CHILEAN WATER REGULATION AND SUSTAINABILITY OF THE COMMON-POOL RESOURCE: PROPOSALS FOR INSTITUTIONAL CHANGE

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Abstract

Water has been historically a central object of conflict, due to its nature as a common good and its status as a scarce resource indispensable for life. Conventional economic theory teaches that the pooling of finite resources by heterogeneous actors with selfish interests leads to the possible exhaustion of these resources, leading to the classic "tragedy of the commons", where the only solution to this situation is to privatize the resource, or leave it in hands of state regulation. However, Elinor Ostrom - first woman to receive a Nobel Prize in economics - shows a much wider field of action, moving away from this dichotomy that provides inefficient solutions. Through Ostrom's contributions, an analysis is made of Chilean water regulations, where it is concluded that it is not a sustainable model over time. Based on this result and Ostrom's findings, recommendations are given on how institutional change in the area of common-pool resources should be addressed.

Keywords: Common-pool resources, Design Principles, Collective Action, Tragedy of the Commons, Governance, Polycentricity.

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1. Introduction

The economy and the satisfaction of human needs rest directly on the balance of natural and environmental resources (Daily, 1997; Figueroa, 2015); moreover, global projections show that material and energy consumption of the world economy continues to grow, due to the constant increase of population (Krausmann et al., 2009). Thus, the current panorama of unprecedented environmental crisis (Bravo, 2013), and the constant increases in material and energy requirements, coupled with the enormous degradation of ecosystems (Gaudiano, 2007), will define the future of humanity and, therefore, of economic growth (IPCC, 2021).

Natural resources can be classiflied as "Common-Pool Resources" (CPR's). Following the definition of Elinor Ostrom (1994) - first woman to receive the Nobel Prize in Economics - "CPR's are natural (or human-made facilities) that generate flows of usable resource units over time". On the other hand, CPR's share two important characteristics: (1) it is costly to exclude potential beneficiaries from them, and (2) the resource units used (harvested, consumed, enjoyed) by one individual are not available to others (Ostrom, 1994). Due to these two characteristics and under the neoclassical assumption of short-run utility maximizing agents, conventional economic theory teaches that CPR's are destined to be depleted, leading to a sub-optimal social equilibrium (Hardin, 1968; Dawes, 1974; Olson, 1965). A well-known illustration of the latter is the "Tragedy of the Commons" described by Garret Hardin (1968).

In fact, in his classic example, Hardin (1968) explains what happens with a pasture or common grazing land, to which anyone can bring their animals to graze. As everyone wants to make as much profit as possible, they will increase their number of animals on the pasture, until inevitably, the resource is exhausted, and thus, all individuals who had access to the pasture are trapped in a socially sub-optimal equilibrium, because the resource is depleted.

Ostrom (1990, 1994, 2005, 2010) showed that the conventional approach in economics to the study of common resource management was incomplete. The conventional approach assumes that when people share a resource, such as groundwater, fish or a forest, everyone acts in their own self-interest, leading to overexploitation of the common-pool resource. Thus, according to the prevailing literature up to that time, the only two ways to avoiding this were to establish private property rights or regulation of the resource through government intervention, on the other hand.

In a series of studies conducted over several decades, Ostrom showed that people in communities are able to self-organize and successfully manage shared resources. Moreover, she derived and proposed the conditions under which a common resource management system is sustainable over time, independent of its organizational form. These findings improved the understanding of the economics of common-pool resources, and helped to explaining the ineffectiveness of many failed governance policies and regimes that intended to avoid the abundant tragedies of the commons occurred in all latitudes of the globe. Ostrom's findings have also helped to improve the public policies for common-pool resources in the last decades.

On the other hand, Chile has become a leading example in the world for its free market approach to water laws and water resources management, due to its treatment of water rights not only as private property but as a fully tradable good. While other countries have also recognized different variants of private water rights, no other country has done so as unconditionally and non-regulated as Chile does (Bauer, 2004).

Water management in Chile includes many problem areas in different critical management issues, such as social equity, environmental protection, watershed management and conflict resolution (Guerrero et. al., 2018). These issues are at the core of current debates in Chile and internationally,

and they also constitute big global concerns regarding water policy and water management. Social problems related to the exclusion of people in some geographic areas arise because private initiatives of mining, agriculture, electricity, and water companies are too profit seeking-oriented and do not appropriately take into consideration the human needs to water provision and access (Hervé, 2010). The private nature of water means that the state has neither the capacity nor the obligation to care for the common good, and conflicts of ownership or use have to be resolved through the market.

An example of this is what happens in Petorca, La Ligua and Cabildo [1], where private companies have priority in the use of water for their crops over the inhabitants. Mega-drought conditions, combined with intensive agricultural activities and the current water management system, have led to water scarcity problems (Muñoz, et al. 2020). In fact, watersheds in these areas are overexploited, but there is not a strong enough institutional framework to restrict water use (Bolados, 2018; Guerrero and Fragkou, 2021).

The current Chilean legal and institutional framework has proven incapable of addressing these problems (León, 2019; Guerrero, 2021), and therefore, in the face of increasing demand and competition for water, it could only worsen the current situation, making urgent to reformulate the model. This thesis first analyses the current Chilean water regulatory framework: The Water Code. This institutional framework is analyzed to determine its compatibility with Ostrom's Design Principles (DP's) of sustainable governance of common-pool resources. The hypothesis of the thesis is that based on these DP's, it is possible to conclude that the current Chilean Water Code is not sustainable over time.

The findings of this thesis support the tested hypothesis, where it is possible to conclude that the

[1] These are three communes in the Fifth Region of Valparaíso, located between 32º 02' and 33º 57' south latitude and between meridians 70º and 72º, and therefore corresponding to the so called Central Zone of the country.

Chilean institutional framework is unsustainable in the long term. In addition, using the methodology of Sirak Gari et al., (2018), it is possible to characterize Chile's Water Code as fragile/weak.

Based on the conclusions obtained from this analysis, public policy recommendations for water management are provided. Although the research so far has been based on the behavior of communities, and the respective compliance with the DP's [2] - in contrast to this study which analyses the institutional framework - this thesis aims to provide guidance on how Ostrom's evidence can be a basis for a good reform.

The thesis is structured as follows: first, the relevant literature on collective management and common-pool resources is reviewed and the Chilean case of water management is presented. Second, the research methodology is described, followed by a presentation of the main results. Finally, policy recommendations are given based on Ostrom's findings.

2. Literature review

Common-pool resources (CPR's) share two important characteristics: (1) Rivalry, which means that when they are used, the chances of their consumption by others disappear or decrease; and, (2) Non-exclusion, which implies that it is not possible, or too costly, to exclude people from consuming the resource. Examples of resources with this characteristic are fisheries, forests, water, air, etc.

However, due to these characteristics, CPR's face problems of depletion due to over-exploitation or over-utilization, since no one can be excluded from its consumption. On the other hand, under assumption of individuals maximizing their utility in the short run - as neoclassical theory teaches - individuals motivated only by personal interests, and acting independently and rationally, end up

[2] See for example Cox et al. (2010); Gari et al. (2018)

depleting the resource, causing a negative externality on other users by reducing their consumption possibilities, and even exhausting it.

Following this, conventional economic theory teaches that CPR's are destined to be depleted, leading to the "tragedy of the commons", described by Hardin (1968), in which individuals end up destroying a limited common resource even though it is not in the interest of them, either individually or collectively, for such destruction to occur, leading to a sub-optimal social equilibrium.

When comparing the situation of CPR's versus a hypothetical situation of competitive markets operating according to the neoclassical model paradigm, it is concluded that the cause of the problem is that property rights are not well defined, i.e. when, for example, a person cuts down a tree, they do not take into account all the negative consequences of that action because they do not own the forest [3] . The theory then concludes that the solution is to have well-defined property rights [4] , or for the state to regulate logging [5] .

Where well-defined property rights exist, the resource owner(s) will exploit (harvest) the resource at the socially optimal rate. The existence of well-defined property rights usually implies privatization of the previously CPR, or government expropriation of the resource. However, these solutions are not free of problems.

In the case of privatization, the solution leads to one or a few people owning resources that were

[3] If it were, and property rights are well defined, it would log trees only until the marginal benefit and marginal cost of felling a new tree equalise, thus ensuring that it is getting the greatest value from the use of the forest. In contrast, when exclusion is not possible, loggers will log until the total benefits and total costs of logging equalise, whereupon the rent generated by logging is dissipated and the economic surplus generated by logging, which is equal to the sum of the consumer surplus and the producer surplus, becomes zero.

[4] In this case, the resource owner will log until the marginal benefit of logging equals the marginal cost of logging, thus maximising the economic value of their forest.

[5] In this case the state will determine that logging can be done only up to the tree for which the marginal cost of logging is equal to the marginal benefit of logging, or it will impose taxes until this equality exists.

previously in common use which affects democracy because it is perceived as unfair among individuals and therefore generates social conflicts (Bauer, 2004). On the other hand, not all resources that comprise the ecosystem are generally privatizable, e.g. air.

At the same time, the governmental solution has information and incentive problems. Central governments lack of complete and symmetrical information available to the inhabitants where the CPR is located, and are unaware of the characteristics and problems generated by the use of local resources in contrast to the communities that are fully aware of this information. In addition, any bureaucratic structure faces its own incentive and information problems, which are not limited to the management of CPR's, but are not absent in this case either (Ruiz, 2002). For these reasons, the institutions that governments design will be inefficient because important analyses are omitted.

In this context, where neither of the two solutions provided by conventional economic theory is optimal, the question arises as to whether the Water Code - which leaves the water resource in hands of the market - is a sustainable institutional framework over time. On the other hand, if the Water Code does not promote the sustainable use of resources, the question arises as to where policy makers should focus on in order to achieve a robust long-term institutional framework.

Until the 1980s, studies of CPR's were based on the assumption that the users of these resources could not self-organise to manage them; therefore, solutions to avoid depletion were based on the imposition of government or private ownership. Much of the pessimism about the practical viability of collective management in the use of CPR's stems from the conclusions of the major theories of collective action. One of these is "The Tragedy of the Commons" (Hardin, 1968). The second theory, the "Prisoner's Dilemma" model (Dawes 1973, 1975), presents a non-cooperative game situation, where prisoners are left in a sub-optimal equilibrium because they do not cooperate

with each other [6] . Finally, the third theory is the "Logic of Collective Action" (Olson, 1965) which explains that people have little incentive to cooperate for the common good. A summary of these theories is shown in Table 1:

Table 1: Theories of Collective Action

Theory	Author	Conclusions
Tragedy of the Commons	Hardin (1968)	It inevitably leads to overexploitation of the common resource.
Prisoner's Dilemma	Dawes (1974)	Non-Cooperative game. Both individuals are stuck in a suboptimal equilibrium.
Logic of Collective Action	Olson (1965)	Without coercion, there is no incentive to achieve collective action.

Contrary to what was thought years ago, even in difficult situations of restricting consumption, absolute resource depletion is not always found. This happens when communities that have adequate rules and norms for the proper governance of the CPR are able to self-manage it without the need for state intervention or without privatizing the resource (Ostrom 1990, 1994, 2005).

Elinor Ostrom was the first woman to win a Nobel Prize in Economics because of her pioneering contributions on CPR's. Ostrom (1990) discovered that there are communities that manage CPR's efficiently, contrary to what economic theory had said so far. This possibility has numerous examples of reasonably successful management.

For instance, the interaction of the same group of individuals over time is the key to success. This permanence over time of the same group can generate incentives for all its members to moderate their use of the common resource. Indeed, each of them realizes that, if they overexploit the common resource today, they may cause the other individuals in the group to over exploit the resource

[6]This theory formalises the non-cooperative game that also occurs in the "Tragedy of the Commons"

in the future.

Ostrom's proposal moved from the challenges of the "tragedy of the commons" to the "dilemma of the collective". In the latter case, the challenge is now to determine what conditions are required for the collective management of a common resource to exist.

It is important to highlight that in this context, the neoclassical assumption of the rational economic agent that maximizes their individual utility as a function of their income - $U(y_i)$ - is broader and more complete than previously thought, i.e. new objectives are added to their utility function, where one of them is a social distance function (d), where individual i does not want to move away from the average consumption of the community: $\bar{x}$. This paradigm shift can be seen in the following formulation:

$$\text{Common Resources} = \begin{cases} \text{Tragedy of the Commons (Hardin, 1968)}, & \text{Max} \quad U(y_i) \\ \text{Dilemma of the Collective (Ostrom, 1990)}, & \text{Max} \quad U = d|\bar{x} - x_i| \end{cases}$$

With Ostrom's contributions, the assumption of the rational economic agent in economics became more complex and moved to an approach in which people are motivated not only by their own self-interest, but also by the reciprocity they can obtain by belonging to a community, by the rules of justice and by values such as altruism and empathy, changing many economic conclusions related to CPR's and collective action.

Moreover, Ostrom (1990) analyzed the behavior of these communities and came up with a set of eight general Design Principles (DP's) that characterized the effectiveness of the rules imposed on these communities. The DP's derived from the studies on commons governance systems are shown in Table 2. On the other hand, these principles are the basis for any governance regime for

the CPR's to be sustainable over time, regardless of its form of management [7]. Nevertheless, it is much easier to find these DP's in self-managed communities.

Table 2: Design Principles (DP's) by Ostrom (1990)

1. Clearly defined boundaries	The boundaries of the resource system and the individuals or households with rights to harvest resource units are clearly defined.
2. Proportional equivalence between benefits and costs	The rules specifying the quantity of the resource assigned to a user are related to local conditions.
3. Collective choice agreements	Many of the individuals affected by the rules of exploitation and protection are included in the group of actors who can change these rules.
4. Monitoring	Actively monitor the biophysical conditions and behaviour of users.
5. Graduated sanctions	Users who violate the rules are subject to penalties.
6. Conflict resolution mechanisms	Users and their staff have quick access to low-cost local action scenarios to resolve conflicts between users.
7. Minimum recognition of organising rights	The rights of users to design their own institutions are not challenged by government authorities.
8. Nested bodies (for resources that are part of larger systems)	Ownership, provision, monitoring, enforcement, conflict resolution and governance activities are organised in multiple layers of nested bodies (the entire system is integrated).

Communally managed forms of exploitation can provide mechanisms of self-governance that ensure equity of access, radically democratic control, while providing protection, and vitality to the common-pool resource. Thus, in the face of the possibility of overexploitation, Ostrom's option is to *"increase the capacities of participants to change the coercive rules of the game in order to achieve outcomes other than ruthless tragedies"* (Ostrom, 1990).

[7] Whether privately owned, state-owned or collectively managed.

Institutional Design Principles follow Douglass North's (1990) conception of institutions as mechanisms for reducing uncertainty in complex and uncertain environments. As uncertainty is reduced, trust and norms of reciprocity can be built and maintained, and collective action can be achieved (Cox et al., 2010). In this context, the central role of DP's is to understand under what circumstances it is possible to build and maintain trust and reciprocity to sustain a governance model of CPR's.

In order to analyze the compatibility of the Chilean Water Code with the DP's, the methodology of Gari et al. (2018) is employed, where the management of CPRs is analyzed in more than 54 cases worldwide. From this analysis it will be possible to distinguish what the final outcome of the Water Code is in terms of sustainability over time.

On the other hand, Michael Cox et al. (2010) developed an analysis of approximately 100 case providing the evidence that the DP's hold true even when tested against the data. The authors show in their work that some principles can be divided into sub-sections in order to better analyze their presence [8], where they divided DP 1 into their component parts: user boundaries and resource boundaries and DP 2 into congruence with local conditions and appropriation and provision. Authors also divided DP 4 (monitoring) into two components: users monitoring one another's behavior (social monitoring) and users monitoring the condition of the resource (environmental monitoring). Each of these subcategories was often important in determining the success of the natural resource management and were then included in Ostrom (2010).

2.1. The case of Water in Chile

In 1973, a military coup took place in Chile and during the dictatorship, the Chilean Constitution of 1980 was established, which currently still governs the country. The Constitution was designed

[8] The principles that can be reformulated are 1, 2, and 4.

under neoliberal guidelines in order to promote economic growth. These reforms insert the values of the rationalizing and maximizing individual in practically any social relationship (Carrillo, 2010). In this way, the formal norms that govern Chilean society and shape human interactions promote competition over cooperation and individualism over collective action (Larraín, 2020).

During the dictatorship, the legal framework for water in the country was drastically changed, which then began to be determined by the 1981 Water Code. With the establishment of the 1980 Constitution, water sources and their management were defined through property rights, where numeral 24 of article 19 states that: *"The rights of individuals over water, recognized or institutionalized in accordance with the law, shall grant their holders ownership over them"*, promoting a water management system based on the free market, with low state regulation, strongly reducing the participation of civil society and communities, in addition to generating a rapid concentration of ownership of resources in national and transnational private companies (Aedo, 2015).

On the other hand, the Water Code, introduced in 1981, states in Article 5 that *"Water is a national asset for public use and private individuals are granted the right to use it"*, so there is a contradiction regarding the economic nature of water because the question arises as to whether it is a national asset for public use or whether it is a private asset over which there are property rights. When these two sides come into conflict, the institutional framework does not prioritize, but leaves the resolution of conflicts to the normal courts (Bauer, 2004).

Overall, the 1981 Water Code greatly strengthened private property rights, increased private autonomy in water use, and favored free markets for water rights to an unprecedented extent. For the first time in Chilean history, the new Water Code separated water rights from land ownership, and created market mechanisms and incentives. As a result, the Water Code drastically reduced the role of government in the management, regulation and development of water resources (Bauer, 2004).

On the other hand, the water market is structured through water use rights (DAA) [9]. These provide structure to the water market, as they are the tradable good that can be sold, bought or leased. The General Water Directorate (DGA) is in charge of managing, verifying and spreading the country's water information, according to the guidelines provided by the Water Code. The DGA is forced to deliver the DAA's as long as the resource is available and does not affect the rights of third parties.

In other words, water use rights constitute private property and under the logic of the free market, this increases economic efficiency by allocating resources to their most valuable uses through the pricing system (Bauer, 2004). In this way, the state is limited to regulating the definition and protection of property rights, under the assumption that negotiation between owners is the most efficient way to resolve territorial conflicts over the use of water.

Moreover, this system generated clear problems of accumulation of rights and speculation (World Bank, 2011), which together with the restricted role of the state in regulation and the lack of participation in water management by users who do not have rights, produced a situation of stress in the system, as evidenced by the variety of conflicts generated in the country (Larraín, 2010).

The Chilean context - where the market has taken over all spheres of a society - is a perfect case for analysis in order to examine how its common-pool resource institutions perform. From this background, the question arises as to whether the current Chilean Water Code is sustainable over time and what can be done to improve the institution in order to achieve a proper management of the fundamental element for life and, therefore, for the economy.

A considerable body of literature has accumulated on the usefulness and validity of Ostrom's DP's,

[9]The Spanish translation is "Derechos de Aprovechamiento de Agua" (DAA).

and reactions have been mixed [10] . Although these principles have received considerable support, it has not been observed that these are regularly applied in institutional designs. Since much has been written about DP's after 1990, it is useful to analyze the compatibility of these principles with the Chilean institutional framework for water resources which is a case of analysis due to its treatment of water as a fully tradable good.

3. Research methodology

This thesis first analyses the current Chilean water regulatory framework: the Water Code. This institutional framework is first subjected to an analysis to determine its compatibility with Ostrom's Design Principles of sustainable governance of CPR's. Based on the conclusions obtained from this analysis, public policy recommendations for institutional change are provided.

The hypothesis of the thesis is that based on the DP's, it is possible to conclude that the current Chilean water institutional framework is not sustainable over time. Although the studies carried out so far on compliance with the principles have been based on the behavior of communities and not on how institutional frameworks behave, this thesis aims to provide guidance on how Ostrom's evidence can be a basis for a good institutional reform.

To test this hypothesis, the Water Code is reviewed for evidence of compliance with each of the 8 DP's. To code the findings, the methodology of Gari et al. (2018) was followed, where values are given to the DP's, coding them from 0 to 1, indicating the absence and presence of the Principles respectively (Table 3), as well as the intermediate options: Rarely present (RP), Sometimes present (SP), Mostly present (MP). Finally, the values are summed to obtain the total score and the final outcome.

[10] See, for example, Sar et al., 2021; Foster and Iaione, 2019; Sarker et al. 2015; Saunders, 2014, Wilson et al., 2013, USAID, 2011; Brosius et al., 2005; Sultana and Thompson, 2004; Agrawal, 2003.

Table 3: Values of the coded frequency of the DP's by Gari et al. (2018)

Code for DP's Frequency	**Value**	**Score**	**Outcome**
Absent (A)	0	0-2.9	Failed
Rarely Present (RP)	0.25	3-3.9	Fragile
Sometimes Present (SP)	0.5	4-4.9	Weak
Mostly Present (MP)	0.75	5-8	Succesful
Present (P)	1		Succesful

Because these codes are based on observations of communities - and not on observations of an institutional framework - it is difficult to differentiate the intermediate values, being possible to code only 3 states: Present (P), Sometimes Present (SP), Absent (A), by modifying the classifications in the table above to:

Table 4: New values of the coded frequency of the DP's

Code for DP's Frequency	**Value**	**Score**	**Outcome**
Absent (A)	0	0-2.9	Failed
Sometimes Present (SP)	0.5	3-5	Fragile/Weak
Present (P)	1	> 5	Succesful

The first state: Present (P), is determined by the presence in the Water Code of mechanisms that favor compliance with the DP, which will be determined by "articles" that contain the essence of what the DP proposes. On the other hand, when there is evidence that an important variable is being omitted from the institutional framework - which Ostrom did consider in her analysis - despite the existence of other mechanisms that help compliance with the principle, it will be classified as: Sometimes Present (SP). Finally, Absent (A) is when the regulation does not address the issue.

Finally, in order to better analyze compliance of the Water Code with the DPs, the subcategories suggested by Cox et al. (2010) will be followed, dividing DP's 1, 2 and 4 into 2 subcategories. The total scores for these three DP's will be derived through a simple average of the 2 subcategories. Finally, a description of the subcategories is given in Table 5.

Table 5: Subcategories by Cox et al. (2010)

Design Principle	**Subcategories**	**Explanation**
1. Clearly defined boundaries	1.1 User boundaries	Clear boundaries between legitimate users and nonusers must be clearly defined.
	1.2 Resource boundaries	Boundaries that define the resource system are present.
2. Proportional equivalence between benefits and costs	2.1 Congruence with local conditions	Appropriation and provision rules are congruent with local social and environmental conditions.
	2.2 Appropriation and provision	The benefits obtained by users from a CPR, as determined by appropriation rules, are proportional to the amount of inputs required.
4. Monitoring	4.1 Monitoring users	There exists an accountable process of monitoring the appropriation and provision levels of the users.
	4.2 Monitoring the resource	Monitors who are accountable to the users monitor the condition of the resource.

It should be noted that this analysis is not based on how the articles are actually implemented or not implemented, but is an analysis of what the framework is currently shaping and which ultimately determines how has transformed the relationship between water and society in Chile (Budds, 2018).

On the other hand, based on the fulfilment of the hypothesis, this reasoning will be applied to see how the institutional framework could be improved in order to reach one that is sustainable over time. In order to carry out this discussion, Ostrom's findings will be a guide for institutional reform and recommendations for policy makers.

4. Results

According to what has already been stated, the growing scarcity of water resources, together with the social and environmental problems generated by the current water management model in Chile, give clear signs of a model that is not sustainable over time. In order to carry out a more detailed analysis of the sustainability of the Chilean model, Elinor Ostrom's Desing Principles (DP's) - applicable to an efficient and sustainable management of common resources - are contrasted with Chilean legislation. According to the analysis developed, the following can be noted:

4.1. Sustainability of Water Code

1. **Clearly defined boundaries:** *The boundaries of the resource system and the individuals or households with rights to harvest resource units are clearly defined.* Following the subcategories suggested by Cox et al. (2010) it is possible to divide this DP into two: user boundaries and resource boundaries.

   1.1 **Resources Boundaries: Present (P).** The exploitation rights are defined as a real right (art. 6 Water Code), allowing its disposal (art. 15 Water Code) without restrictions of any kind and depriving the administrative authority of the State of powers for the management and development of this natural resource. When the right holder is deprived of part of the water that corresponds to them, even in case of a declared scarcity zone, they have the right to be compensated for that deprivation (art. 314 Water Code).

   1.2 **Users Boundaries: Sometimes Present (SP).** This analysis is not clear because there are many historical users who have not yet regularised their status to have a water right title, and there are many imperfect water right titles that do not specify their flow, basin or aquifer, and other characteristics that make it difficult to abstract between legitimate users and nonusers (World Bank, 2011). Since the water code does promote the legal

registration of these rights, but not address these incongruences, it can be concluded that it is only sometimes present (SP).

From these two sub-analyses it is possible to conclude that while one part of the analysis is present in the Water Code, the other part is only sometimes present. Averaging the respective scores for DP 1 gives a total of 0.75.

2. **Proportional equivalence between benefits and costs:** *The rules specifying the amount of resource allocated to a user are related to local conditions.* Again, following the subcategories suggested by Cox et al. (2010) it is possible to divide this DP into two: congruence with local conditions and appropriation and provision.

   2.1 **Congruence with local conditions: Sometimes Present (SP).** The right to use water is equal for all, the law applies throughout the territory of the republic. Nevertheless, in 2005 a reform was implemented where certain regulations related to local conditions are integrated, for example, a minimum ecological flow. Unfortunately, these reforms are focused on newly constituted rights (2005 onwards) (Larraín, 2019), i.e. rights constituted before this year are not related to local conditions.

   2.2 **Appropriation and provision: Absent (A)**. The initial allocation of the resource is given by the State since the Water Code does not establish priorities when designating water rights, leading to an unequal and unfair distribution of the resource because industrial interests are better organized and therefore will have more rights than rural and probably poorer communities (Cornejo et al., 2021).

A good example of this situation is the case of "La Ligua" river, located in Petorca (Fifth Region of Chile), where commercial initiatives eventually dried up the river. Fruit production for export increased considerably (mostly avocado production) due to a combination of several factors such as an optimal climate, a growing export market, access to uncultivated land, and the availability of groundwater rights from the under-exploited aquifer (Budds, 2004). With the increase in fruit plantations, applications for available groundwater rights increased

considerably as well.

However, since the prolonged drought in 2010, the area was characterized by severe water scarcity - caused by a combination of increased groundwater abstraction, which is exacerbated by increased water demand from fruit plantations - and successive dry winters. Finally, La Ligua river stopped flowing, and since then, it only flows again during flash floods (Budds, 2018).

Furthermore, this situation affected also rural drinking water supply systems organized by autonomous committees or village cooperatives where these systems depend on wells, which are exempt from formal water rights, and most of them were dried up (Budds, 2018). Clearly, the market perspective of the Water Code leads to unequal cost-benefit ratios, generally exacerbated for the poorest rural populations.

From these two sub-analyses it is possible to conclude that while one part of the analysis is sometimes present, the second part to complete this DP is absent. Finally, the average of the DP 2 is 0.25.

3. **Collective choice agreements:** *Many of the individuals affected by harvesting and protection rules are included in the group of actors who can change these rules.*

   Sometimes present (SP). It is possible to find statutes that allow the participation of all users in the modification of their rules [11]. Nevertheless, votes are proportional to the size of the water rights, so small users are practically excluded from the decision process. Following this, individuals who do not have water rights cannot modify the rules, as they are not the owners of these rights. Among the bodies linked to this management, the majority of the

[11] See for example Art. 251 Water Code

spaces for participation are held by ministries, with almost no links to actors representing interests other than those of the government of the day and no presence of citizen organizations (Retamal et al., 2013).

On the other hand, municipalities do not participate in water management, except as a support institution in emergencies and in works to improve watercourses (World Bank, 2013). There is no integration of actors at the basin level, as the minimum territorial scale for water governance. There is not even integration of the basin at higher administrative levels, which would allow influence on the formulation of public policies (Retamal et al., 2013), which is also related to the non-compliance with the eighth principle.

Since most of the individuals affected by harvesting cannot change the rules, it is possible to conclude that DP 3 is only sometimes present (SP), giving a total score of 0.5.

4. **Monitoring:** *Actively monitor biophysical conditions and user behavior.* Again, following the subcategories suggested by Cox et al. (2010) it is possible to divide this DP into two: monitoring users and monitoring the resource.

   4.1 **Monitoring users: Present (P).** The General Directorate of Water (DGA) is in charge of water monitoring as mandated by the water code, with 37 water monitors for a population of 138,356 registered users (DGA, 2021).

   4.2 **Monitoring the resource: Sometimes Present (SP)**. It was not until 2005 that the Water Code established the term *minimum ecological flow* [12] - which is considered an instrument that establishes the quality, quantity and regime of water flow required to maintain aquatic ecosystems - which stipulates that it cannot exceed 20% of the average annual flow of the respective source, a figure established without any technical requirement (Larraín, 2020). An important point is that this regulation is aimed only at newly

[12] See Art. 129 Water Code.

constituted rights, i.e. all previously granted rights are not governed by this regulation, as it would be unconstitutional due to the extreme protection of private property that prevails in the country.

On the other hand, when the DGA declares a locality as a "drought zone", the Water Code stipulates that it can only be for 6 months, and is not extendable, again without any technical support for the decision (Larraín, 2021). It is clear that the Water Code is not capable of regulating the biophysical conditions of an area. Following Guillermo Larraín (2021), the norm is so insufficient that article 314 of the Water Code allows for the declaration of "water scarcity" in the event of a drought, so that the authority has special powers and the possibility of relaxing some of the rules for the use of the resource. Clearly, this logic makes it practically impossible to monitor biophysical conditions, especially if the authority is allowed to be more flexible on environmental issues, without respecting the minimum ecological flow (Boettinger, 2019).

A case that serves to exemplify this situation is that of the communities of Pica and Huasco in the North of Chile where local communities have been protesting against mining activities for years, arguing that environmental impact studies in the area were inaccurate and underestimated the damage. In 2005, local authorities went to the area to estimate the real damage caused by the mining industry, where they were able to verify the communities' complaints (Cornejo et al., 2020).

Finally, the authorities found that the DGA granted more water rights than it should have, thus contributing to water stress in the region. Although state officials recognize the clear evidence that water rights exceed the recharge capacity of affected aquifers, they cannot revoke water rights once they have been granted, despite new evidence that

modifies the original assessment (Cornejo et al., 2020), so it is possible to conclude that the Water Code does not allow for effective monitoring of biophysical conditions. However, the principle can be classified as sometimes present (SP), because it is possible to find the presence of this sub DP in the new rights established since 2005.

From these two sub-analyses it is possible to conclude that although "monitoring users" is present in the Water Code, "monitoring the resourse" is not always found since there are incongruences in the institutional framework. The average score for DP 4 is 0.75.

5. **Graduated penalties:** *Users who violate the rules are subject to penalties.*

   Present (P). Articles 172 and 173 provide for sanctions. The regulation was also recently partially modified, establishing a patent for the non-use of water, through Law Nº 20.0172 (Diario Constitucional, 2021).

6. **Conflict resolution mechanisms:** *Users and their officials have quick access to low-cost local action situations to resolve conflicts.*

   Absent (A). The Water Code has no regulatory power to intervene in these matters. Whenever there is a conflict, the solution is left to the market. Once a private solution has not been reached, the only recourse is to go to the ordinary civil courts of justice - because Chile does not have specialised courts - despite their limited experience in water issues (Bauer, 2004).

7. **Minimal recognition of organisational rights:** *The rights of users to design their own institutions are not challenged by government authorities.*

   Present (P). Article 196 of the Water Code establishes that water communities will be understood to be organised by their registration with the General Water Directorate (DGA), thereby obtaining legal personality, and can then be registered with the Real Estate Registry (Rivera, 2016).

8. **Nested bodies:** *Ownership, provision, monitoring, enforcement, conflict resolution and gov-*

ernance activities are organised in multiple layers of nested bodies.

Absent (A). There is no place in the Water Code for an organised multi-level system for the control and management of water resources. The coordination of different water uses depends on the general logic of the Water Code, i.e. on private negotiations between rights holders. As the Water Code does not have regulatory power, the coordination of multiple uses and watershed conflicts has been left to the free market (Bauer, 2004).

Finally, in Table 6 a summary of the results can be found. According to the analysis, the Chilean water regulatory framework gives a total value of 4.25 points, according to Ostrom's guidelines. This score places the Water Code as a fragile/weak regulatory framework, in terms of sustainability over time. For this reason, the reformulation of the current water legal framework is urgently needed to achieve sustainable resource management.

Table 6: Results Water Code

Design Principle	**DP1**		**DP2**		**DP3**		**DP4**		**DP5**		**DP6**		**DP7**		**DP8**		**Total Score**
Sub Categories	1.1	1.2	2.1	2.2	-	-	4.1	4.2	-	-	-	-	-	-	-	-	
Code	P	SP	SP	A	SP		P	SP	P		A		P		A		**Fragile/ weak**
Value	0.75		0.25		0.5		0.75		1		0		1		0		**4.25**

5. Discussion

Institutional structures reflect the accumulated beliefs of society over time, and changing these structures is often a process that reflects the constraints that the past imposes on the present and the future, and for this reason there is considered to be a path dependence in institutions, which makes them "rigid" (North, 2006). Nevertheless, natural resources and environmental conditions are dynamic, constantly evolving and today more than ever the pace at which they are changing has increased (Hill & Regan, 2020).

This raises the question of how we can improve our institutions considering their rigidity versus the dynamism of natural resources. Moreover, these two concepts together make institutional sustainability of CPR's impossible because they are not adapting to environmental challenges fast enough and for this reason, institutional rigidity must somehow decrease in order to face these important environmental challenges.

The principles that provide the basis for sustainable governance of natural resources are already known, now the challenge is to develop institutions that have the capacity to adapt - with the necessary speed - to climate change. This is not an easy challenge, since economic interests will fight arduously, however, the evidence shows that we are capable as a society of obtaining better outcomes than what economic theory has suggested.

Since Design Principles are observed regularities derived from a posteriori case analysis, the question then arises of how we can use DP's in practice. One way to use DP's is to translate them into questions concerning how to improve institutional arrangements for governing the commons (Ostrom, 2005). The questions to be addressed can be found in Table 7.

Table 7: Ostrom's Desing Principles as questions to think about improving the sustainability of a common-pool resource

DP's	Questions
DP1	How can we better define the boundaries of this resource, and of the individuals who are using it, so as to make clear who is authorized to harvest and where harvesting is authorized?
DP2	How can we clarify the relationship between the benefits received and the contributions to the costs of sustaining this system?
DP3	How can we enhance the participation of those involved in making key decisions about this system?
DP4	Who is monitoring this system and do they face appropriate incentives given the challenge of monitoring?
DP5	What are the sanctions we are authorizing and can they be adjusted so that someone who makes an error or a small rule infraction is sufficiently warned so as to ensure longer-term compliance without our trying to impose unrealistic sanctions?
DP6	What local and regional mechanisms exist to resolve conflicts arising over the use of this resource?
DP7	Are there functional or creative efforts by local appropriators to craft effective stewardship mechanisms for local resources that should be recognized?
DP8	How can we create a multi-layer, polycentric system that can be dynamic, adaptive, and effective over time?

Source: elaborated from Ostrom (2005), Chapter 9: Robust Resource Governance in Polycentric Institutions), pages 475-476.

Nevertheless, it is difficult to consider the applicability of these questions in the context of rigid institutional frameworks, so a paradigm shift is needed in the design of the institutions that shape our behavior as a society in order to obtain better outcomes.

Shifting institutional perspective

In terms of governance of CPR's, Ostrom proposes not to think in dichotomies: neither the governmental nor the private solution is a panacea (Ostrom, 1990). The fact that people are able to

cooperate to achieve sustainability of a CPR shows a totally different perspective, opening a great field for the development of new institutions and public policies.

One of Ostrom's major contributions was to show that to solve social problems we need a mix of private, community and government efforts that interconnect at many levels of governance (Hill & Regan, 2020). On the other hand, institutions developed by local communities are generally the most successful in solving environmental problems because they usually have the presence of the DP's (Ostrom, 2009).

In order to achieve the goal of creating CPR institutions that are sustainable over time and coherent with local conditions, a paradigm shift from a monocentric system - where a few in charge make decisions for all - to a polycentric one where different units of governance work autonomously and are interconnected is necessary. Polycentric governance considers multiple decision-making centers with some degree of autonomy, formal and informal mechanisms that promote coordination, cooperation, conflict resolution and knowledge sharing (Ostrom et al., 1961; Ostrom, 2009).

In this way, polycentric systems facilitate self-governance by dispersing decision-making power to lower levels of governance where it is actually possible to observe the diversity and dynamism of resources, taking into account the preferences and values of a particular community. Importantly, these systems show a balance between centralized governance and fully decentralized governance, or in other words, fully left to community management (Carlisle & Gruby, 2019).

On the other hand, it is not enough to have many decision-making centers to be considered a polycentric system. Moreover, units need to be interconnected, generating cooperative and competitive relationships and being able to resolve conflicts (Ostrom et al., 1961). In this way, polycentric governance of CPR's allows better adaptation to social and environmental changes due to decen-

tralized decision-making, also provides a good adjustment to the complex and dynamic context of natural resources due to the autonomy they present, which allows them to experiment, choose certain policies and learn in the process, and also mitigates the risk of institutional failure because if a particular unit fails, the others will learn from those mistakes and that is why interconnectedness among them is so important (Cole, 2015).

It is now evident that by moving from a monocentric view to one with greater polycentric governance attributes, it will be much easier to implement these principles in order to achieve institutional sustainability of water resources. It is also possible that these 8 DP's will emerge naturally in this way of governance, as autonomy, cooperation, coordination and knowledge will lead to institutions that are robust and coherent with the environmental and social challenges we are facing as a society.

People make decisions based on the information they have available to them, the incentives they face and the institutional framework they use to judge this knowledge (Carlisle & Gruby, 2019). Clearly individuals will be selfish and uncooperative if their institutional framework motivates them to be so. The reality is much more complex than the Prisoner's Dilemma. For instance, this dilemma - which is a formalization of the tragedy of the commons described by Hardin - assumes that prisoners cannot communicate with each other. It is known that reality is not so limited and restrictive, so clearly the conclusions will not be the most appropriate. Infinitely repeated social-dilemma games generate multiple equilibria so that the expected outcomes of these situations are not as obvious as an "inevitable tragedy".

6. Conclusions

Chile's current institutional framework for water resources, represented by its Water Code, has generated a large number of problems in terms of environmental and social justice. In addition, an analysis along Ostrom's guidelines confirms the hypothesis that the institutional framework is not sustainable over time, moreover, it can be classified as fragile/weak.

The degradation of our environment can be seen as an obvious outcome that comes from an inevitable tragedy as the neoclassical theory suggests. Nonetheless, this view is biased and is a simplistic analysis, since we have a vast body of evidence that human behavior can generate other outcomes if there are norms and rules that contribute to cooperation and thus to collective action.

An institutional framework that promotes individualism will not lead to any environmental solution. As can be seen from the analysis of the Water Code, a totally mercantilist orientation does not produce more efficiency when it is about common-pool resources, an analysis that can also be extended to the context of climate change, considering the planet as a large common-pool resource.

Moreover, as climate change and droughts become more severe, the more difficult it will be to address this problem, because the resource will become scarcer and interests will fight harder. To achieve a successful water management model - and for CPR's in general - it is necessary to stop thinking dichotomously between private and state solutions. Ostrom's contributions provide an enormous field of action, where success in the governance of the commons will be achieved through coordination and cooperation between the state, the private sector and communities.

There are important lessons to be learned from Ostrom. First of all, there are no panaceas. Reality is much more complex than theory can predict, which is why she devoted herself to studying di-

verse contexts and situations where she was able to discover that many times the outcomes obtained by society are not an inevitable tragedy as theory would predict. State-market binary thinking is far from appropriate, both are incomplete and introduce biases and inefficiencies in the governance of a common-pool resource.

The rules of the game shape our behavior as individuals and as a society and define the location of our decisions. That is why moving towards a vision of polycentric governance will probably be the only way we can coordinate society, state and market to achieve sustainability of our CPR's. If the rules of the game change, and return decision-making power to lower levels of resource governance, it will allow for greater democracy over the destination of the resources and, as the evidence suggests, it will also allow to avoid what it seems to be an inevitable tragedy.

As a society we are reaching a limit point and it is necessary to make radical changes in our institutional framework in order to address today's challenges. It is clear that neither the state nor the market will come up with optimal mechanisms to address environmental issues, because unfortunately, it has not happened yet.

Additionally, it is necessary for policy makers to move away from binary or dichotomous visions; reality is much more complex and it is essential to shift towards a holistic approach, where the existence of institutions that bring out the best potential of human beings and the environment is possible. In Ostrom's words, the main objective of governance should be: *"facilitate the development of institutions that bring out our best as humans"*.

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