus, the frequency and intensity of extreme events, such as droughts, are expected to increase making current levels of water extraction in the basin unsustainable [35]. Evidence of these changes is already noticeable at the regional and local levels, with recorded rainfall reductions and increased temperature variations of around one degree centigrade [36,37]. Droughts also appear to be affecting the region more frequently, with a State of Emergency (SoE) being declared in 2003, 2006, 2007, and 2017. Since 2000, these SoE events have lasted 25 months in total, with an average duration of 6.25 months per declaration. A coordinated climate change adaptation strategy that identifies the main impacts of climate change for a number of socio-economic sectors in Italy was adopted in 2015, followed by a National Adaptation Plan for Climate Change (PNACC) [38]. The PNACC encourages institutions to identify effective ways to mainstream adaptation into existing plans and regulations at different levels of territorial government [21,39]. River Basin Authorities are responsible for identifying and coordinating drought adaptation actions and measures.

2.1. Water Abstraction Licenses Regime in Italy: An Obstacle to Climate Change Adaptation

The current system of creating and managing water abstraction licenses (WAL) in Italy creates a significant obstacle to the effective implementation of these two adaptation strategies. Originally, Italian legislation viewed water as a plentiful resource, and this attitude has remained essentially unchanged since the 1930s. As a result, the volume of authorised WAL in the PRB now exceeds average water availability; for example, current hydroelectric and agricultural licenses amount to 1840 m^3/s, against an average river flow of 1470 m^3/s [21].

Although many licenses are dormant, over-allocation complicates the management of water deficits during drought periods. WAL quotas are also difficult to implement in Italy [40,41] due to the fragmented nature of WAL, and the challenging interplay of Italian water institutions [42] where regional governments have been granted the power to regulate WAL matters. For these reasons, the PNACC proposed a revision of the WAL regime system [38,39]. Recent legal definitions and laws now recognise the limits to national water use, and articulate collective uses of water resources in Italy with respect to protection of environmental water resource uses (Law 183/1989), integrated water resource management (Law 36/1994), and the protection of water quality (Environmental Code 152/2000). The government sought to reorganise water services in the early 2000s, in what was then regarded as a first step towards the introduction of market and pricing reallocation mechanisms. In June 2011, a law favouring privatisation of water supply and sanitation, largely viewed as opening the possibility of water trading, was repealed by referendum. The prevailing view following the referendum was that access to water should be treated as a fundamental right, not subject to free market reallocation. Thus, the referendum outcome limited the use of formal market instruments such as water pricing, trading, or buyback for drought management [43], requiring alternative institutional arrangements. Ultimately, the capacity of river basin managers to coordinate parties and address climate change impacts and future population and economic growth, and/or to prioritise different water uses during drought has been compromised, and regional governments granted the power to regulate WAL matters. Governance of water resources in Italy thus remains complex, emergency-driven, and focused on short-term problem-solving. This is particularly evident during drought events in 2003, 2006, 2007, 2015, 2016, and 2017, where reactive strategies probably increased the negative impacts of water scarcity.

2.2. Formal Drought Management Institutions

In the absence of market-based reallocation mechanisms drought management in Italy has traditionally focused on formal command and control approaches, where the state intervenes in the management of basin water resources as a last resort instrument (Law 225/1992) to enact water restrictions with sanctions for non-compliance [44]. By contrast, recent evidence of climate change and increased drought events from 2003 onwards have served to focus EU Member States' attention on alternative political and technical responses that involve participatory (e.g., informal) approaches [45] over prescriptive (e.g., formal) sanctions. A key document was the communication addressing the problem of water scarcity and droughts in the European Union [46], which presented an initial set of non-mandatory policy options at the European, national, and regional levels to address and mitigate the challenge posed by water scarcity and drought.

During the process of transitioning the European Water Framework Directive (EU-WFD) into national legislation, the PRB experienced a severe drought event in 2003 that presented a significant threat to urban, industrial, and agricultural water supplies. The Italian government formally declared a SoE, which enabled them to: (i) centrally manage drought emergency interventions in the PRB for a period not exceeding 180 days (but which could have been extended by another 180 days by the central government); and, (ii) allocate funding for initial drought management interventions, with the option for further interventions where recognised as necessary by the delegated commissioners in charge of managing the emergency. This formal institutional arrangement was managed by the National Civil Protection Department (NCPD), anchored to the Presidency of the Council of Ministers which supervised all activities.

2.3. Informal Arrangements for Drought Management—The Case Study

In the 2003 drought event, the NCPD and Po River Basin Authority (PRBA) jointly sought to avoid last resort interventions by the central Italian government. Both were concerned about the impact of the drought on energy supply, and the need to act more rapidly (and collectively) to address issues in line with EU best drought management practices. Consequently, a Drought Steering Committee (DSC) was initiated, presided over by the PRBA, with the purpose of coordinating communication and voluntary responses to drought across a large number of organisational members. The DSC constituted an informal institution, because it was not legally recognised, and stakeholders participated on a voluntary basis. Further, there was no capacity for sanctions in the case of non-compliance with decisions made at the meetings and, in cases of conflict, the DSC could not be sued and/or prosecuted due to its informal status. Therefore, any decisions had to be made via agreement or consensus due to a lack of explicit legislative (formal) mandate in support of those activities. Ultimately, trust among the membership, networking and shared objectives were expected to reduce total institutional transaction costs of drought management, as outlined below.

The mission of the DSC, sanctioned under a Memorandum of Interest (MoI), was to manage severe water deficits in a unified manner and to delay or prevent critical water shortages. Two main objectives were included in the MoI: (i) maintenance of minimum water withdrawal opportunities for downstream irrigators and Po River Delta water users (e.g., aquaculture); and, (ii) maintenance of hydroelectric outflows to guarantee maximum possible electricity production, as requested by the national transmission grid operator. Under these common objectives, the DSC initiated a network of information gathering aimed at measuring lake storage data, monitoring of PRB water flows in real time, and a summary of WAL water uses. These measures served to better assess and understand the negative impacts of the drought, contributed to an overall stabilization of water flows and availability, and brought progressive increases in supply to WAL-holders during the drought. This initial success meant that, since 2003, the DSC has been convened again when necessary to deal with PRB drought events and to limit (potentially costlier) state intervention. Drought management planning through the DSC is now enshrined in the Po River Basin Plan [47], along with requirements for water-stress mapping, temporary restriction measures for intensive (e.g., back-to-back rotation) cropping, and early-warning systems that are based on basin modelling.

The success of the DSC has also become a reference point for the management of water crises in Italy more generally, given its capacity to aggregate and coordinate various stakeholders' interests when considering regional differences. Therefore, the DSC is now recognized by the Italian government as an effective instrument for the fair and sustainable management of water withdrawals. In 2016, legislation provided for the mandatory activation of a DSC in each of the seven Italian basin districts, along with responsibility for coordinating different local water authorities. These DSCs are aimed at harmonizing adaptation efforts under the larger Permanent Observatory (PO) institutional structure in Italy, which monitors climate dynamics and variability, climate hotspots, and natural environmental hazards from extreme weather events.

The success of the original PRB-DSC suggests that it may provide a useful model for jurisdictions beyond Italy, particularly in the EU. Incentives for a jurisdiction to participate in their own version of the DSC are two-fold. First, the DSC represents an opportunity to coordinate with other water users before any drought declaration is made, after which centralized (distant and/or coercive) decision-making arrangements may dominate to reduce negotiation/adaptation opportunities.

Second, the DSC is an opportunity to foster greater mutual understanding and trust among relevant organisations, increased information exchange, and collaboration between water users that may otherwise be hampered by administrative and political fragmentation. The informal nature of the DSC may also lead to relatively inexpensive institutional arrangements that are more readily enacted (institutional transition costs) and administered (static transaction costs) by other watersheds with limited or poor water right structures.

From this assessment, we conclude that our understanding of the equilibria transition from formal to informal drought management institutions in the PRB is enhanced by considering complementarities and how they have hindered certain institutional choices, while fostering the selection of others. This lends support to H_2 and the value to economic investigations from a consideration of the historical context. However, whether the transition has broadly resulted in low(er) costly modes of organisation (H_1)—and therefore productivity increasing outcomes—is the subject of our subsequent analysis.

3. Materials and Methods

3.1. Stakeholders, Interviews, Document Analyses, and Assessment of Governance Arrangements

Our measurement of transaction/transition costs was based upon extensive stakeholder consultations. The stakeholders are all of the interested parties who affected, were affected by, or otherwise influenced drought governance decisions. We defined the domain of stakeholders involved in the DSC and different focus levels, which range from identifying relevant institutions and key persons to finding the interactions and associated transaction costs. Our methodology comprised: (i) analysis of water allocation governance frameworks in place; and, (ii) analysis of informal DSC institutions and how these are embedded within the national and regional PRB governance. Initial meetings were held with senior members of the DSC to identify whom to interview. Face-to-face and telephone interviews were scheduled and conducted involving a total of 12 experts, with each interview lasting around two hours. The interviews enabled us to explore technical and organizational details that are necessary to identify sources of transaction cost data.

3.2. Transaction Costs Data Collection, Categorisation and Analysis

McCann et al. [30] established a framework and typology for transaction costs measurement based on previous work from Thompson [48], which we follow in this study. The data collection approach is similar to that detailed in Loch and Gregg [49]. The main function of the DSC is to coordinate stakeholder participation and consensus in the wake of significant drought event periods. Routine technical meetings during non-drought periods—which, together with hydrologic basin modelling, constitute the bulk relevant transaction costs—are also commonly arranged by regional authorities with the support of Environmental Protection Agencies (EPAs). DSC meetings were used to track stakeholder involvement, with the salary cost rates (per hour) at each expert-level providing a proxy base value for transaction costs estimates. These data were obtained while also considering: physical or virtual participation by experts in meetings; estimates of travel distances and/or costs from the organization to which they belong to the venue of the meeting; and, the duration of the meeting. Information for the study was collected through interviews and meetings minutes. For some meetings the minutes were not available, requiring additional interview data collection to fill information gaps. Our approach was informed by previous studies that interviewed government staff [50] and representatives of stakeholder groups [51] to identify the time spent on various relevant activities within the organisations. Further, in 28 out of 235 cases, the mean salary cost values (~€70,000 per annum) had to be assigned when information was not publicly available or provided in the interviews. DSC meetings and related transaction costs were then classified based on their key focus: meetings to agree memoranda of understanding involved ex-ante enactment costs; meetings to develop/test new hydrologic models for the basin involved ex-ante design and implementation costs; meetings to extend the modelling framework and, thus, enhance institutional capacity to monitor water use and compliance and limit illegal abstractions that are involved ex-post monitoring and detection costs; while meetings to incorporate the DSC institution within the PO arrangements for Italy as a whole provided some measure of lock-in (i.e., substitution-hindering complementarity) transaction costs.

The DSC was assisted by the PRBA through organisation of meetings, data collection and analysis, and technical advice. Initially (2003–2008), this role was accomplished with the support of an external service provider that was subsequently transferred to the PRBA (2008–2016). Financial data from the PRBA provided transaction costs related to the collection of information in support of decision-making by the DSC, including hydrologic modelling and analysis. As an example, two external staff from the Regional Environmental Agency of the Emilia-Romagna Region (ARPA-ER) worked part-time on the development and maintenance of the hydrological model to support DSC activities. It should be noted that the total transaction costs involved in the DSC process were absorbed by different organisations at different points of the original program life-cycle (2003–2016).

Table 2. summarizes for the case of the DSC the classes, sub-classes, typology, and categorisation of transaction costs, plus the data sources used for data collection.

Table 2. Categorisation of transaction costs, adapted from [30], Garrick [27], and [14], including categorisations identified for the Drought Steering Committee (DSC) case study, and related data sources.

Classes	Sub-Classes	Typology of Transaction Costs	Categorisation of Transaction Costs for the Drought Steering Committee	Data Source
Ex-ante	Institutional transition costs	Research and information	The meetings of the DSC (minutes)	Meeting minutes (stakeholders involved, duration of the meeting), personal interviews (salary cost rates, physical or virtual participation, participation in meetings, travel distances, duration of meeting) and estimates through sensible adjustments of comparable costs (travel costs)
		Enactment or litigation	Enactment: includes all the meetings for the signing of the memorandum of understanding for the DSC	
		Design and implementation	Hydrologic studies and modelling of allocations supporting the decision of the DSC	Financial records and other publicly available information (reports)
Ex-post	Static transaction costs	Support and administration	The organisation of the meetings (design costs)	2003-2008: Financial records; 2008-2016: Structured interviews with representatives of stakeholders to obtain information of the personnel involved, plus estimates through sensible adjustment of salary costs
		Contracting	Not present	NA
		Monitoring and detection	The meetings for the hydraulic modelling	As in research and information typology
		Prosecution and enforcement	The meetings of the PO	As in research and information typology
	Institutional lock-in costs	Adaptation or replacement	Meetings to include DSC arrangements within PO framework	As in research and information typology
Source: [28]	Source: [29]	Sources: [14,18,30]; [30]	Source: Authors' elaboration	

As an example, in order to calculate the research and information costs corresponding to the physical participation of an expert from Torino in a DSC meeting, the travel time between Torino and Parma (headquarters of the PRBA) was obtained, and multiplied by a standard cost per km to generate the transportation costs by car, or alternatively the cost of the train ticket was used, depending on the type of transportation used. This amount was added to the salary cost rate (per hour) times the duration of the travel plus the duration of the meeting to obtain the corresponding transaction cost(s). Following this travel cost calculation, we could estimate that a representative of the Regional Environmental Agency of the Piedmont Region (ARPA-Piedmont), taking part in an in person meeting in 2017, spent EUR 120 in the train trip (economy ticket, high speed train). Next, the salary cost was obtained from institutional salary tables (60,000 EUR/year), its' hourly equivalent calculated (assuming a standard 36 h/week working time and 52 weeks per year yields EUR 32.1), and multiplied by the duration of the meeting (1.3 h) plus the duration of the round trip (5.2 h), which gives as a result EUR 208.3. The total cost for this participant is therefore estimated at EUR 328.36 (208.3 + 120).

Another example is provided for hydrological model implementation, the most significant transaction cost in the 2006–2011 period. This transaction cost is obtained as the sum of the cost of the contract with an external provider during the 2006–2011 period, obtained from accounting records (EUR 700,000), plus the cost of the personnel employed by ARPA-ER from 2008 to support the consulting firm and maintain and update the model once the consultancy was over, which is obtained as in the example above multiplying the hourly cost of the personnel dedicated to model support and maintenance times their dedication to the task.

After data for each cost item were carefully collected and calculated, they were transformed into real values using 2017 as the base year (e.g., meeting costs during the 2003 drought were converted into euro of 2017 using data from the World Bank [52]).

All final transaction costs were then categorised into institutional transition (ex-ante) and static transaction (ex-post) costs, as per Table 2. Following the method adopted by Loch and Gregg [49], analyses were performed to identify: trends in each category over time, summed total transaction costs for the DSC, and comparisons between drought and non-drought periods. The following sections detail the results of the institutional mapping exercise, which assists in our assessment of whether the institutional transition achieved similar/improved outcomes, and subsequent transaction cost analysis to measure and assess the costs of that process.

4. Results

4.1. Stakeholder Map and Assessment of Drought Governance Arrangements

Current drought management systems in the seven Italian river basin districts involve three main actors with differentiated roles and responsibilities for River Basin Management Plans (RBMPs): national government and ministries in coordination role; river-basin district authorities in operational role; and, regional governments and administration in both coordination and operational roles (Figure 4). They are all part of PO, and they have to implement the RBMP through a Protection Plan (PTA) by addressing the qualitative and quantitative water resource management objectives.

Based on the objectives of the PTA, the Optimal Territorial Areas (ATO, for the domestic use of water) and the Land Reclamation Boards (LRB, for the management of irrigation water) are in charge of preparing the Area Plan (AP, in Italian: *Piani d'Ambito*) and Water Conservation Plans (WCP), respectively. During this process, drought is monitored through the relevant sub-basin's Drought Management Plan (DMP), a subsidiary instrument to the RBMPs that assesses the basin status on a continuous basis using four stages (normal, pre-alert, alert, and emergency), and identifies appropriate measures for delaying and/or mitigating drought impacts (e.g., information campaigns) [40]. Therefore, a variety of legislative requirements must be adhered to with respect to drought events. Critical Italian government institutions (from 2016 onwards) include the NDCP, the Ministry of Agriculture, the Ministry of Infrastructure, and the Ministry of Environment; all of which are accompanied by the National Association of Land Reclamation Boards (ANBI), the Italian research organization dedicated to the agri-food supply chains (CREA), the National Institute of Statistics (ISTAT), Institute for Environmental Protection and Research (ISPRA), the Foundation representing companies operating in the public services of water, environment and energy (UTILITALIA), the Association for the reorganization of the Integrated Water Service (ANEA), and the National electricity company association (ASSOLETTRICA). The PO are now operating in each of the seven Italian RBDs: Padano (i.e., PRB), Alpi Orientali, Appennino Settentrionale, Appennino Centrale, Appennino Meridionale, Sardegna, and Sicilia. The PRB regions are the Autonomous Region of Valle d'Aosta; Piedmont; Liguria; Lombardy; Emilia-Romagna, Veneto; Autonomous Province of Trento; and, Toscany.

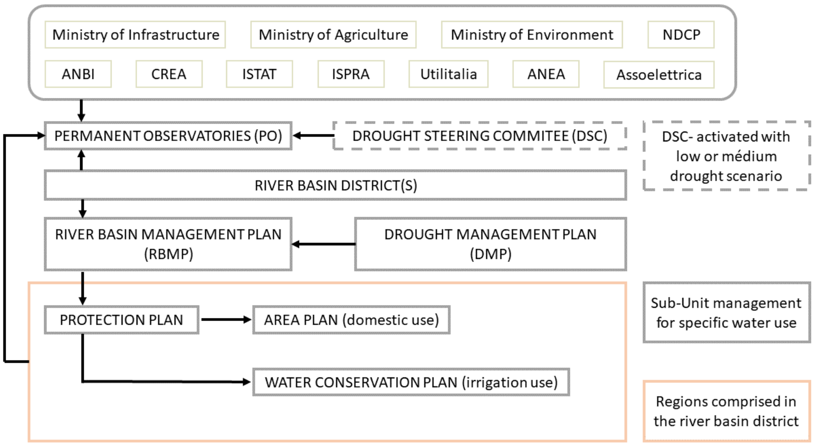

Figure 4. Framework of drought management planning and arrangements in Italy.

When a drought emergency is declared in the PRB, the DSC is triggered. Naturally, this process requires coordination at a decentralized level. The PRBA is responsible for coordinating all DSC stakeholders (local and national), and their responses to the emergency drought status (Figure 5). The PRBA collects, updates, and disseminates information on the availability and use of water resources across the relevant river basin organisations. These include: the Italian Ministries of Agriculture, Environment, Infrastructure, and Productive Activities; representatives from each of the five Lake Regulators; the Dam Management Agencies; the operator of the national transmission grid (GRTN); the inter-regional agency for the Po river (AIPO); the national Association of Land Reclamation Boards (ANBI); the agencies responsible for energy supply (SPE); representatives from regional drought committees responsible for managing these emergencies at the local level; and, a representative from the autonomous province of Trento. The PRBA is responsible for notifying these stakeholders that a DSC has been convened, and inviting them to participate in the process and provide the latest technical synthesis reporting to describe current water resources through indicators, bulletins, reports, etc. This technical information is supported by hydrologic modelling data and technical information provided by ARPA-ER, and used to reach decisions on water reallocation via agreement or consensus.

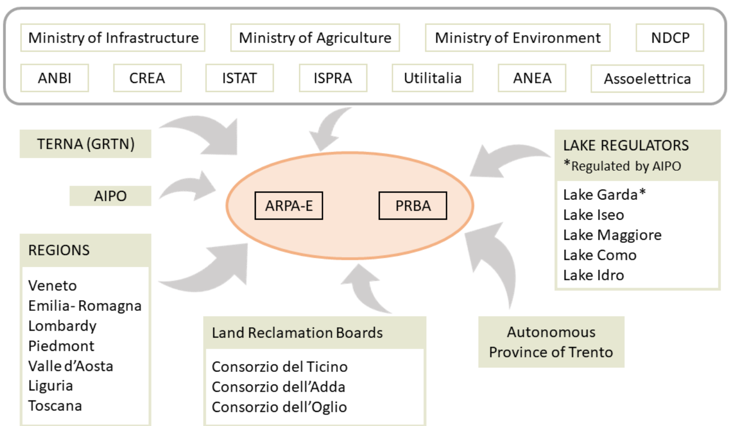

Figure 5. Participatory map of the Permanent Observatory (PO) of the PRB and stakeholders, 2016–ongoing.

From the interview process, it became clear that, when first implemented, the DSC was not trusted to deliver interventions on its own and needed the administrative support from one or more relevant authorities (i.e., the PRBA and other key institutional stakeholders). However, this is changing under new PO regulatory structures aimed at strengthening informal cooperation and dialogue between water governance organisations within each district to promote sustainable use of water resources in line with the EU-WFD. Nevertheless, these arrangements did not increase formal institutions. The PO is a voluntary and subsidiary structure supporting integrated water governance to manage the collection, update, and dissemination of data on the availability and use of water resources in the districts. Thus, the PO provides guidelines rather than prescriptive arrangements for the regulation of withdrawals, resource use, and possible compensation to users. During droughts, the PO interacts with the DSC to ensure common objectives that include an adequate flow of information that is necessary for the assessment of critical water scarcity levels, the evolution of that scarcity and current water withdrawals, and for implementing appropriate emergency actions to proactively manage the drought event. Therefore, public and private organizations at all levels of water governance can participate in the decision-making to achieve these common strategic objectives during a drought.

Thus, the arrangements identified for the PRB above offer a good example of informal water governance institutions for managing drought events, where we recall that: (i) the DSC is not legally recognized and stakeholders participate on a voluntary basis; (ii) there is no capacity for sanctions in the case of non-compliance with decisions made at the meetings; and, (iii) in cases of conflict, the DSC cannot be sued and/or prosecuted because of its informal status. Yet, the arrangements detailed above also have an increased potential to meet EU-WFD objectives over existing institutional approaches due to their integrated water resource management methods, coupled with processes aimed at avoiding political or legal interference (last-resort measures) during drought emergency response implementation. The DSC demonstrates capacity for coordinating actions on a voluntary basis and encompassing a wide range of stakeholder trust (democratic legitimacy), while achieving robust water governance institutions. Thus, the transition to informal institutional arrangements in support of successful adaptation to drought events appears to have achieved improved drought management outcomes, but at what cost?

4.2. Transaction Costs Measurement and Analysis

We must be able to observe some reduction in the average static transaction costs and that any periodic institutional transition costs associated with drought events must be short-lived (i.e., evidence of improved total outcomes) in order to test whether a transition to informal institutions with improved outcomes has been achieved at low(ered) costs over time. Our measurements of total DSC transaction costs for establishing, coordinating, and managing the DSC are summarised in Figure 6, while the share of ex ante and ex post transaction costs is shown in Figure 7—where a change in (ex-post) transaction costs for new institutions cannot take place without (ex-ante) transition costs in support of those changes. A more detailed breakdown of the individual ex ante and ex post transaction cost categories is available in Appendix A. The base-line for our cost-reduction analysis is the 2003 drought event, when the DSC officially came into existence.

The initial transaction costs were relatively significant in that year, consisting mainly of enactment and research/information gathering investments. Growth in total transaction costs was then experienced in response to three-consecutive drought events (2005–2007). This corresponded to investments in further information gathering, administrative costs for the DSC, and hydrological modelling to monitor water use across the relevant PRB sub-regions. Interview analysis revealed that a significant fraction of these costs that are involved identifying and agreeing upon common objectives for the DSC, consistent with informal network requirements and building trust between the stakeholders.

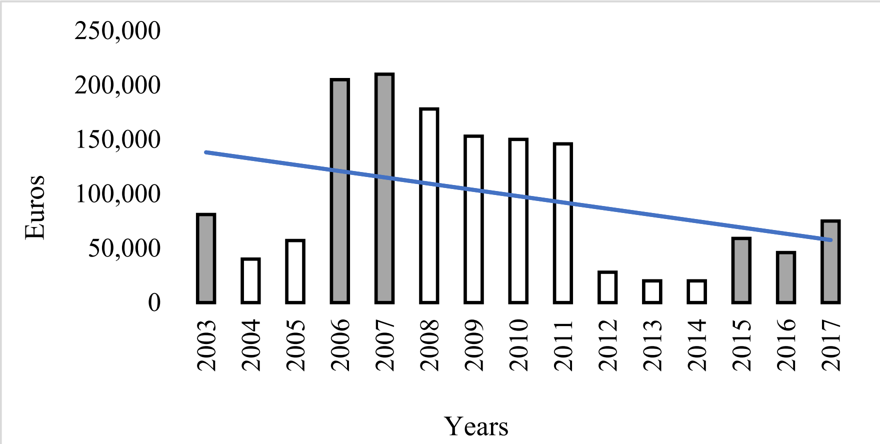

Figure 6. Total transaction costs for the DSC (years with droughts are in grey).

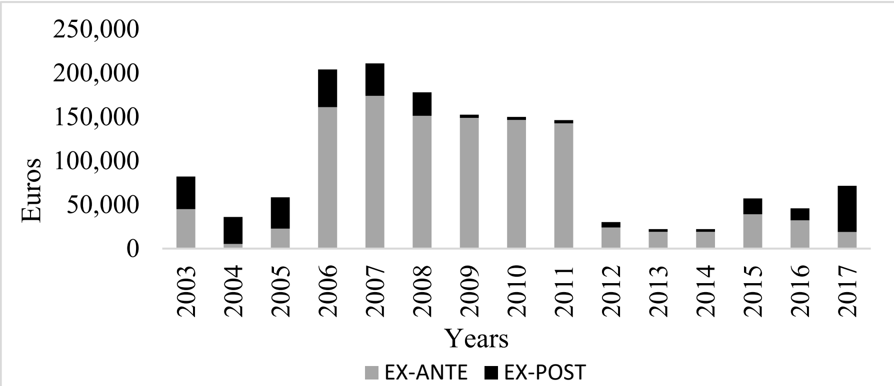

Figure 7. Ex-ante and Ex-post transaction for the DSC. Droughts in 2003, 2006, 2007, 2015, 2016, 2017.

Post-2007, no drought emergency events occur in the PRB. Investments in the hydrological modelling continued at high levels for a few years (2008–2011) until the contract with the external provider that supported the development of the model finished. After 2011, the DSC total transaction costs generally fell due to reduced hydrological modelling implementation costs and because extraordinary meetings were not needed; thus administration costs for routine management comprised the majority of required investment. However, in the period between 2015 to 2017 the PRB experienced a series of consecutive drought emergency events. This period also reflected a shift toward interaction with the PO arrangements, requiring some increased transaction costs. In response, the total transaction costs rose over that period due to increased administration and the enforcement of DSC requirements—but critically this increase is approximately one-third of the peak transaction costs of previous periods. Some of that lowering of transaction costs was due to an increased use of technology to support/conduct DSC meetings, as well as a lower degree of drought severity in the later events, relative to the period before 2010. Many of the meetings were now held at the PRBA while using media (Skype) lowering the requirement for travel and salary costs to attend meetings in person for many of the organisations, as well as the response and coordination times for managing drought emergencies.

With specific regard to individual transaction costs categories (Appendix A, Figure A1), the average static transaction costs decreased over the period considered, while short-lived institutional transition costs increases were observed during drought events (Figure 6). In total, the trend is downward, which suggests a lowering or minimisation of total costs across the life of the informal DSC governance arrangements.

According to Garrick [27], such trends indicate robust institutional outcomes—i.e., institutions that are capable of taking corrective action through "relatively less transaction cost-intensive autonomous and planned adaptation". For our purposes, the measurement of transaction costs enables a confirmation of positive transition costs to establish new institutions—as we should expect, and in support of H_1—but also that this new mode of organisation provides scope for productivity and efficiency gains for Italian water users.

5. Discussion

The results from our analysis of the collected data offers a novel contribution to the transaction cost literature by: (i) applying ex-ante and ex-post transaction cost measurement to informal water governance institutions, (ii) providing evidence in support of the usefulness of measuring transaction costs for evaluating institutional transition or substitution objectives, (iii) highlighting the relevance and value of historical context for economic investigations; and, (iv) showing how informal institutions may underpin water governance/management arrangements to lower total transaction costs related to drought management in an EU context. Beyond our support for the two main hypotheses, the results from the informal management of drought events at river basin scale determined the following key points.

5.1. Drought Management Arrangements

Drought requires a flexible management approach that is able to monitor the evolution of the event, to then respond within and across multiple governance levels (e.g., across multiple economizing orders in Williamsons' framework [13]). In comparison to formal arrangements that are available in Italy, the informal DSC approaches outlined above may be more flexible and adaptive with respect to drought management and adaptation (third-order economizing), which is also consistent with new EU water governance objectives. Shifting the management focus to a local level increases the appreciation of drought impacts, and provides for more appropriate responses in shorter timeframes than that of monocentric models, although such shifts may also lead to local capture of, and rent-seeking in, the policy process.

Positive effects of the DSC also arise from improved information transmission among stakeholders, and a tangible capacity to lower drought impacts and increase adaptive capacity. Further, monitoring the availability of water resources (inflows, reservoirs, outflows) and their adjustment in real time has allowed for the DSC to more quickly recognise and react to drought events via the use of short to medium term forecasting tools, drought indicators, and event evolution scenarios. These scenarios have also contributed to the construction of regional technical tools in support of managing water balances at the basin scale. Finally, the recent institutionalisation of DSCs and relevant stakeholder involvement across all (ordinary) periods of water management through the PO, rather than limiting their existence to drought periods, is an improvement upon the typically reactive (emergency) commencement of Italian management measures.

Without a measurement of the marginal centralised transaction costs in contrast to counterfactual institutional arrangements, we cannot draw any formal conclusions regarding the value for money or total transaction cost differentials. However, the PRB DSC arrangements have now been extended across each of the seven River Basin Districts (RBDs) in Italy, formally established in May 2017. According to interviewed stakeholders, the DSC arrangements were attractive to the Italian government because they did not require any additional funding to implement (i.e., lower transition costs), while avoiding some negative impacts of drought events (i.e., improved management outcomes). Thus, it seems logical to conclude that the political value of these transaction costs and their institutional outcomes has been recognised. By favouring an informal institution, like the DSC, the Italian government could potentially observe an increase in the effectiveness of water governance arrangements, although it will require further evidence over time to support this conclusively. This will be the focus of a future research project involving hydro-economic modelling of costs and benefits.

5.2. Transaction Costs and Policy Performance Analysis

Our findings are relevant for policy makers and other stakeholders beyond the PRB. Here, the measurement and analysis of transaction costs undertaken paves the way toward performance assessment of similar initiatives based on informal voluntary partnerships for water management in Italy and Europe. These include incipient river contracts, forums for dialogue and knowledge sharing between public/private stakeholders, and local communities in compliance with the EU's subsidiarity principle, which are gaining momentum in Italy and elsewhere in Europe [53]. A constraint to any application of the findings reported here may arise from the non-conjunctive catchment characteristics of the PRB; that is, they do not share water resources with other basins. This is often not the case for the other river basin contexts in Italy or elsewhere in Europe, for whom the issues may be more challenging as a consequence, and involve higher transaction costs.

Moreover, comparisons of the cost-effectiveness of alternative policy options to enhance flow rates during droughts must account for the total costs of the options relative to a baseline or status-quo scenario. These include the transaction costs of the reform measures, along with any abatement costs incurred by economic agents during the implementation of local adaptation strategies. Recent research focusing on the analysis of abatement costs in the PRB shows that the proportional rule used to reallocate water under the DSC approach—which relinquishes a fixed percentage of the initial allocation from users, irrespective of the economic losses involved—underperforms other formal drought management arrangements, such as water charges [54]. This gap will be further amplified via forward and backward linkages among economic sectors within the PRB, and with other Italian regions outside the basin. Thus, a complete policy performance assessment calls for empirical analyses that combine transaction and abatement costs estimates [55]. This too will be incorporated into future research work in the area.

5.3. Transaction Costs and Uncertainty Analysis

Finally, water resource management is performed in a context of Knightian or deep uncertainty, where it is often not feasible to identify all of the possible outcomes and/or assign a probability to each identified possible outcome [56]. Under deep uncertainty, rather than optimal institutional settings, we should aim for robustness through the avoidance of path dependent institutional trajectories to enable future adaptation in the face of unpredictable future events that are explainable only after they happen. This requires adaptive institutional frameworks [27].

As indicated above, our transaction cost measurement framework can provide initial information on the robustness/adaptive ability of PRB institutional arrangements. However, conclusions regarding the robustness of these arrangements in response to future uncertainty would need to consider additional measures of adaptive efficiency according to Garrick [27]. For completeness, these measures would also have to include the lock-in cost impacts of institutional options to allow for a cost-effectiveness evaluation [14]. Similar to the work undertaken by Loch and Gregg [49], this would entail identifying and measuring three performance indicators over space and time: (1) how well the drought management objective(s) have been met; (2) the average transaction costs per unit of those met objective(s); and, (3) total program budgets. For adaptively efficient and robust institutions, these three performance indicators should be increasing, decreasing and sufficient respectively. Measures of these indicators are beyond the scope of this pilot study, but remain an objective for a wider research program focused on identifying instruments best-suited to achieving water policy and management targets. The wider research focus of this work will examine maximised benefits per unit of transaction cost (alternative measure of cost effectiveness), as well as maximising the net public/private gains from transaction cost expenditure (social welfare). This broader assessment framework should enable a more comprehensive assessment of total policy or program benefit-cost outcomes.

Finally, future climate change and economic dynamics may change the outcomes that are reported in this study. Further research will be necessary to determine under what conditions this may happen, and any requirement to adjust or change policy accordingly [57].

6. Conclusions

Transaction costs matter for effective organisation and institutional management of scarce and costly resources, such as water. During times of drought, formal institutions may provide costly and inflexible management arrangements that may increase the total transaction cost requirements. This paper explores the transaction costs that are associated with a historical transition toward informal drought management arrangements in the PRB of northern Italy. We test two hypotheses related to the value of transaction cost analysis in support of institutional transition/substitution choices, and the value of historical context to economic investigations. By measuring and tracking transaction costs with respect to drought periods in the basin we explore the total costs associated with a new institutional approach, and note that the DSC arrangements have been mandatorily adopted by the six other River Basin Districts in Italy—somewhat ironically, as this has formalised what was originally an informal process. It remains to be seen whether the formalisation of drought management arrangements based on the PRB DSC will ultimately increase total transaction costs, or further reduce the total transaction costs of drought management in Italy by following a participatory, consensus-based approach elsewhere. However, it is impossible to draw more robust conclusions without a more detailed study of centralised costs. That said, in contrast to standard approaches where a complete set of empirics might be provided, some may find our approach here less satisfying. However, we would argue that value is provided by the thought and measurement processes that have gone into the study, rather than arriving at any 'number'. The process of empirically identifying, measuring, and assessing transaction costs is in its infancy; but remains a critical means by which adaptive effectiveness and efficiency for future institutional choices will potentially be explored, as we have done in this case. While our empirics may not be complete they do provide a valid contribution where—as we have pointed out—it is our intention to explore additional means by which we can get at a final set of 'numbers' in support of the full costs and benefits. Like all good research, it is a process, and one that we are interested to continue following. Overall, though, our study highlights the usefulness of transaction cost case studies, and the need for extensions to this approach that incorporate not only transaction and abatement cost minimisation evaluations, but also assessments of per unit private/public welfare benefits that accrue from policy and programs, such that more comprehensive evaluations and uncertainty analyses may be achieved in the future. We believe this to be a rich area of future research that may require the incorporation of climate, hydrological, and economic modelling assessments to be successful.

Author Contributions: Conceptualization, S.S., A.L., and C.D.P.-B.; methodology, A.L., S.S.; validation, S.S.; formal analysis, S.S., A.L., C.D.P.-B.; investigation, S.S.; resources, S.S., J.M.; data curation, S.S.; writing—original draft preparation, A.L., S.S., C.D.P.-B.; writing—review and editing, A.L., C.D.P.-B., S.S.; visualization, J.M.; supervision, A.L., C.D.P.-B., J.M.; project administration, J.M.; funding acquisition, J.M., A.L., C.D.P.-B. All authors have read and agreed to the published version of the manuscript.

Funding: Adam Loch's involvement in this research was funded under an Australian Research Council DECRA grant (DE150100328) and the 2015-16 UNESCO Grants Program. Carlos Dionisio Pérez-Blanco's involvement in this research was supported by the Program for the Attraction of Scientific Talent's SWAN (Sustainable Watersheds: Emerging Economic Instruments for Water and Food Security) Project, and by the Ministerio para la Transición Ecológica y el Reto Demográfico, through Fundación Biodiversidad (ATACC Project—Adaptación Transformativa al Cambio Climático en el Regadío).

Acknowledgments: The authors are thankful to Graham Marshall and David Adamson for useful comments and advice on earlier drafts of the paper, and to the experts from the Po River Basin Authority and the Environment Agency of Emilia-Romagna for their valuable support in this research. The authors thank Mattia Amadio for drawing Figure 1c.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

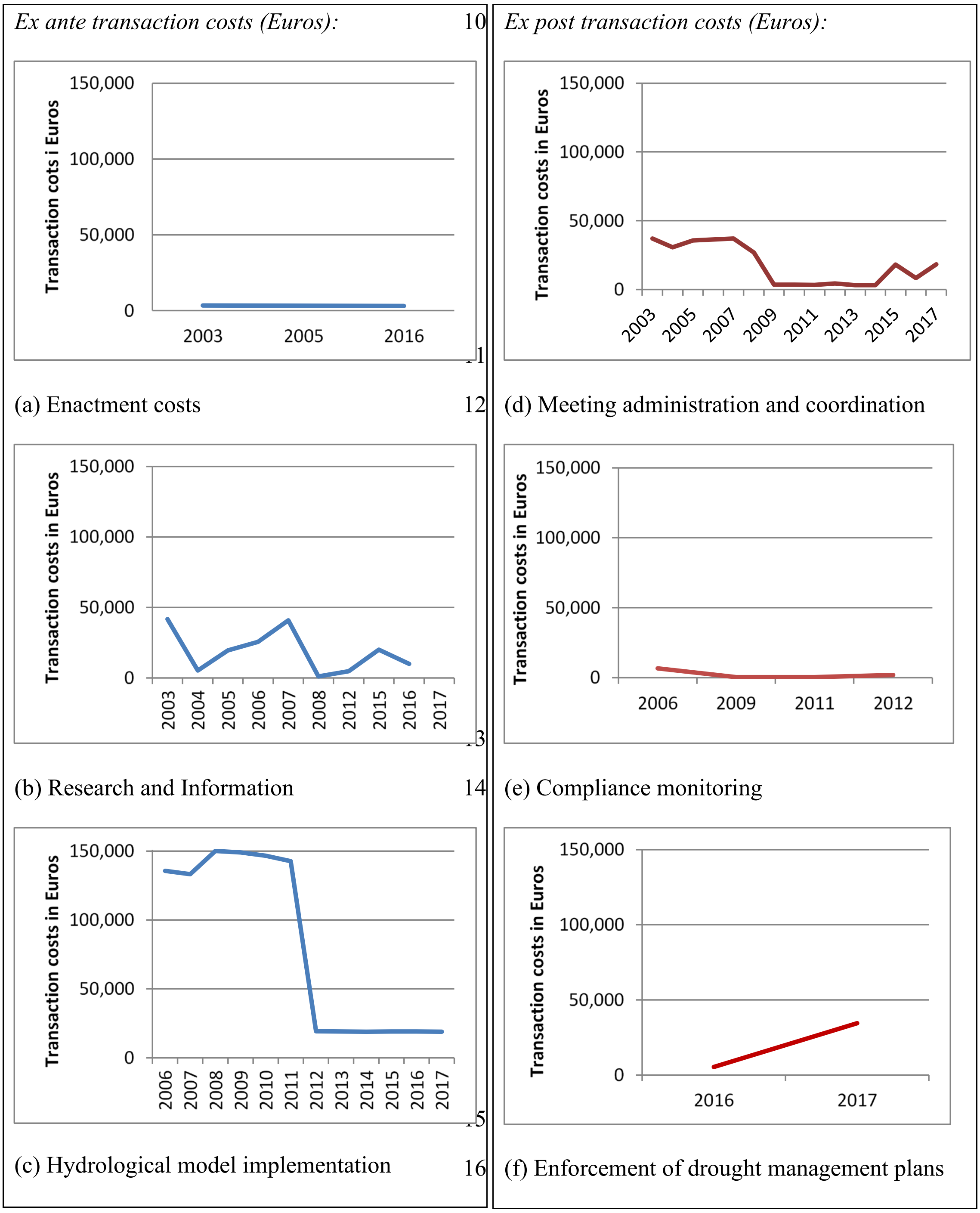

Figure A1. Measures of DSC individual ex ante/ex post transaction cost categories over time.

References

1. Pachauri, R.K.; Allen, M.R.; Barros, V.R.; Broome, J.; Cramer, W.; Christ, R.; Church, J.A.; Clarke, L.; Dahe, Q.; Dasgupta, P.; et al. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; IPPC: Geneva, Switzerland, 2014.
2. OECD. *Water Resources Allocation: Sharing Risks and Opportunities*; OECD Publishing: Paris, France, 2015.
3. World Bank. *High and Dry: Climate Change, Water, and the Economy*; Water Global Practice; World Bank: Washington, WA, USA, 2016.
4. North, D.C. *Institutions, Institutional Change, and Economic Performance*; Cambridge University Press: Cambridge, UK, 1990.

5. Williamson, C.R.; Kerekes, C.B. Securing Private Property: Formal versus Informal Institutions. *J. Law Econ.* **2011**, *54*, 537–572.
6. World Bank. *The Social Dimensions of Climate Change*; World Bank: Washington, WA, USA, 2009; doi:10.1596/978-0-8213-7887-8.
7. Coase, R. *The Firm, the Market, and the Law*; University of Chicago Press: Chicago, IL, USA, 1990.
8. Catlin, G.E.G.; Robbins, L. An Essay on the Nature and Significance of Economic Science. *Polit. Sci. Q.* **1933**, *48*, 463.
9. Pagano, U.; Vatiero, M. Costly institutions as substitutes: Novelty and limits of the Coasian approach. *J. Inst. Econ.* **2014**, *11*, 265–281, doi:10.1017/s1744137414000198.
10. Ostrom, E. A General Framework for Analyzing Sustainability of Social-Ecological Systems. *Science* **2009**, *325*, 419–423.
11. Coase, R.H. The Problem of Social Cost. *J. Law Econ.* **1960**, *3*, 1–44.
12. Coase, R.H. The Nature of the Firm. *Economica* **1937**, *4*, 386–405, doi:10.1111/j.1468-0335.1937.tb00002.x.
13. Williamson, O.E. The New Institutional Economics: Taking Stock, Looking Ahead. *J. Econ. Lit.* **2000**, *38*, 595–613.
14. Marshall, G.R. Transaction costs, collective action and adaptation in managing complex social–ecological systems. *Ecol. Econ.* **2013**, *88*, 185–194, doi:10.1016/j.ecolecon.2012.12.030.
15. Krutilla, K. Transaction Costs and Environmental Policy: An Assessment Framework and Literature Review. *Int. Rev. Environ. Resour. Econ.* **2011**, *4*, 261–354.
16. McCann, L. Transaction costs and environmental policy design. *Ecol. Econ.* **2013**, *88*, 253–262.
17. Garrick, D.E.; Aylward, B. Transaction Costs and Institutional Performance in Market-Based Environmental Water Allocation. *Land Econ.* **2012**, *88*, 536–560.
18. McCann, L.; Easter, K.W. A framework for estimating the transaction costs of alternative mechanisms for water exchange and allocation. *Water Resour. Res.* **2004**, *40*, 1–6, doi:10.1029/2003WR002830.
19. Landry, R.; Amara, N. The impact of transaction costs on the institutional structuration of collaborative academic research. *Res. Policy* **1998**, *27*, 901–913.
20. Hernández-Mora, N.; De Stefano, L. *Los Mercados informales de Aguas en España: Una Primera Aproximación. In Usos Del Agua: Concesiones, Autorizaciones y Mercados Del Agua*; Thomson Reuters Aranzadi: Cizur Menor, Spain, 2013.
21. Santato, S.; Mysiak, J.; Pérez-Blanco, C. The Water Abstraction License Regime in Italy: A Case for Reform? *Water* **2016**, *8*, 103, doi:10.3390/w8030103.
22. Mobarak, A.; Mushfiq, A.; Rosenzweig, M.R. Informal Risk Sharing, Index Insurance, and Risk Taking in Developing Countries. *Am. Econ. Rev.* **2013**, *103*, 375–380.
23. Sobels, J.; Curtis, A.; Lockie, S. The role of Landcare group networks in rural Australia: Exploring the contribution of social capital. *J. Rural Stud*. **2001**, *17*, 265–276.
24. Quiggin, J. *Economics in Two Lessons*; Princeton University Press: Princeton, NJ, USA, 2019.
25. Werner, R. Measuring Transaction Costs. *AIMR Conf. Proc.* **2001**, *2001*, 37–44, doi:10.2469/cp.v2001.n2.3079.
26. Bris, A.; Welch, I.; Zhu, N. The costs of bankruptcy. *J. Financ. Forthcom.* **2004**, 4–13, doi:10.1353/hcr.2006.0040.
27. Garrick, D. *Water Allocation in Rivers under Pressure*; Edward Elgar Publishing: Cheltenham, UK, 2015.
28. Hanna, S. Efficiencies of user participation in natural resource management. In *Property Rights and the Environment: Social and Ecological Issues*; The World Bank: Washington, WA, USA, 1995; pp. 59–67.
29. Marshall, G.R.; Alexandra, J. Institutional path dependence and environmental water recovery in Australia's Murray-Darling Basin. *Water Altern*. **2016**, *9*, 679–703.
30. McCann, L.; Colby, B.; Easter, K.W.; Kasterine, A.; Kuperan, K.V. Transaction cost measurement for evaluating environmental policies. *Ecol. Econ*. **2005**, *52*, 527–542.
31. Amadio, M.; Mysiak, J.; Carrera, L.; Koks, E. Improving flood damage assessment models in Italy. *Nat. Hazards* **2016**, *82*, 2075–2088, doi:10.1007/s11069-016-2286-0.
32. ADBPO. *Caratteristiche Del Bacino Del Fiume Po E Primo Esame Dell'impatto Ambientale Delle Attività Umane Sulle Risorse Idriche*; Autorità di Bacino del Fiume Po: Parma, Italy, 2006.
33. Vezzoli, R.; Mercogliano, P.; Castellari, S. Scenari di cambiamenti climatici nel periodo 2021-2050 : Quale disponibilità idrica nel bacino del fiume Po ? *Ing. dell'Ambiente* **2016**, *3*, 44–52.

34. Zollo, A.L.; Rillo, V.; Bucchignani, E.; Montesarchio, M.; Mercogliano, P. Extreme temperature and precipitation events over Italy: Assessment of high-resolution simulations with COSMO-CLM and future scenarios. *Int. J. Clim.* **2015**, *36*, 987–1004.
35. Guerreiro, S.B.; Dawson, R.; Kilsby, C.G.; Lewis, E.; Ford, A. Future heat-waves, droughts and floods in 571 European cities. *Environ. Res. Lett.* **2018**, *13*, 034009.
36. Baffo, F.; Gaudioso, D.; Giordano, F.L. *Adattamento ai Cambiamenti Climatici: Strategie e Piani in Europa*; ISPRA: Rome, Italy, 2009.
37. Tibaldi, S.; Cacciamani, C.; Pecora, S. Il Po Nel Clima Che Cambia. *Biol. Ambient.* **2010**, *24*, 21–28.
38. MATTM. *Piano Nazionale di Adattamento ai Cambiamenti Climatici PNACC*; Prima stesura per la consultazione pubblica; MATTM: Rome, Italy, 2017.
39. MATTM. *Strategia Nazionale di Adattamento ai Cambiamenti Climatici Indice (National Strategy of Adaptation to Climate Change)*; MATTM: Rome, Italy, 2014.
40. EC. *Drought Management Plan Report*; Office for Official Publications of the European Communities: Luxembourg, 2007.
41. Pérez-Blanco, C.D.; Gomez, C.M. Insuring water: A practical risk management option in water-scarce and drought-prone regions? *Hydrol. Res.* **2013**, *16*, 244–263, doi:10.2166/wp.2013.131.
42. OECD. *OECD Environmental Performance Reviews: Italy*; OECD Publishing: Paris, France, 2013.
43. Gómez, C.M.G.; Pérez-Blanco, C.D.; Adamson, D.; Loch, A. Managing Water Scarcity at a River Basin Scale with Economic Instruments. *Water Econ. Policy* **2018**, *4*, 1750004, doi:10.1142/s2382624x17500047.
44. GU. *Legge 5 Gennaio, N. 36 Disposizioni in Materia Di Risorse Idriche*; Gazzetta Ufficiale: Rome, Italy, 1994.
45. EC. *Water Framework Directive 2000/60/EC*; Office for Official Publications of the European Communities: Luxembourg, 2000.
46. EC. *Addressing the Challenge of Water Scarcity and Droughts in the European Union*; Office for Official Publications of the European Communities: Luxembourg, 2007.
47. ADBPO. *Piano Stralcio del Bilancio Idrico del distretto Idrografico Padano*; Piano per La Gestione Delle Siccità E Direttiva Magre; ADBPO: Parma, Italy, 2016; Volume Allegato 3.
48. Thompson, D.B. Beyond Benefit-Cost Analysis: Institutional transaction costs and regulation of water quality. *Nat. Resour. J.* **1999**, *1*, 517–541.
49. Loch, A.; Gregg, D. Salinity Management in the Murray-Darling Basin: A Transaction Cost Study. *Water Resour. Res.* **2018**, *54*, 8813–8827.
50. McCann, L.; Easter, K.W. Evaluating transaction costs of nonpoint source pollution policies. *Land Econ.* **1999**, *75*, 402–414.
51. Ofei-Mensah, A.; Bennett, J. Transaction costs of alternative greenhouse gas policies in the Australian transport energy sector. *Ecol. Econ.* **2013**, *88*, 214–221, doi:10.1016/j.ecolecon.2012.12.009.
52. World Bank World Bank DataBank. Available online: https://databank.worldbank.org/databases/exchange-rates (accessed on 28 June 2020).
53. Scaduto, M.L. *River Contracts and Integrated Water Management in Europe*; Springer International Publishing: Berlin, Germany, 2016.
54. Pérez-Blanco, C.D.; Koks, E.E.; Calliari, E.; Mysiak, J. Economic Impacts of Irrigation-Constrained Agriculture in the Lower Po Basin. *Water Econ. Policy* **2018**, *4*, 1750003.
55. Pérez-Blanco, C.D.; Standardi, G.; Mysiak, J.; Parrado, R.; Gutiérrez-Martín, C. Incremental water charging in agriculture. A case study of the Regione Emilia Romagna in Italy. *Environ. Model. Softw.* **2016**, *78*, 202–215.
56. Walker, W.; Harremoes, P.; Rotmans, J.; Van Der Sluijs, J.P.; Van Asselt, M.; Janssen, P.; Von Krauss, M.K. Defining Uncertainty: A Conceptual Basis for Uncertainty Management in Model-Based Decision Support. *Integr. Assess.* **2003**, *4*, 5–17, doi:10.1076/iaij.4.1.5.16466.
57. Kandlikar, M.; Risbey, J.S.; Dessai, S. Representing and communicating deep uncertainty in climate-change assessments. *C. R. Geosci.* **2005**, *337*, 443–455.