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The Social and Environmental Costs of the Water Management System of Chile

Inequalities in a Context of Scarcity

by

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Abstract The purpose of this thesis is to present a more complete picture of Chile's water management system in terms of the three pillars of sustainable development, namely regarding the social, environmental, and economic outcomes of the 1981 Water Code. The contribution of this research relies in the understanding of the law's reproduction of socio-ecological inequalities and in the investigation of a possible link between commercial agricultural activities and prices of potable water in the sixteen administrative regions of Chile. The mixed-methods approach consists of the application of the Critical Environmental Justice Framework on the 1981 Water Code and the econometric estimation of the relationship between the agricultural sector's contribution to regional GDP and potable water prices in the summer and winter seasons. The results suggest that the Water Code encourages the reproduction of inequalities over time and across space to the detriment of vulnerable communities and of water resources themselves, but they cannot confirm a relationship between agricultural water extraction and prices of potable water faced by consumers. For this reason, future research should focus on the impact of over-extraction on the determinants of potable water prices, and policies should shift Chile's water resources management to a more integrated and holistic approach.

Keywords *Water Market; 1981 Water Code; Water Scarcity; Potable Water; Socio-ecological Justice; Power Relations; Agriculture; Campesinos; Indigenous Communities*

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Table of Contents

List of Tables

List of Figures

Glossary

AGR	Agricultural Sector's Share in Regional GDP
AP	Average Precipitation Rates
APR	*Programa Nacional de Agua Potable Rural*
AR	Administrative Regions
BLUE	Best Linear Unbiased Estimator
CASEN	*Caracterización Socioeconómica Nacional*
CEJ	Critical Environmental Justice
DGA	*Dirección General de Aguas*
EcJ	Ecological Justice
ECLAC	Economic Commission for Latin America and the Caribbean
EJ	Environmental Justice
GDP	Gross Domestic Product
GWH	Geneva Water Hub
IDB	Inter-American Development Bank
INE	*Instituto Nacional de Estadísticas*
IWRM	Integrated Water Resources Management
MC	Marginal Costs
MT	Average Maximum Temperatures
NPWP	Nonpeak Potable Water Prices
OCPWP	Over-consumption Potable Water Prices
OLS	Ordinary Least Squares
PD	Population Density
PO	Share of Poverty

PE	Political Ecology
PPWP	Peak Potable Water Prices
RSS	Residual Sum of Squares
RWC	Rural Water User Committees
SEJ	Socio-ecological Justice
SISS	*Superintendencia de Servicios Sanitarios*
UN	United Nations
VIF	Variance Inflation Factor
WA	Water Availability
WB	World Bank
WC	Water Code
WEF	World Economic Forum
WQ	Water Quality
WSI	Water Scarcity Index
WSS	Water and Sanitation Sector
WUAs	Water User Associations

1 Introduction

In 2022, Chile entered the 13th year of record-breaking drought (The Guardian 2022). The capital of Santiago has announced a plan to ration water when it becomes excessively scarce, and Claudio Orrego, the governor of the administrative region, reported that it "is [the] first time in history that Santiago has a water rationing plan due to the severity of climate change" (The Guardian 2022). However, in Chile, the stress of water resources is strongly linked to the export-oriented and natural-resources dependent economy as well, given that the agricultural sector and the mining industry demand large volumes of water for their respective production and mineral extraction.

This development has been the result of the country's neoliberal turnover with the Pinochet Dictatorship (1973-1990), which introduced a privatized water market through the *Código de Aguas* of 1981, granting private property rights and allowing users to trade them (Prieto, Fragkou & Calderón 2020). Although Chile transitioned to a democratic system in 1990, the main pillars of the neoliberal water management system are still in place today (Budds 2004). This scenario of over-extraction of water resources, coupled with increasing exposure to climate change, resulted in demands for change from the local population and in unsuccessful attempts from the government to improve the water management system (Gallagher 2016). Moreover, assessing Chile's water market is urgent because the current dynamics increase inequalities among different actors in society, thus failing to provide an inclusive and resilient development process. For this reason, the research question of this thesis is the following:

> RQ: *Does the Chilean water management system encourage over-extraction and discourage access to water resources for certain actors in society, while reducing affordability of potable water in water scarce areas?*

The most recent findings in the literature about this topic reveal that water markets have been assessed, but mostly in terms of their economic efficiency, instead of assessing social and environmental outcomes (Campanhão et al. 2021). Therefore, this thesis aims to investigate whether the Water Code of 1981 reproduces socio-ecological inequalities, leading to the following sub-research question:

> SRQ1: *Does the 1981 Water Code reproduce inequalities across time and space for both the human and natural worlds?*

Moreover, although the research output related to water prices is very extensive in a global perspective, little is known about Chile's case. Accordingly, this thesis aims to investigate whether the widely recognized idea that the agricultural sector demands a lot of water for its production (Larraín 2006) is related to potable water tariffs charged to consumers. Thus, the second sub-research question is the following:

> SRQ2: *To what extent is the agricultural sector's share of regional GDP related to drinking water prices in Chile's administrative regions in 2007?*[1]

The focus on the case study of Chile is particularly interesting because the privatized water management system was heavily promoted by the World Bank and the International Monetary Fund in the 1990s and recognized as the neoliberal economic model *par excellence*, but its success has been relativized by the same organizations in the following decades (Budds 2004; Gallagher 2016). The contribution of this research relies in the assessment of Chile's water management system, and the 1981 Water Code more specifically, in terms of the reproduction of unequal power relations between actors of the society and economy, and with respect to the environment, through the Critical Environmental Justice framework (Pellow 2018). Furthermore, this thesis envisages to contribute to the frontier by investigating the socio-environmental determinants of potable water tariffs through an econometric estimation, with the aim to understand whether the water-intensive agricultural sector influences the prices of potable water in the sixteen administrative regions of Chile. Finally, the purpose is to gain and present a more complete picture of Chile's water management system, in terms of the three pillars of sustainable development, namely the environmental, social, and economic outcomes of the water market.

The thesis is structured as follows. The next chapter presents the theoretical framework underpinning this research and – after introducing the properties of water resources – it presents the theories related to the management of open-access resources, such as water, as well as the link between privatization and socio-environmental inequalities. Chapter three presents and discusses previous research related to water scarcity, water governance, water pricing, and water conflicts and attempts to contextualize the case study of Chile in a worldwide perspective. Chapter four is dedicated to some background information of Chile, with the idea to present all the relevant features of its water-intensive economy, as well as of the water management system and the potable water provisioning system. Chapter five presents the data sources, illustrates the process of data cleaning and assembling, and discusses the limitations of the data. Chapter six introduces the methods used in the context of this thesis: given the mixed methods approach for the two sub-research questions, the first part will present the qualitative method, namely the Critical

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[1] The focus on the year 2007 is due to data constraints, as will be explained in 5.3 Limitations of the data.

Environmental Justice framework. On the other hand, the second part of the methods section is dedicated to the explanation of the quantitative econometric method, which is the Ordinary Least Squares, the model specification, and the respective limitations. In chapter seven, the results of the two analyses will be presented and discussed. Finally, the conclusion will wrap-up the main findings, highlight gaps for future research, and propose policy implications.

2 Theoretical Framework

The following chapter summarizes the main theories related to the management of water resources. It begins with an overview of the properties of water resources, it then discusses the "tragedy of the commons" in relation to water resources, given that they are open-access, and it concludes by highlighting the relationship between privatization and inequalities.

2.1 Nature of Water Resources

After air, water is considered to be the second-most vital source on earth, suggesting that there are few other resources of equal importance (Ibrahim 2022). Water has an economic value given its importance for economic growth, for example for industrialization or the development of an intensive modern agricultural sector (Bakker 2003). However, water has also an environmental and ecological value and plays an important role for the well-being and health of societies. Finally, water is often also perceived as a spiritual resource and has thus an important cultural and traditional value (Ibrahim 2022). For this reason, according to some scholars, the value of water cannot be quantified monetarily because it has several other intangible values.

In terms of its economic properties, water is a renewable global flow resource that is however mismatched in space and across time, and which is "freely" available to human needs for production purposes (Debaere et al. 2014). More importantly, while water resources are partially substitutable, drinking water cannot be substituted at all, as it is essential for life (Bakker 2003; Bakker 2007). Water is an imperfect public good, as it is non-excludable but rival in consumption and as such it is often treated as a common-pool resource (Bakker 2007).

2.2 The Tragedy of the Commons & Privatization

Given that environmental resources, such as water, tend to be open to enjoyment by all, there is a serious risk of over-exploitation because when individuals decide to consume or extract these resources they generate negative externalities that do not fall entirely on them, but on society as a whole (Sinden 2007). The idea that this behavior adds up to a result that is bad for everyone has taken the name of "tragedy of the commons", as presented by Hardin (1968). In the case of water, a high degree of negative public health and environmental externalities are reflected in its over-extraction (Bakker 2007). For this reason, it is common understanding that water resources need to be managed differently so that some boundaries determining the ideal amount of extraction are defined to prevent pervasive externalities. One option emerging from the literature is government regulation, which is however perceived only as a second-best solution for this problem. The other solution emerged during the 1970s and is widely accepted as the better option: the privatization of the commons (Sinden 2007). The idea is that by dividing these common resources into parcels of private property, there will be no remaining negative spillover effects to society because each owner has an incentive to take care of his property (Sinden 2007). Note that privatization refers to an institutional change targeting the implementation of private property rights, which does not include other neoliberal reforms, such as marketization, deregulation, commercialization, etc. (Bakker 2007).

There is an ongoing debate about whether the privatization strategy generates benefits or rather costs for society and the commons themselves. On the side of the supporters there is the free-market environmentalism view[2] considering that environmental problems can be solved simply by implementing and enforcing private property rights, through typical market-driven procedures (Sinden 2007). The idea is that by fully pricing the common resources, including environmental externalities, these goods will be allocated more efficiently by the free market, thus preventing over-extraction. As such, market environmentalists consider the resources to be economic goods (Gialis, Loukas & Laspidou 2011). When it comes to water, this view understands it as no different from other essential commodities and argues that water must be managed profitably by private companies to prevent scarcity. This view thus "offers hope of a virtuous fusion of economic growth, efficiency, and environmental conservation" (Bakker 2007: 432).

On the side of the opponents of privatization there are the human rights view and the commons view, which both consider that the neo-liberalization of nature focuses only on economic gains while leading to the degradation of the environment and reducing access to the resources through various forms of "accumulation by dispossession" (Bakker 2007: 432). The human rights view argues that the involvement of private companies in the management of water resources is incompatible with the principle of water being a human right open to all citizens of the world (Bakker 2007). This argument relies on two justifications, which are that water is non-substitutable

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[2] Also called green neoliberalism, liberal environmentalism, green capitalism, or ecological modernization (Bakker 2007).

and essential for life, and that other human rights recognized in United Nations (UN) conventions, such as the right to food, assume the availability of water (Bakker 2007). On a different note, the commons view considers that water has multiple values that go beyond the economic one, as mentioned earlier, and thus argue that water resources should be managed collectively by communities in order to include the social, cultural, spiritual and environmental values as well (Ostrom 1990). Indeed, the idea is that these local management systems are characterized by a collectivist ethic of solidarity encouraging users to avoid wasteful behavior (Bakker 2007). In conclusion, privatization appears as a possible solution for the management of scarce resources that has been very prominent internationally, but which is rather biased in favor of the economy and in disregard of societal and environmental outcomes (Prizzia 2002).

2.3 Privatization & Inequalities

Within the field of political ecology (PE) the management of natural resources is considered to be linked with inequalities through politics. Indeed, PE departs from the idea that "nature and environmental issues are inherently politicized and cannot be understood in isolation from the political and economic contexts within which they are produced" (Budds 2004: 325). For this reason, the discipline focuses on power structures produced in the political system that impact socio-economic as well as ecological outcomes in the ways that natural resources are managed and allocated, with a particular focus on the weaker social actors (Budds 2004; Dietz 2014). Privatization is an economic process that changes power relations between actors given that "a property right is a form of power and 'a sanction and authority for decision-making' over resources" (Kornfeld 2012: 50). In fact, during this transition, water is reduced to an economic good that disregards its simultaneous natural, social, or traditional qualities, thus changing the power relations between institutional actors and traditional users (Budds 2004).

Within the field of PE, the environmental justice (EJ) framework considers that environmental inequalities mostly affect socially vulnerable and marginalized groups that already suffer from social inequalities by race and class, given that they are excluded from policymaking bodies that could influence the distribution of these externalities (Pellow 2018: 12–13). More specifically, within the process of privatization, local rural communities are excluded from the access of common water resources and citizens lose their ability to access them through their right to a vital resource, as they need to purchase the commodity as consumers (Bakker 2003; Heynen & Robbins 2005). On a different note, the ecological justice (EcJ) framework relies on the idea that the relationship between human beings and nature is characterized by a conflict of interests, where "human practices degrade or destroy the natural world by failing to treat it with respect and dignity" (Parris et al. 2014: 71). Similar to the EJ framework, the EcJ considers that the process of privatization reduces complex ecosystems into commodity through pricing, thereby producing unequal power relations where, however, the environment is the weakest tie (Heynen & Robbins 2005). Indeed, when it comes to water scarcity, the EcJ argues that privatization is not the consequence of scarcity, but rather the cause of it, given that private firms operate to maximize their profits at the expense of the environment (Bakker 2003).

Given the duality of the EJ against the EcJ when assessing socio-environmental inequalities in relation to privatization, where the rule is to either protect certain human categories from environmental hazards, or to protect nature form human society, the socio-ecological justice (SEJ) framework is an attempt to show that rights and interests of both go hand in hand (Yaka 2019). The idea is that the demands for justice for vulnerable communities and for the environment, them all being the weakest ties within the power relations produced by the process of privatization, are not different from each other, as they all suffer from inequalities and ask for more inclusive processes (Yaka 2019). In light of this, the critical environmental justice (CEJ) framework assessing the original source of socio-ecological inequalities offers a holistic approach allowing to evaluate the power dynamics within an economic system (Pellow 2018: 21).

3 Literature Review

This chapter presents the main findings related to the purpose of this thesis. It aims to contextualize the case study of Chile and to present the latest evidence related to four main topics: water scarcity, water governance, water pricing, and water conflicts.

3.1 Water Scarcity

According to Mekonnen and Hoekstra (2016) water scarcity is a problem that affects a large number of people worldwide. Indeed, they find that two thirds of the global population face severe scarcity for at least one month a year and that approximately half a billion people live under severe scarcity during the whole year (Mekonnen & Hoekstra 2016). Similarly, in 2015 the World Economic Forum (WEF) concluded that global water scarcity will be one of the major challenges to face in the future, especially with the impact of climate change leading to higher temperatures, more extreme weather events, changes in rainfall patterns, and to faster snowmelt (Geneva Water Hub 2017). The acknowledgment of this challenge is also reflected in the literature in terms of the development of several indicators measuring water scarcity, water stress, or water poverty. These indicators range from simple thresholds of freshwater availability per capita, such as the Water Scarcity Index (WSI), to more complex metrics accounting for changes in water demand, adaptive capacity, environmental requirements, and social and environmental factors (Damkjaer & Taylor 2017). In general, research is moving towards more holistic measurements, but Liu et al. (2017) and Damkjaer and Taylor (2017) conclude that the quantification of the environment reduces contextual complexities and very often underplays issues of power and equity. Besides the challenges related to real water scarcity, Mehta (2003) and Mehta et al. (2019) point to the increasing instrumentalization of water scarcity, which becomes a narrative useful for political purposes. For example, Mehta finds that in the Kutch region of western India, the concept was used to legitimize the construction of large-scale dams (Mehta 2003).

Concerning the state of the resource on the global landscape, the Geneva Water Hub (GWH) (2017) considers that 60% of the world's freshwater reserves are distributed among nine countries only: Brazil, Colombia, Peru, the United States, Canada, Russia, China, India, and Indonesia. Moreover, the GWH considers that unequal distribution and water scarcity can become serious security threats both across and within countries (Geneva Water Hub 2017). Within Chile, the literature points to very uneven water distribution across the sixteen administrative regions (AR). Indeed, Parra et al. (2020: 1) and Aitken et al. (2016) suggest that, while water availability within Chile is sufficient, people and the main industries are located in areas with relative water scarcity, such as in the central area with Mediterranean climate and the northern area with desert climate respectively. Furthermore, when they computed the WSI for eight of the sixteen AR, Aitken et al. (2016) found that water resources are heavily over-exploited as a result of mining and agricultural activities.

3.2 Water Governance

Water governance has been researched extensively in Latin America because the continent presents large amounts of water resources in some parts and extreme scarcity in others (Rogers 2002). Therefore, this geographical focus presents a variety of different strategies that can range from local management systems supported by user groups, such as in Brazil, private systems such as in Chile, to governmental management systems as in Honduras (Rogers 2002). More globally, the literature points either to centralized systems where governments ensure the quality of water supply to their citizens, such as in Scandinavia, Germany, or Japan (Angelakis et al. 2021), or to the adoption of so-called water markets. Water markets have been researched extensively and are an increasingly popular instrument used by authorities to fight water scarcity, given that the trade of water rights allows to enhance economic efficiency (Campanhão et al. 2021; Debaere et al. 2014; Grafton et al. 2020). Examples of water markets can be found in Australia, the US, South Africa, Turkey, China, Morocco, Indonesia, the Philippines, Thailand, Mexico, Bolivia, and Chile (Bakker 2003; Debaere et al. 2014; Grafton et al. 2020). Within this context, Chile's water market is considered part of the "model of natural resources management according to economic and market principles *par excellence*" by the World Bank (WB) (Budds 2004: 3). Grafton et al. (2020) carried out a comparison between the water markets of the US, Australia, Chile, South Africa, and China in terms of efficiency, equity and sustainability to assess strengths and limitations. They found that the three pillars of sustainable development can coexist within water markets, but that they perform differently across countries because of different institutions and historical processes. However, in their literature review of articles related to water markets, Campañhao et al. (2021) found that research in this context mainly documents outcomes related to economic impacts and fails to assess environmental impacts, as well as issues of equity and justice in access to water resources. The most recent literature related to water markets in Latin America is shifting to the inclusion of social and environmental effects of these systems, as for example Harris and Roa-García (2013) investigate (partial) constitutional changes in water governance in Uruguay, Ecuador, and Bolivia and evaluate these demands in terms of alternatives to neoliberalism.

3.3 Water Pricing

Related to water governance, water pricing is a widely accepted instrument for matching water supply and demand in an efficient way. The research output related to water pricing is vast and covers different sectors, as well as different methods considering economic, social and natural conditions to determine water prices (Mohammad-Azari, Bozorg-Haddad & Biswas 2021). To start, Dinar and Subramanian (1998) carried out an investigation of 22 developing and developed countries and found that they all have very different objectives when it comes to water pricing, ranging from cost recovery to water conservation. Indeed, also Rogers, De Silva and Bhatia (2002) consider that water pricing can promote other aspects besides the efficiency one, such as equity, affordability or sustainability of water, but they point out that it usually requires significant government intervention. Other scholars, such as Toan (2016) and Grafton, Chu and Wyrwoll (2020) add that water prices almost never equal the true value of water and do not cover the extraction costs.

Research has also focused on the determinants of water demand, of water pricing and of a dynamic water market. For example, Moncur (1987) finds that the main determinants of demand for water are the price of water, income, household size, as well as precipitation rates. Min (2007) investigates whether the "forward-looking hypothesis", a theory suggesting that expected water shortages push prices upwards, impacts water pricing and finds supporting evidence. Finally, Bjorlund and Rossini (2005) investigate the factors driving activities in a water market and conclude that commodity prices, supply and demand, macroeconomic indicators, but also the level of seasonal allocation, rainfall patterns and evaporation play relevant roles. Related to environmental considerations within water pricing, Pesic, Jovanovic and Jovanovic (2013) consider that seasonal water pricing differentiating between periods of more and less water stress can have a beneficial effect on water conservation measures. Moreover, Macian-Sorribes, Pulido-Velazquez and Tilmant (2015) report that scarcity-based pricing can have positive effects on economic efficiency as well, and Donoso and Molinos-Senante (2017) propose a water rate model supposed to consider water scarcity, equity, and affordability of water through an increasing block strategy.

In conclusion, some research focused on the relationship between water pricing and the agricultural sector. For example, Varela-Ortega et al. (1998) analyzed the effects of different water pricing on agricultural water demand, farmers' income, as well as government revenue and found that outcomes differed based on institutional, regional and structural factors. In addition, while Ayana et al. (2015) reported that an increase in water prices is not desirable for farmers when the water distribution systems are poor and irrigation systems are insufficient, Mamitimin et al. (2015) found that the farmers' response to price increases is the transition to more efficient agricultural practices.

3.4 Water Conflicts

Regarding water conflicts, the literature differentiates between two types: interstate conflicts between neighboring countries sharing transboundary surface or groundwater sources, and intrastate conflicts between two or more parties within the same country (Angelakis et al. 2021). The literature on the motives of water conflicts within countries is extensive, and three main reasons were summed up by Rodríguez-Labajos and Martínez-Alier (2015): the first relates to water extraction for industrial production, power generation, or other natural resources extraction (minerals, oil, gas). Second, the authors suggest that transport and trade represent another source of water conflicts, given the negative effects that water supply megaprojects, river and aquifer infrastructure, or dams stairways can have on local populations and environments (Rodríguez-Labajos & Martínez-Alier 2015). Finally, they consider that waste and pollution resulting from urban and agricultural contamination, acid rain, or glacier retreat due to climate change can enhance water conflicts as well (Rodríguez-Labajos & Martínez-Alier 2015).

Water conflicts have been researched extensively in Latin America, especially when it comes to the clashes between agricultural and industrial activities and local populations including rural, indigenous and peasant communities (Boelens, Getches & Guevara-Gil 2010). Indeed, both Boelens, Getches and Guevara-Gil (2010) and Boelens and Zwarteveen (2005) conclude that the neoliberal language used in water policies in Latin America is ill-suited for recognizing social, political, and cultural specificities of water distribution, given that peasant and indigenous water claims are not taken into consideration. In fact, by comparing the different water management systems of Chile, Argentina and Bolivia, Montaña, Diaz and Hurlbert (2016) find that the development pathways relying on simplistic and technocratic approaches fail to protect rural people of the Andean drylands from climate change. More specifically, a lot of research has been focusing on Chile. For example, when assessing the effects of water availability on small-scale farmers, Fernandez et al. (2016) find that in the Vergara River Basin, poor *campesinos* are hit harder by changes in water availability than wealthy small-scale farmers because of worse adaptive capacity. Another example was presented by Romero, Méndez and Smith (2012) who discovered that the water withdrawal in the Atacama Desert, one of the driest desert areas in Chile, supported by neoliberal legislations was in conflict with local ecosystems and communities given the scarcity of the resource. Furthermore, research about water conflicts in Chile is strongly related to its water market, in which rights are traded between sellers and buyers. Correa-Parra, Vergara-Perucich and Aguirre-Nuñez (2020) and Larraín (2012) investigated rights distributions in Chile and found that they are heavily concentrated within few industries: while the former calculated a Gini Coefficient for the distribution of consumptive surface water rights discovering a high degree of inequality, the latter found that non-consumptive rights are concentrated in the hands of big and mostly foreign-owned hydropower plants. In both cases, the authors conclude that this development harms indigenous communities and peasants in their access to water resources. This was confirmed by Romano and Leporati (2002) who conclude that the distribution of water rights has worsened since privatization of the water management system in 1981, as peasant's share of rights decreased significantly. Finally, Torres and Bolin (2015) investigate the outcomes of water privatization in Chile and consider that, coupled with climate change, universal access to water resources decreased since 1981 and that water conflicts between peasants, indigenous people, local communities, environmentalists and mining, agribusiness, and hydropower firms increased.

In conclusion, this literature review shows that the research output related to the topic of this thesis is very extensive, as many studies have been carried out in terms of water markets, water pricing, as well as water conflicts. Nevertheless, as highlighted by Campañhao et al. (2021) research of water markets has been mostly about their economic performance, and less about socio-environmental outcomes related to indigenous, peasant, and rural communities. Furthermore, although the research output in terms of water pricing is remarkable, almost no studies deal with the determinants of potable water prices in Chile, in terms of socio-environmental factors. Therefore, it is relevant to ask the following research question:

> RQ: *Does the Chilean water management system encourage over-extraction and discourage access to water resources for certain actors in society, while reducing affordability of potable water in water scarce areas?*

4 Chile: Country Profile

This chapter illustrates the main characteristics of the Chilean economy, presents the features of its water management system in relation to water resources used for production purposes and describes the provisioning system of potable water for urban and rural consumers.

4.1 Export-oriented Economic Growth

4.1.1 Chile's Political and Economic Transitions

Between 1924 and 1973 Chile experienced ever-expanding state functions including regularly held elections and the protection of individual rights, making Chile a unique case within the Latin American context (Borzutzky 2020: 2). Nevertheless, especially Salvador Allende's state-centrist approach aiming to strengthen political inclusion, maintain social harmony and reduce economic inequalities was a dangerous road threatened by the political and economic elites of the country and by the United States (Borzutzky 2020: 4). On September 11th 1973, Chile's socialist political institutions were permanently transformed through the violent *coup d'état* initiated by Augusto Pinochet, who set in place a neo-liberal economic project in which private economic actors became key players (Prieto et al. 2020). The "paradigm changed from one in which the state must protect and oversee optimal allocation of resources to one in which the market is responsible for allocating resources in an efficient manner" (Donoso et al. 2015: 86). In fact, while the generals controlled the political system during the military dictatorship, neo-liberal economists – or the so-called Chicago Boys – designed and implemented economic policies reducing the investment, regulatory and distributive functions of the state, privatized state-owned properties as well as social policies, and opened the economy to external competition (Borzutzky 2020: 5). Although the Pinochet regime ended in 1990 after a plebiscite in 1988, the economic model embedded in the 1980 Constitution is still in place today and has not been subject to major transformations since the transition to a democratic regime (Borzutzky 2020: 10).

4.1.2 Water-Intensive Growth

Since the 1990s, Chile has experienced significant economic expansion at an annual real Gross Domestic Product (GDP) growth rate of 6.2%, substantially improving quality of life by reducing absolute poverty rates "from over 40% in 1990 to 7.8% in 2013" (OECD 2016), by creating jobs and boosting incomes, and by increasing social spending rates (Donoso 2014: 219; Valdés-Pineda et al. 2014; OECD 2016). These numbers are also a result of Chile's export-oriented growth strategy, which relies heavily on the export of natural resources, particularly copper ore, refined copper as well as copper alloys, and agricultural products, such as wine, grapes, fish, nuts, salmon or avocados (Atlas of Economic Complexity 2022). The contribution of the export sector to Chile's overall GDP ranges between 30% and 45% (1990-2020) and a visual representation can be found in APPENDIX A.1. Furthermore, Figure 1 below shows the composition of Chile's export basket over time and illustrates the strong dependency on agriculture and mining, demonstrating that besides manufacturing, natural resources play an important role for Chile's economic growth.

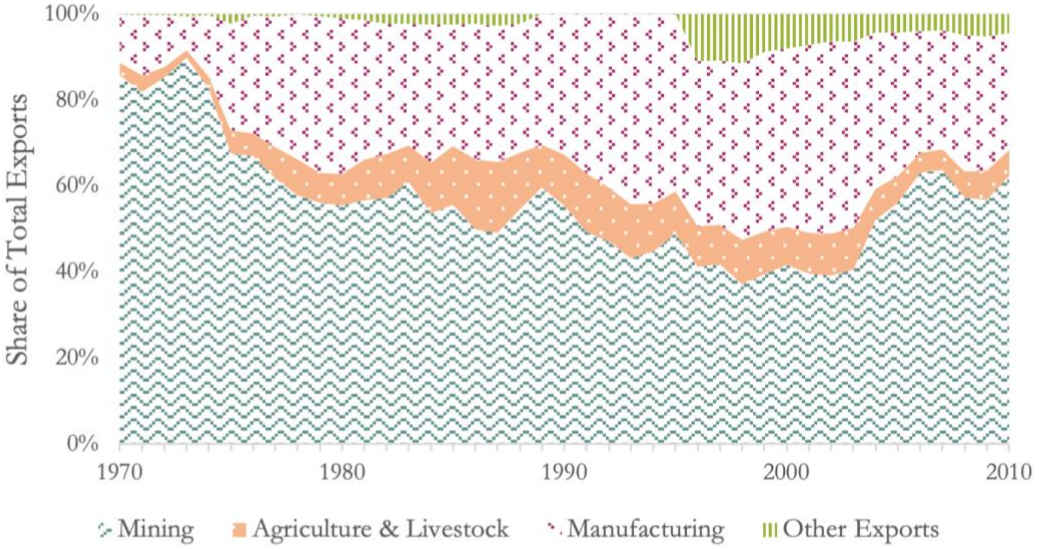

Figure 1: Chile's Export Basket Composition over Time (1970–2010) – Source: author's own elaboration with data from Díaz, Lüders & Wagner (2016)

Related to this observation, it is important to highlight that the Chilean economy is not only reliant on natural resources and agricultural goods, but indirectly on water too, given the high dependency of the production processes on water resources (Donoso 2014: 219). Indeed, Donoso (2014: 219) identified the five highest water-consuming economic activities as "manufacturing (12%), retail, restaurants and hotels (10%), mining (8%), agriculture and forestry (4%) and electricity, gas and water (3%)". Furthermore, while the economy's constant economic growth has increased demand for water, as highlighted by Valdés-Pineda et al. (2014: 2546) arguing that "the use and demand of water in the various productive sectors has experienced significant growth, about […] 160%

between 1990 and 2002", social development over the last decades has increased water demand of both surface and groundwater resources as well.

4.2 Chile's Water Management System

The neoliberal turnover of the 1970s also touched the water sector. Indeed, following the advice of the Chicago Boys, the military dictatorship passed the Decree Law 2603 in 1979, the legal basis for the new Water Code (WC) of 1981 (Prieto et al. 2020). As with the rest of the economy, the growing role and authority of the State in water management was reduced and a *laissez-faire* model for managing water was established (Prieto et al. 2020). More concretely, while restricting the government's agency in water resources management, planning, and regulation, the aim of the 1981 WC was to allocate water apolitically in a free market to maximize efficiency and social welfare (Prieto et al. 2020). Similarly to the 1980 Constitution, the 1981 Water Code remains in effect until today despite the return to a democratic government in 1990 (Bauer 2005).

4.2.1 The 1981 *Código de Aguas*

"Chile's current Water Code is a classic example of what in Latin America is often called the 'law of the pendulum': the historical tendency to swing from one extreme to the other in political and economic affairs, without finding a point of balance somewhere in the middle." (Bauer 2005: 150). Among others, the WC put in place a nationwide strategy for managing water resources without really considering climatic, cultural, economic, or local specificities (Prieto et al. 2020). The first consequence of the 1981 WC is that water became an economic good treated as a fully tradable commodity subject to the laws of supply and demand in an unregulated market, in which its value equals its market price (Bauer 2005). Moreover, although in formal legal terms water results as a public good, the fact of granting private and exclusive rights to users makes the resource *de facto* as private (Prieto et al. 2020). Indeed, private water users have a strong autonomy in managing their property, as they have for example no legal obligation to use water and could theoretically waste it although it is harmful for the rest of society (Bauer 2005). Another particularity of the Code is that the mobile property rights over water resources are separated by the immobile property rights over land resources (Bauer 2005; Donoso 2014: 217; Prieto et al. 2020). Finally, the whole water management system of Chile since the 1980s is based on a free market principle for trading water rights: as any other property, water rights can be bought and sold by buyers and sellers, mortgaged, transferred, and inherited (Bauer 2005; Donoso 2014: 217).

The authorities within the water market are both public and private. The *Dirección General de Aguas* (DGA), or the General Water Directorate, is the government water rights agency that is responsible for monitoring and enforcing water use rights, as well as collecting hydrological data and maintaining the Public Registry of Water Use Rights (Donoso 2014: 223). While the centralized administrative bodies of the State deal with water quantity and quality management, decentralized actors such as private user organizations manage their water resources independently. These Water User Associations (WUAs) were more than 4000 in 2014 and can be of different nature: water communities that share a common source of water; channel user associations operating on a distribution channel system; and vigilance committees that administer and allocate water to different channels (Donoso 2014: 223).

4.2.2 Regional Water Availability

One of the main reasons for establishing a neoliberal water management system is that, in some regions, Chile experiences problems of water scarcity, which could be tackled through an efficient water market. Indeed, although Chile as a whole can be considered privileged in terms of water resources[3], the regional distribution of water is highly unequal, especially considering the population's distribution, as shown in Figure 2: given the arid climatic conditions from Santiago to the North, average water availability is below 800 m^3 per person per year, while south of Santiago water availability exceeds 10000 m^3 per person per year (Donoso 2014: 220). Besides being subject to unequal water resources distribution, Chile presents a very irregular climatic scheme in terms of temperatures and precipitations, which are illustrated in Figure 2 as well. While the north has a dry pacific climate, where water flows are mainly rain driven during the rainy season in the very hot summer months (November to February) and reach 45 m^3 per second, the south has a humid pacific climate characterized by high rainfall and low temperatures, where water flows are driven by glaciers' snowmelt in central Chile and by rainfall in the southern part of the country, and can reach flows of 27600 m^3 per second (Donoso et al. 2015: 84).

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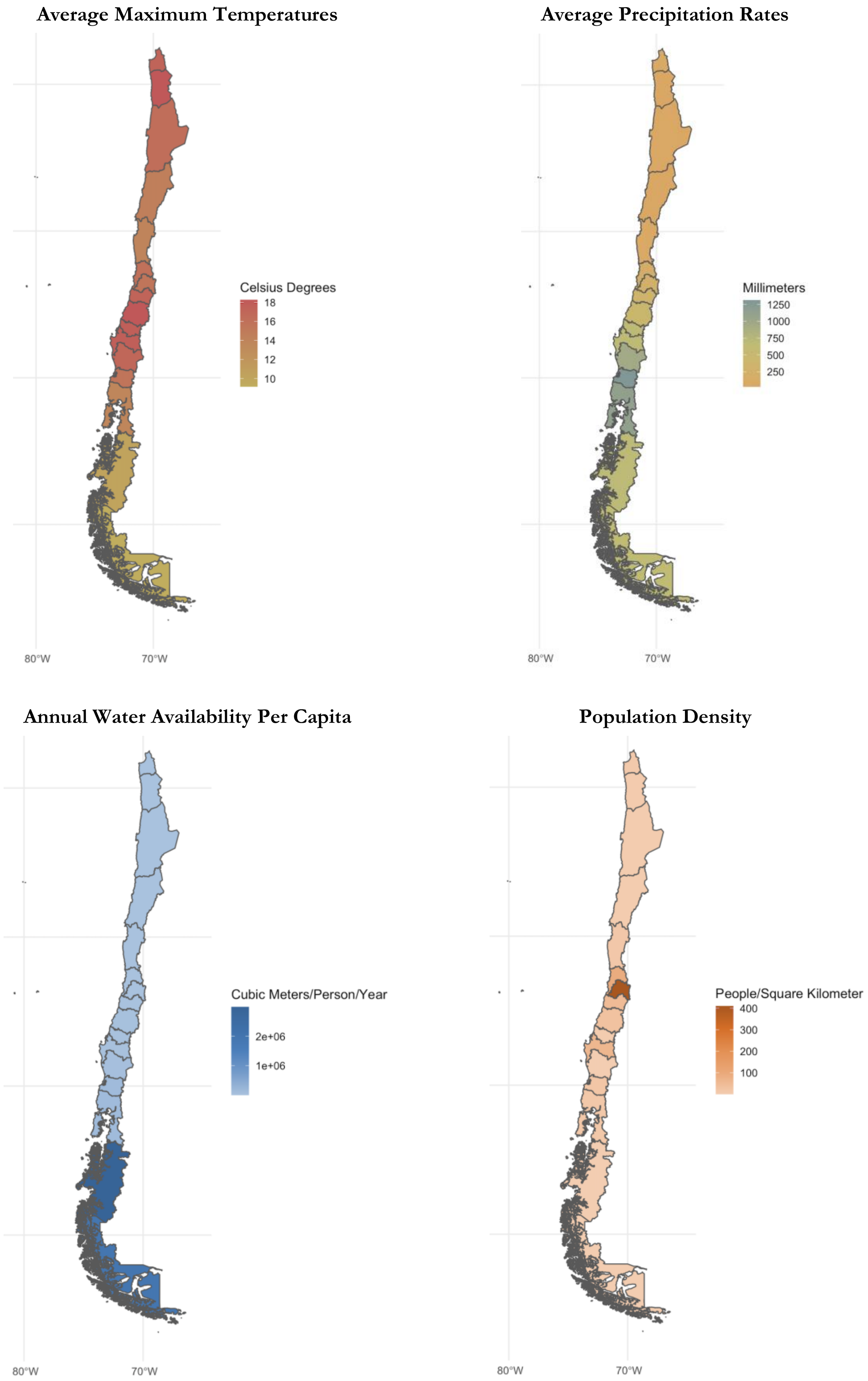
[3] The average total runoff is equivalent to 53000 m^3 per person per year, which is considerably more than the world average equal to 6600 m^3 per person per year (Donoso 2014: 220).



Average Maximum Temperatures

Average Precipitation Rates

Annual Water Availability Per Capita

Population Density

Figure 2: Mapping of MT, AP, WA & PD – Source: author's own elaboration

Besides regional disparity in water availability, Chile also presents differences in the demand for water. For example, in the northern Chile desert, the limited water resources sustain a few coastal cities, some specialized agricultural industries, but especially large copper mining operations (Donoso 2014: 220). In central Chile, the major urban and industrial areas are present and water resources are highly demanded by sanitation services, irrigated crops, industries, and hydroelectric plants. Finally, southern Chile is water abundant, but scarcely populated and only presents little irrigated areas, given that the main economic activities are related to the aquaculture industry (Donoso 2014: 220).

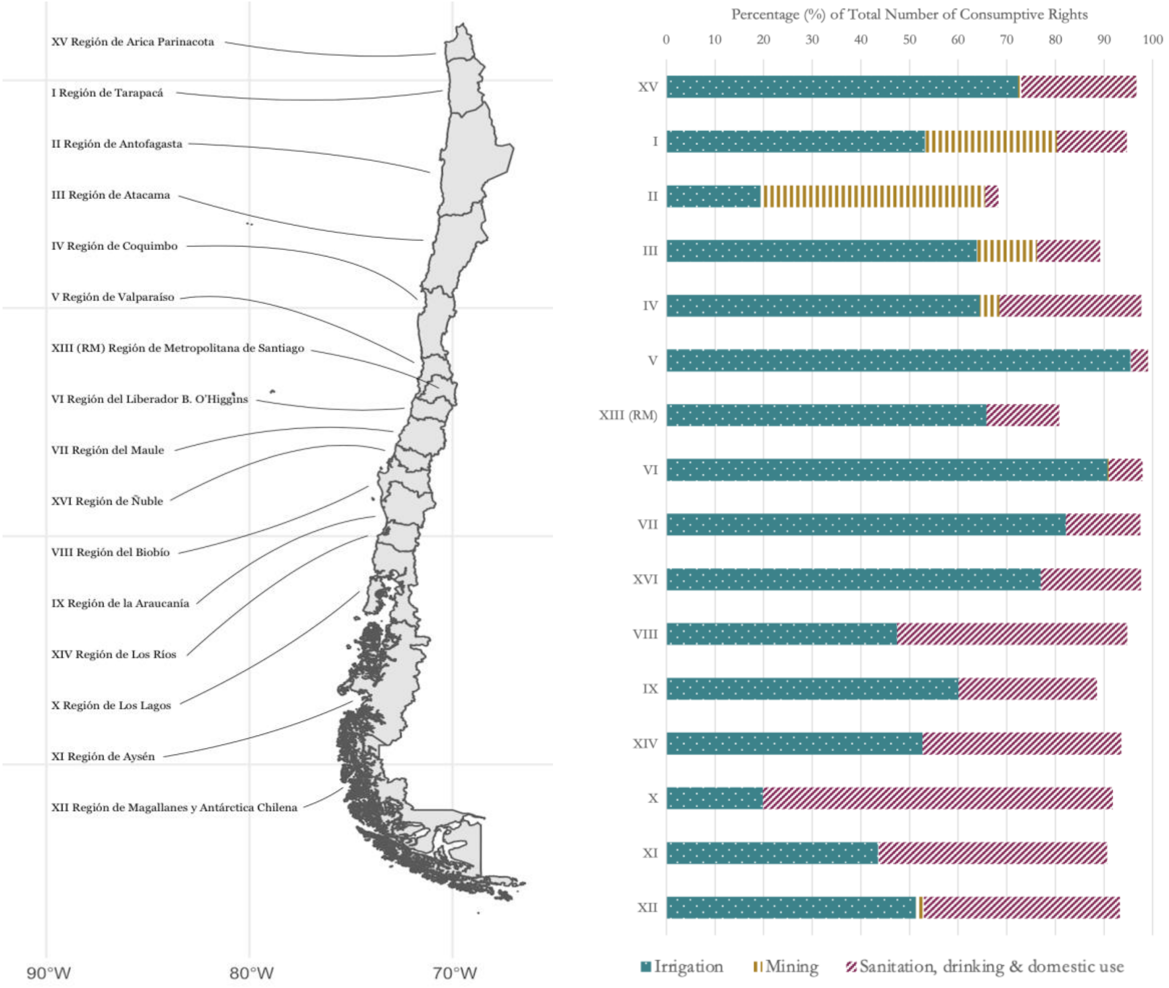


Figure 3: Water Rights Distribution according to Chile's Administrative Regions (excluding rights without data about use) – Source: author's own elaboration with data from the Dirección General de Aguas (2021)

In terms of water rights distribution, the DGA's Public Registry of Water Use Rights reveals that 85% of all rights are used in non-consumptive hydroelectric generation, while of the remaining 15% of consumptive rights, irrigation holds approximately 73%, mining accounts for 9% and potable water supply represents 6% (Donoso 2014: 220). Figure 3 represents Chile's sixteen AR and illustrates the distribution of consumptive water rights according to the regions and in terms of sector share of the total number of consumptive rights.[4] As can be observed, mining operations hold relatively large shares of consumptive water rights in the northern regions, and also irrigation is very present in most regions, the center of Chile being the most important area. Interestingly, although Chile's population is heavily concentrated in Santiago (XIII – RM) with 410 people per square kilometer, the agricultural industry seems to hold most consumptive water rights, while the rights destinated to sanitation, drinking and domestic use are comparatively very low.

4.3 Management of Potable Water

In line with the 1980 Constitution, also the drinking water and sanitation sector (WSS) underwent the transition from governmental water-supply utilities in the 1980s to a system characterized by private operators from 1988 (Donoso et al. 2015: 89). The system established in the 1990s separated the "regulatory and supervisory functions […] from the investment, production, and sale of service functions" (Donoso & Molinos-Senante 2017: 163), so that the State was in charge of regulating the provisioning system and companies were in charge of providing sanitation services and selling potable water.

4.3.1 Provisioning System

On the regulatory side, the governmental entity in charge of supervising the sanitation companies is the *Superintendencia de Servicios Sanitarios* (SISS), which covers the national scale (Cerda Toro 2017). The legal framework of the WSS sector put in place in 1988 presented the following principles (Donoso et al. 2015: 89):

- Full recovery of operation and maintenance costs
- Funding of necessary infrastructure reposition and development plan investment
- Tariff reductions when operators increase efficiency
- Operational margins that are consistent with the opportunity cost of capital

The idea behind these objectives is to make sure that the sanitation companies can satisfy demand over a 15-years horizon while selling potable water at efficient prices. Like this the tariffs guarantee

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[4] The Register of Water Use Rights of the DGA does not include information about the nature of water use for all rights. For this reason, Figure 3 illustrates the number of rights based on the total number of consumptive rights per region for which information is provided. Given that the missing information corresponds to a large share, this illustration is approximative and is probably not representative for the totality of consumptive rights.

the self-sufficiency of the WSS providers and the rentability of their operations, thus ensuring the continuity of potable water supply (Cerda Toro 2017). Therefore, on the provisioning side there are private companies supplying the service in urban centers and in rural areas. In urban regions, there are 53 private WSS providers that supply more than 99% of the urban population with high quality drinking water, placing Chile among developed countries in this field worldwide (Valdés-Pineda et al. 2014). Indeed, the regulatory scheme of 1988 improved the efficient allocation of resources and the quality of the service, increased the WSS provision coverage, and improved water conservation by consumers (Donoso et al. 2015: 93). In opposition to urban centers, rural areas suffered the lack of a public agency responsible for regulating the supply of drinking water and in 1960 less than 10% of the rural population enjoyed an adequate water supply system (Cariola & Alegría 2004; Donoso et al. 2015: 93). For this reason, since 1964, the Chilean government – initially supported by fundings from the Inter-American Development Bank (IDB) – adopted the Rural Sanitation Master Plan as part of the *Programa Nacional de Agua Potable Rural* (APR) (Donoso et al. 2015: 93). The APR aimed at providing semi-concentrated rural areas and concentrated rural towns with potable water[5] (Cariola & Alegría 2004). Within the program, the government subsidizes the installation of infrastructure and rural water user committees (RWC) manage the provision of water, as well as the tariff setting, in their areas (Donoso et al. 2015: 94). However, in contrast to urban areas, water-supply installations are vulnerable and the provision of water is of poor quality because the RWC have failed to set tariffs allowing them to fully recover their costs (Donoso et al. 2015: 94).

4.3.2 Tariffs

Concerning the tariffs set by the sanitation companies, the legal framework of the Chilean water and sanitation tariff system lists four principles that need to be respected when determining potable water prices (Donoso et al. 2015: 90; Donoso & Molinos-Senante 2017: 158):

- Economic efficiency
- Water conservation
- Equity
- Affordability

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[5] Semi-concentrated rural areas include settlements with 150-3000 inhabitants and a minimum population density of 8 households/km^2. Concentrated rural towns include all areas with over 3000 inhabitants and a minimum population density of 15 households/km^2 (Donoso et al. 2015: 94).

The objective of these principles is to conciliate the existence of a water and sanitation provider monopoly with the optimal allocation of water resources (Cerda Toro 2017). Indeed, the process of tariffs setting simulates a competitive market in order to comply with economic efficiency: WSS tariffs are based on a two-part tariff where the fixed tariff covers the monopoly's average costs related to investments and infrastructure, and a variable tariff, equal to the long-run marginal costs (MC) at which social welfare is maximized, covers the profitability of the operations (Donoso & Molinos-Senante 2017: 158). To comply with water conservation, WSS companies need to set the variable tariffs based on the different provisioning costs of the service due to seasonal changes and demographic differences. In fact, the Executive Decree 453 of 1988 establishes that nonpeak variable tariffs are set for the winter season when water is relatively more abundant and peak variable tariffs are set for periods of high demand during summer months (together with over-consumption tariffs when the average winter consumption is exceeded during the summer months). Like this, variable tariffs are determined in a way that consumers consider the scarcity of water in their consumption (Donoso et al. 2015: 90–91). For this reason, fixed and variable water tariffs vary according to location.

Finally, to meet the equity and affordability criteria of water tariffs, the Chilean government provides subsidies directly to the most vulnerable households, which are classified based on the annual *Caracterización Socioeconómica Nacional* (CASEN) survey estimating household per capita income (Donoso et al. 2015: 91). More concretely, the subsidy is directed to households of the lower socio-economic strata that face difficulties in covering their basic needs (Hormazábal & Muñoz 2006). The system is regulated by the Ministry of Interior and the Ministry of Planning which determine the amount of the block subsidy transferred to municipalities, which in turn covers between 15% and 85% of the water bill of the eligible households and up to a maximum consumption of 20 m^3 of water per month (Cariola & Alegría 2004; Hormazábal & Muñoz 2006).

In conclusion, this chapter illustrating Chile's water management system and explaining the principles governing the provision of potable water as well as the tariff setting mechanism provides the background information necessary to answer the research question:

> RQ: *Does the Chilean water management system encourage over-extraction and discourage access to water resources for certain actors in society, while reducing affordability of potable water in water scarce areas?*

5 Data

This chapter presents the data used in the analysis and is structured as follows: first, the sources from which the data were collected are presented; then, the process of cleaning and assembling is outlined; and finally, the strengths and weaknesses of the data are discussed.

5.1 Data Sources

The data result from a variety of different sources, coming from the Government of Chile, International Organizations, as well as academic articles. Moreover, the data is very diverse, as it includes legal texts, national registers, household surveys, private companies' reports, and geographic information system data. This is due to the mixed methods approach chosen in the context of this research. For the qualitative part, the *Código de Aguas* of 1981 will be at the center of the analysis, as it sets the rules of water resources management in Chile. The *Decreto con Fuerza de Ley 1122* was found on the national website of the Ministry of Justice of Chile (Ministerio de Justicia 1981). In addition, several academic articles and policy reports analyzing the water market will be used to interpret the WC according to the Critical Environmental Justice Framework (Pellow 2018).

For the quantitative part, different variables have been selected to construct the econometric model aiming to investigate a relationship between the agricultural sector's share of regional GDP and the final prices of potable water in the sixteen regions of Chile. More concretely, the model is composed of three dependent variables, namely the peak potable water prices, as well as the over-consumption water prices, that apply in the summer season between December and March, and the nonpeak potable water prices that consumers face in the winter season that lasts from April to November. These data were retrieved from the website of the SISS (Superintendencia de Servicios Sanitarios 2022). The main interest variable is the agricultural sector's share of regional GDP, which was found on the website of the Central Bank of Chile (Banco Central de Chile 2018a) and was estimated with information from the *Instituto Nacional de Estadísticas* (INE), the *Oficina de Estudios y Políticas Agrarias*, and the *Servicio Agrícola y Ganadero* (Banco Central de Chile 2018b). Moreover, several variables were selected to control for the measurement of the targeted relationship. Among others, the data of water quality were found in a report of the SISS (Superintendencia de Servicios

Sanitarios 2007). The information concerning the availability of water per region was taken from a report from the World Bank assessing the management of water resources in Chile (Banco Mundial 2011) and the data relating to the mean maximum temperatures and the mean precipitation rates per region between 1990 and 2020 were found on the website of the Climate Change Knowledge Portal of the World Bank (The World Bank Group 2021). The data for the variable "poverty" were collected from the *Informe de Desarollo Social* report that evaluated several results of the CASEN surveys between 2006 and 2017 (Ministerio de Desarollo Social 2021). Finally, the variable "population density" was calculated with information about Chile's regional population coming from a report of the INE regarding population trends and projections between 2002 and 2035 (Instituto Nacional de Estadísticas 2019a) developed with several different national registers and household surveys (Instituto Nacional de Estadísticas 2019b) and data about the regional surface areas (Instituto Nacional de Estadísticas 2022).

5.2 Cleaning & Assembling

Given that the qualitative analysis is mainly based on one legal document, no data cleaning or assembling has been carried out. In contrast, the data selected for the quantitative part have been subject to different operations. The first adjustment relates to many of the variables and is due to the chosen point in time of the analysis, which is situated ± 5 years around 2007. Indeed, the regions of *Los Ríos* (XIV) and of *Arica y Parinacota* (XV) were both divided from today's *Los Lagos* (X) and *Tarapacá* (I) regions respectively and started to operate independently in 2007 (Banco Central de Chile 2018b). For this reason, sometimes the XIV and XV regions do not appear in the data. Similarly, often there is no data concerning the *Ñuble* (XVI) region which split from the *Biobío* (VIII) region only in 2018 (Parra et al. 2020). Nevertheless, many documents and datasets acknowledged the problem of missing observations for the totality of today's AR, suggesting that their reported data are a mean of the previously united regions. In consequence, to avoid too many missing values in the final dataset composed of only sixteen observations, the same values were reported for *Los Ríos* and *Los Lagos*, for *Arica y Parinacota* and *Tarapacá*, and for *Ñuble* and *Biobío.*

The second operation that took place is related to the variable's meaning. Indeed, in the case of the contribution of the agricultural sector's share to regional GDP, the values were expressed in absolute terms without giving any indication of their relative importance. Because of this, the regional production of the agricultural sector expressed in current prices was transformed to indicate the share of agriculture in relative terms. Similarly, the data relating to population density was constructed on the basis of two different sources, one related to total population per region in 2002 (Instituto Nacional de Estadísticas 2019a) and the other presenting Chile's AR surface in km^2 (Instituto Nacional de Estadísticas 2022), because the information about population densities was not available for the years of interest. Nevertheless, most variables were ready to be used the way they were collected. This is the case for the data about water availability, precipitation rates and temperatures, as well as relative poverty rates, which were kept in their original form.

Finally, some variables have been subject to various operations and more time-consuming assembling. For example, the data for the three variables related to the prices of potable water were retrieved from the website of the SISS (Superintendencia de Servicios Sanitarios 2022), which is structured by company per each AR. However, the information about the prices for the year 2007 varies within each company according to their location of business in the respective regions. For this reason, the data has been collected for each place of activity and was then assembled for each operating firm in every region. The final resulting prices for each region are thus the arithmetic mean of all the different prices charged by each business. Furthermore, the prices for 2007 were divided in different months of the year and presented in terms of *fijo* (fixed), *no punta* (nonpeak), *punta* (peak), and *sobreconsumo* (over-consumption). Therefore, the final prices were assembled according to the seasonal information, given that the nonpeak tariffs apply in the winter season while the peak and overconsumption tariffs apply in the summer season. Similarly, the information about water quality was listed in terms of twenty of the most important sanitation companies supplying potable water in the country (Superintendencia de Servicios Sanitarios 2007). Thus, these enterprises were used as proxies for the sixteen regions and an arithmetic mean was calculated for those supplied by more than one firm.

5.3 Limitations of the data

In terms of reliability, the data about potable water prices, as well as potable water quality used in the context of this thesis are provided by the private sanitation companies themselves and communicated to the SISS. The problem is that these firms are biased, as they have clearly no interest in exposing themselves with inconvenient data, and that the SISS has only a limited capacity to check and control the validity and accuracy of the information received (Superintendencia de Servicios Sanitarios 2007; Superintendencia de Servicios Sanitarios 2021).

In terms of representativity, the data about the volume of water available per person in each region presents some shortcomings. First, water availability is expressed in terms of average total surface runoff, which constrains the indicator to only surface water, therefore neglecting moisture and groundwater storages (Damkjaer & Taylor 2017). Second, the variable only gives an indication of how much surface water is available per person in each region after the net contribution of precipitation controlled for outflows related to evapotranspiration[6], without however giving any indication about water stress related to demand or consumption of water by agriculture, mining, industries, or urban centers for instance (Damkjaer & Taylor 2017). Indeed, the values vary significantly with respect to the WSI proposed by Aitken et al. (2016) for eight of the sixteen regions of Chile, as this measurement includes the water demand of several sectors of the economy and puts them into relation with the regions' respective water availabilities for the year 2007 (Dirección General de Aguas 2007a; Dirección General de Aguas 2007b). Moreover, also the data illustrating the relative contribution of the agricultural sector to regional GDP is very approximative. Indeed, it assembles different activities, such as agriculture, fruticulture, livestock, and forestry without giving specific information about the relative importance of each (Banco Central de Chile 2018b). More generally, the data selected for the purpose of this thesis is representative for the particular year of constraint, given that almost each variable is available for all regions. Nevertheless, given the cross-regional nature of the analysis, the sample is very small as it presents only sixteen observations. Unfortunately, the very specific data chosen for this cross-sectional comparison were not available in a consistent way over time, which is the reason why it was decided to focus on the year of 2007.

Closely related to the question of representativity, the final assembled dataset used for the quantitative part of this thesis has a strong internal validity for the case study of Chile, as it allows to gain in-depth understanding of the reality of water resources in the sixteen regions around the year 2007. Although the findings relate only to this year, they allow for a certain degree of generalizability for Chile because 2007 does not represent any particular year within Chile's history. Moreover, the insights of the qualitative analysis, which is based on the 1981 Water Code and applies to the whole of Chile, will indicate some general trends, thus strengthening the external validity of the case study.

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[6] Evapotranspiration indicates the loss of water through evaporation from the soil in combination with the loss of water related to transpiration of leaves of plants. Evapotranspiration can also be understood as the "natural losses" of water resources independent from human activities. Evapotranspiration is affected by "the amount of solar radiation, atmospheric vapor pressure, temperature, wind, and soil moisture" (Rafferty 2022).

6 Methods

This thesis proposes a mixed methods approach for the analysis of the Chilean water resources management system to answer the two sub-research questions. This research design is the most appropriate to gain an in-depth understanding of the case study, as the quantitative analysis is unable to capture issues related to the reproduction of unequal power relations. This approach therefore encompasses the interpretation of the 1981 Water Code through the lenses of the Critical Environmental Justice Framework (Pellow 2018) and the evaluation of the determinants of potable water prices in the sixteen AR through an econometric analysis. For this reason, this chapter starts by outlining the four pillars of the CEJ framework that will guide the qualitative analysis and then discusses its limitations. The second part of the chapter focuses on the quantitative analysis and first specifies the model, then presents the descriptive statistics and finally illustrates the econometric method, the Ordinary Least Squares (OLS) (Wooldridge 2015: 68–186), and discusses its assumptions as well as its limitations.

6.1 Critical Environmental Justice Framework

6.1.1 Qualitative Method

The method chosen for the qualitative analysis of the 1981 Water Code is the CEJ Framework proposed by Pellow (2018). The framework sets the principles guiding the evaluation of the legal document.

Pellow (2018: 22–23) proposed the CEJ Framework as a reaction to the principles resulting from EJ, which – in his opinion – demands that the state intervenes through legislative changes, institutional reforms, or policy concessions to change unjust power relations, therefore possibly reproducing them without questioning the true origin of the observed social and environmental inequalities. For this reason, the CEJ Framework investigates the primary actors responsible for producing social and environmental inequalities through its four pillars.

(1) The first pillar recognizes that inequalities characterized by violence, destruction, and discrimination within the human and non-human worlds are inherently connected. Indeed,

CEJ considers that oppression is intersectional across people, animals, ecosystems, and the environment through a logic of domination practiced by more powerful groups (Pellow 2018: 23–25). More specifically, multiple social categories are entangled in the production of social and environmental inequalities, that can range "from race, gender, sexuality, ability, and class to species" (Pellow 2018: 23).

(2) The second pillar focuses on the scale and temporality of the production of socio-ecological injustices. The idea proposed by Pellow (2018: 23) is that inequalities are the result of "complex spatial and temporal causes, consequences and possible resolutions of environmental justice struggles" and that inequalities need to be investigated according to specific geographic locations and with regards to the past, as well as the future, especially in the context of climate change (Pellow 2018: 23–27).

(3) The third pillar of CEJ considers that social and environmental inequalities are not only a product of history, but are deeply embedded in society and state structures, implying that the system itself is producing injustices. This is the main breaking point with EJ studies, given that according to the CEJ perspective, nation states cannot deliver justice and regulate inequalities because they are "authoritarian, racist, patriarchal, exclusionary, and anti-ecological" (Pellow 2018: 29).

(4) The fourth pillar of CEJ proposes the concept of "indispensability" as the road for transformative process, where the idea is that all actors in society – also the marginalized ones – are indispensable to the present and necessary to build a sustainable, just and resilient future (Pellow 2018: 24). This recognition paves the way for the inclusion of marginalized actors within decisional processes.

These pillars will guide the analysis of the 1981 WC. More specifically, the legal text will be evaluated in terms of the reproduction of socio-ecological inequalities for the human and non-human worlds and in terms of its temporal and spatial jurisdiction, by answering the first sub-research question:

> SRQ1: *Does the 1981 Water Code reproduce inequalities across time and space for both the human and natural worlds?*

As already mentioned in 2.3 Privatization & Inequalities, the CEJ attempts to propose a holistic approach to investigate power dynamics within Chile's water management system. Nevertheless, as pointed out by Yaka (2019), this approach is inherently anthropocentric, given that it is based on claims coming from human communities and not from the natural world. Still, the CEJ seems an appropriate approach to answer the sub-research question, as it frames inequalities in terms of justice in a context of human communities being deeply interconnected with their surrounding natural ecologies (Yaka 2019).

6.2 Econometric Analysis

6.2.1 Model Specification

The three outcome variables of the econometric model are the different prices of potable water[7], according to their respective seasonality.

- **Nonpeak potable water prices** (NPWP): this variable is measured in Chilean pesos per cubic meter (m^3) and represents the historical potable water tariff for each sanitation company according to the localities of its dependency during the winter season, which lasts from April to November, in 2007 (Donoso & Molinos-Senante 2017; Superintendencia de Servicios Sanitarios 2021b).
- **Peak potable water prices** (PPWP): this variable is measured in Chilean pesos per cubic meter (m^3) and represents the historical potable water tariff for each sanitation company according to the localities of its dependency during the summer season, which lasts from December to March, in 2007 (Donoso & Molinos-Senante 2017; Superintendencia de Servicios Sanitarios 2021b).
- **Over-consumption potable water prices** (OCPWP): this variable is measured in Chilean pesos per cubic meter (m^3) and represents the historical potable water tariff for each sanitation company according to the localities of its dependency during the summer season, which lasts from December to March, in 2007. The over-consumption tariff applies when the average water consumption registered during the winter season is exceeded during the summer season. In other words, the peak tariff applies until the winter average water consumption is reached and the over-consumption tariff applies when the volume consumed increases further (Donoso & Molinos-Senante 2017; Superintendencia de Servicios Sanitarios 2021a).

The variable of interest is the share of agricultural production within regional GDP:

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[7] The prices of the peak and nonpeak potable water prices used in the analysis were developed by summing the fixed tariffs and the variable tariffs for each season.

- **Share of agriculture** (AGR): the variable is measured in percentage (%) of total regional GDP and indicates the relative importance of the agricultural sector within each regional economy. The idea behind choosing the share of agriculture as the treatment variable is that there could be a positive association with the different prices of potable water. The hypothesis is that where the agricultural sector is relatively more important in the regional economy, it operates more intensively and thus extracts more water resources for its production. The higher volume of water extracted for this purpose would result in relatively higher water scarcity in the region, which would imply that sanitation services have access to fewer water resources, thus demanding higher prices for potable water.

Finally, the variables chosen to control for the desired effect are the following:

- **Water availability** (WA): the variable is measured in cubic meters per person per year (m^3/person/year) and gives an indication of the distribution of total surface water resources according to the population distribution in the sixteen regions of Chile. This variable was included because the assumption is that where water per capita is more abundant its relative offer is larger, thus influencing the prices of potable water negatively. As acknowledged in the data limitations section, this variable is a proxy because it only includes surface water availability and fails to give information about the degree of stress of water resources.
- **Water quality** (WQ): the variable is measured in percentage (%) and indicates the degree of compliance of each sanitation company with the *NCh 409 Agua Potable – Parte 1: Requisitos y Parte 2: Muestreo* regulation, which sets the conditions in terms of bacteriology, turbidity, residual free chlorine, critical and non-critical parameters below which no company is allowed to supply potable water (Superintendencia de Servicios Sanitarios 2007). This variable was included because it is assumed that there is a positive association with prices: when water quality is good sanitation companies have lower costs of filtering and cleaning water prior to sales and can thus charge relatively higher prices (Hollman & Boyet 1975).
- **Average maximum temperatures** (MT): the variable is measured in Celsius degrees (°C) and indicates the average maximum temperature between 1990 and 2020 in each region of Chile. This variable was included because temperatures influence the rate of evapotranspiration, which in turn influences the volume of water available in a region. For this reason, the hypothesis is that the higher the temperatures, the lower the availability of water, forcing sanitation firms to charge higher prices (Rafferty 2022).

- **Average precipitation rates** (AP): the variable is measured in millimeters (mm) and indicates the average precipitation rates between 1990 and 2020 in each region of Chile. This variable was included because it is another indicator of water availability, as the higher the precipitation rate, the higher the rate of recharging, especially for areas strongly dependent on rainfall for water recharge (Donoso, Guillermo & Dinar 2015). Therefore, a high precipitation rate could be associated with lower prices for potable water.
- **Share of poverty** (PO): the variable is measured in percentage (%) and represents the share of households facing income insufficiency for accessing a minimum standard of income necessary to satisfy a set of basic needs (Ministerio de Desarollo Social 2021). The poverty line to which the poverty rates are compared to are calculated by the Economic Commission for Latin America and the Caribbean (ECLAC) based on consumption baskets dating from the 1980s (Comisión Económica para América Latina y el Caribe 2018; Ministerio de Desarollo Social y Familia & Programa de las Naciones Unidas para el Desarrollo 2017). The share of poverty was included in the analysis as a proxy for well-being standards because the assumption is that where poverty shares are higher, living standards are lower, which is reflected in lower prices of potable water.
- **Population density** (PD): the variable is measured as the ratio of total population divided by the total surface of each region (pop/km^2) and indicates the concentration of the Chilean population. The variable was included in the model because it is assumed that the rate of concentration of people affects prices of potable water. Indeed, it is hypothesized that people concentrate in urban centers, where prices are generally higher than in rural areas. Nevertheless, the expected effect is ambiguous because, on one hand, a high population density could be associated with a higher demand compared to the offer of potable water thus implying higher prices, but on the other hand, it could be associated with larger economies of scales with lower unit distribution costs, thus implying lower prices (Thorsten et al. 2009).

Below, Table 1 presents a summary of all the variables included in the quantitative analysis.

Table 1: Overview of Variables – Source: author's own elaboration

Type	Role	Variable	Name	Measurement Unit	Timeframe	Predicted Effect & Hypothesis	
Dependent		NPWP	Nonpeak potable water prices	Chilean pesos/m^3	2007		
		PPWP	Peak potable water prices	Chilean pesos/m^3	2007		
		OCPWP	Over-consumption potable water prices	Chilean pesos/m^3	2007		
Independent	Interest	AGR	Contribution of the agricultural sector to regional GDP	%	2013	+	Where the agricultural sector operates more intensively there is less water available for sanitation companies (P+)
	Control	WA	Water availability	m^3/person/year	2009	-	Where water pro capita is more abundant there is more offer than demand (P-)
	Control	WQ	Water quality	%	2007	+	Where the quality of water is better, sanitation companies can ask for higher prices (P+)
	Control	MT	Average maximum temperature	°C	1990-2020	+	Where maximum temperatures are higher there are larger evapotranspiration losses that make water scarcer (P+)
	Control	AP	Average precipitation rates	mm	1990-2020	-	Where average precipitation rates are higher water recharging is larger, augmenting the availability (P-)
	Control	PO	Share of poverty	%	2006	-	Where poverty rates are higher prices need to adapt to relatively lower living standards (P-)
	Control	PD	Population density	people/km^2	2002	±	Where population is denser there is more overall demand for water (P+) but also larger economies of scale to provide potable water (P-)

The final models include the above explained variables. However, some final adjustments were carried out. First, both the variables "water availability" and "average precipitation rates" were divided by 1000 because the data were too big. For this reason, water availability is measured in $10^3 m^3$/person/ per year and average precipitations are measured in meters (m) in the final models. Moreover, in Model 3 the variable indicating the volume of water availability per person was deleted because of multicollinearity (see 6.2.3 Quantitative Method). Second, the form of the three potable water prices was changed by taking the natural logarithm of their values. The reason for this is that researchers have used hedonic price models[8] for the determination of the cost function of water prices and found that a log-linear specification best represented the relationship (Thorsten et al. 2009). Unfortunately, through this operation four observations of the OCPWP were lost because the reported values were equal to 0, whose log is undefined.

Model 1: Nonpeak Potable Water Prices (winter season)

$$lnNPWP_i = \beta_0 + \beta_1 AGR + \beta_2 WA + \beta_3 WQ + \beta_4 MT + \beta_5 AP + \beta_6 PO + \beta_7 PD + \varepsilon_i$$

Model 2: Peak Potable Water Prices (summer season)

$$lnPPWP_j = \beta_0 + \beta_1 AGR + \beta_2 WA + \beta_3 WQ + \beta_4 MT + \beta_5 AP + \beta_6 PO + \beta_7 PD + \varepsilon_j$$

Model 3: Over-consumption Potable Water Prices (summer season when average winter water consumption is exceeded)

$$lnOCPWP_k = \beta_0 + \beta_1 AGR + \beta_2 WQ + \beta_3 MT + \beta_4 AP + \beta_5 PO + \beta_6 PD + \varepsilon_k$$

---

[8] Hedonic models are used to estimate implicit price functions starting from the characteristics of related products in a particular product class. These have been applied in areas such as housing and labor markets, but also for water and sewer utilities prices (Thorsten et al. 2009).

6.2.2 Descriptive Statistics

In this section, the characteristics of the final sample are described.

Table 2: Summary Statistics – Source: author's own computation

Variable	N° Observations	Mean	Median	Standard Deviation	Min	Max
NPWP	16	7.07	0.21	7.08	6.78	7.45
PPWP	16	7.08	0.20	7.06	6.80	7.45
OCPWP	12	6.96	0.46	6.80	6.39	7.81
AGR	16	0.06	0.05	0.05	0.00	0.13
WA	16	334.53	858.28	14.19	0.05	2993.53
WQ	16	0.90	0.06	0.90	0.77	0.99
MT	16	15.54	2.68	16.12	9.16	18.26
AP	16	0.48	0.41	0.39	0.03	1.31
PO	16	0.31	0.11	0.31	0.12	0.48
PD	16	45.28	100.60	13.43	0.28	409.94

Table 2 reports the main features of the dataset, which is composed of sixteen observations, except for the dependent variable "over-consumption potable water prices" which only counts twelve (see APPENDIX B.1). As can be seen, some variables are very clustered around their mean, such as the "nonpeak potable water prices", "peak potable water prices", "share of agricultural sector", "water quality", as well as "share of poverty" given that their standard deviations are lower than 0.21. For these variables, the mean is thus a good indicator for the observations. In contrast, "average maximum temperatures", but especially "water availability" and "population density" present a very wide range between the minimum and maximum values, which is reflected in their standard deviations too. For example, WA's values start at 0.05 and can reach 2993.53, indicating a very high variability across the observations.

6.2.3 Quantitative Method

Given the cross-sectional nature of the data at one specific point in time, the idea is to compare differences among the sixteen regions. For this purpose, the Ordinary Least Squares (OLS) method has been chosen to estimate the effect of the independent variables on the three multiple linear regression models of potable water prices. The OLS method consists in minimizing the residual sum of squares (RSS), which represents the part of the models that is unexplained by the independent variables, and in predicting the coefficients of each explanatory variable (Wooldridge 2015: 71–77). To carry out an OLS estimation, the five Gauss-Markov assumptions need to hold to make it the best linear unbiased estimator (BLUE).

First, the models need to be linear in their parameters leaving some flexibility concerning the variables themselves, which can be logarithmic or square functions (Wooldridge 2015: 83). Second, the sample needs to be drawn randomly from the population so that the estimated coefficients represent the behavior of the studied population. Third, in the sample there is no perfect multicollinearity among the independent variables, meaning that they cannot be constants or linear combinations of each other. This implies that the variables can be correlated between each other, but not highly (Wooldridge 2015: 84). Here below, Table 3 shows the outputs of the variance inflation factor (VIF) test, where the smaller the outputs the least multicollinearity.

Table 3: Test of Multicollinearity – Source: author's own computation

Independent Variables	Models		
	Model (1)	**Model (2)**	**Model (3)**
AGR	6.77	6.77	5.94
WA	3.98	3.98	
WQ	2.37	2.37	3.44
MT	5.31	5.32	2.68
AP	2.20	2.20	4.66
PO	7.79	7.79	5.79
PD	1.40	1.40	2.22

From the literature it emerges that, to interpret these outputs, 10 is a good cut-off value allowing to conclude that if the values exceed it multicollinearity is a problem for estimating the coefficients (Wooldridge 2015: 98). As can be seen in the table, all outputs appear to be lower than 10. However, the variable "water availability" was deleted from Model 3 because it showed a high correlation with the variable "average precipitation rates" (see APPENDIX B.2).

The fourth assumption is the zero conditional mean, which considers that the error term has an expected value of zero. This assumption is very important for carrying out an OLS estimation, but it is also very likely to be violated in practice, given that it is nearly impossible to account for every factor influencing a dependent variable (Wooldridge 2015: 86–87). The fifth assumption, also called the homoskedasticity assumption, relates to the variance of the errors and demands that it is constant and does therefore not depend on the different combinations of explanatory variables (Wooldridge 2015: 93). For this purpose, a studentized Breusch-Pagan test was carried out to detect heteroskedasticity. The results can be found in Table 4:

Table 4: Studentized Breusch-Pagan Test – Source: author's own computation

Models		
Model (1)	**Model (2)**	**Model (3)**
W = 8.12 p-value = 0.32	W = 5.66 p-value = 0.58	W = 6.59 p-value = 0.36

For this test, the null hypothesis H_0 is that the variances of the residuals are all equal and the alternative hypothesis H_A is that the variances differ. Given that the p-values are all greater than the threshold p-value = 0.05, the null hypothesis is not rejected and homoskedasticity can be assumed. Finally, if the five assumptions hold the OLS is BLUE because it is unbiased (assumptions 1 to 4) and has the smallest variance possible (assumption 5).

Although the Gauss-Markov assumption are respected, a further assumption is necessary, which is the normality assumption of the distribution of the error terms, implying that the population error is independent from the explanatory variables (Wooldridge 2015: 118–119). For this purpose, a Shapiro-Wilk normality test was computed, and its results are presented in Table 5.

Table 5: Shapiro-Wilk Normality Test – Source: author's own computation

Residuals		
Residuals Model (1)	**Residuals Model (2)**	**Residuals Model (3)**
W = 0.97 p-value = 0.87	W = 0.93 p-value = 0.28	W = 0.90 p-value = 0.18

For this test, the null hypothesis H_0 is that the residuals are normally distributed, and the alternative hypothesis H_A is that they are not. Given that the p-values are all greater than the threshold p-value = 0.05, the null hypothesis is not rejected, and a normal distribution of the errors can be assumed. In APPENDIX B.3 density plots of the errors' distribution can be found for the three models.

In conclusion, an OLS estimation has some limitations. First, the method is suited for linear models, which do mostly not represent the true relationships, as real-world interconnections tend to be more complicated (Backward 2012). Second, OLS regressions are very sensitive to outliers and can therefore perform unsatisfactorily if some excessively large or small values are present within the observations (Backward 2012). This could for example be a problem for the variable "population density" given that the values are between 0.28 people/km^2 and 62.08 people/km^2 for fifteen regions but equals 409.94 people/km^2 for the *Región de Metropolitana de Santiago* (XIII – RM). Finally, a last limitation of the OLS method is that it can account only for correlation, but not for any causal relationship. Nevertheless, it is a good method to answer the second sub-research question of this thesis:

> SRQ2: *To what extent is the agricultural sector's share of regional GDP related to drinking water prices in Chile's administrative regions in 2007?*

7 Empirical Analysis

The following chapter presents the results of the qualitative and quantitative analyses and discusses the main findings. The first part is dedicated to the evaluation of the strengths and weaknesses of the 1981 Water Code as well as the interpretation of its main features through the CEJ lenses, while the second part of this chapter illustrates the statistical results of the OLS estimation and discusses the findings in relation to Chile's potable water tariff-setting system.

7.1 Critical Environmental Justice Framework

7.1.1 Results

As mentioned in the country background chapter, together with the 1980 Constitution the 1981 WC grants private property rights for water resources, thus strengthening legal security for water owners. Once they are granted, the rights are governed by private civil law like any other private property right (Bauer 2005). The increased legal security has encouraged private investments in water use and infrastructure, by incentivizing farmers to adopt water-saving technologies for example (Bauer 2015; Donoso et al. 2015: 88). Moreover, the WC does not require water rights owners to use their resources, thus not penalizing users with a "use it or lose it" regulation (Bauer 2005). According to Budds (2020) the combination of the conversion of water rights into individual private property have fostered strategies of accumulation and competitive rather than cooperative behaviors in the water market.

With the 1981 WC, different types of water rights have been created. For instance, there is a distinction between consumptive and non-consumptive rights to separate activities which have different needs of water resources. In line with this, the non-consumptive rights have been beneficial for the development of the hydroelectric power sector in several regions in Chile (Bauer 2005). On the other hand, surface water rights are different from groundwater rights, a distinction that has contributed to the mining sector development in the north of Chile (Donoso et al. 2015: 88). However, Bauer (2004; 2005) argues that the definition of water rights is vague and incomplete, as for example the continuity of water is not considered, resulting in negative externalities that are not regulated by the law (Donoso 2021). Furthermore, the WC does not outline any hierarchy in water use when it comes to the different productive sectors, resulting in complex conflicts between users (Budds 2020).

Another characteristic of the WC is that it allows owners to trade their water rights within a water market, with the advantage of having a high degree of flexibility in water ownership, use and management (Romano & Leporati 2002). Indeed, this system permits reallocation of water rights across geographic areas and from lower to higher values uses between different economic activities (Bauer 2004; 2005). This has proven to be beneficial in mitigating impacts from droughts for example, thanks to temporal transfers to less water-intensive industries (Donoso et al. 2015: 88). Furthermore, the freedom of trading the rights coupled with the guarantee of permanent access to water resources through private property rights has increased water security for rights owners (Budds 2020). Nevertheless, in practice not much active trade is observed, except for areas with high water scarcity, and water rights prices have varied to a great extent, probably because of the lack of perfect competition conditions within the market, characterized by asymmetric information among owners (Banco Mundial 2011; Donoso 2021). Moreover, problems of speculation, accumulation and hoarding make the water market problematic too (Bauer 2004).

The main issues of the WC include the excessive fragmentation of water institutionality, the insufficient data about water rights and their owners, as well as the lack of a proper conflict resolution mechanism. Concerning the first weakness, Chile's institutional framework governing water is fragmented and ineffective because of unclear allocations of responsibilities and competition of powers among ministries (Bauer 2015; Donoso 2014: 225; Donoso 2021). For example, there is bad coordination of water uses because different types of rights are regulated separately, and institutions related to water quality are disconnected from institutions managing water quantity (Bauer 2004; Donoso 2014: 225). Related to the second problem, the DGA – which is in charge of compiling a national registry of water rights – only includes formalized, newly granted or formally traded rights, which however correspond only to a small minority of all water rights, thus resulting in an incomplete record (Valdés-Pineda et al. 2014). This incompleteness has several implications: first, it leads to a lack of transparency within the water market (Banco Mundial 2011; Donoso 2021); second, it leads to over-allocation of water rights by the DGA for certain basins (Donoso et al. 2015: 87); and third, it leads to the over-extraction of water resources because of insufficient information about the quantity of available water (Bauer 2004). Related to the last point, water rights owners are not required to communicate their water-extractive activity to the DGA and when rights are traded in the market the volume of extraction varies according to the economic activity, thus possibly exceeding the environmental limits (Donoso 2021). Finally, the third problem of the WC is related to the lack of conflict resolution mechanisms. Indeed, given that the DGA has no regulatory authority, in case of disputes among water users, they either resolve them themselves, or they hand over the conflict resolution to ordinary civil courts, which however have no expertise in water-related matters (Bauer 2015; Budds 2020; Donoso 2014: 224).

7.1.2 Discussion

Given that the analysis shows that the WC has some general flaws, this section will relate these findings to the CEJ in terms of production of inequalities across time and space for the actors of Chile's society and the environment. The first thing that can be noted is that the 1981 WC is a perfect example of a top-down water policy formulation. Indeed, it is a nationwide and thus universalistic law that promotes objectifying and de-contextualizing principles, directly harming local water user communities. In fact, institutionally recognized water rights often clash with traditional and historical water rights of indigenous communities (Boelens, Getches & Guevara-Gil 2010: 3–5). More generally, water conflicts in Chile have grown deeper in the last decade, especially between extractive economic industries and indigenous as well as peasant communities, and with respect to the environment (Bauer 2015). For instance, several clashes between mining industries in the north have been observed, leading – among others – to the displacement of indigenous communities because of exhaustion or pollution of water. In addition, hydropower companies have been conflicting with indigenous people because of the control of water and implementation of large-scale projects in territories traditionally inhabited by local communities without considering their needs (Torres & Bolin 2015). Related to environmental conflicts, agricultural, industrial, and mining activities have led to the degradation of several watersheds across the country to the expense of indigenous and peasant communities (Larrain 2012).

Another important point highlighting the reproduction of inequalities is the exclusion of indigenous and peasant communities and the environment from decision-making processes. For example, when it comes to taking measures to counter water scarcity, very often the Chilean government imposes top-down infrastructure solutions promoting water-use efficiency instead of considering the needs of all actors of the economy. Indeed, in several occasions the support of water-intensive export industry privileging commercial farmers was preferred instead of diversifying the agricultural sector with a viable mix of small and large farmers producing for the domestic and the export markets within environmental limits (Budds 2020). In general, it can be inferred that the current system under the 1981 WC has a general preference for export-oriented industries. Whether flora and fauna are destroyed as a result of over-extraction, indigenous communities are displaced as a result of harmful economic activities, indigenous communities are prevented access to water through their traditional historical rights, or extraction is allowed until certain areas are declared inhabitable "scarcity zones", the system is set up in a way to encourage the industrial activities nourishing Chile's economy, no matter the effects on vulnerable communities and ecosystems (Banco Mundial 2011; Larrain 2012; Macpherson & Salazar 2020; Martin 2016).

A last outcome of the 1981 WC is that it reproduces unequal distribution of water rights across the Chilean economy, thus undermining equal access to water resources. As mentioned in the country background chapter, most of the water rights are concentrated in the hands of the export oriented activities, with the hydroelectric sector owning 85% of non-consumptive rights, irrigation holding 73% of consumptive water use, and mining owning most rights in the northern regions of the country (Donoso et al. 2015: 82–84; Larrain 2012). Given the tight relationship of these industries with the political elites, this system generates negative impacts especially on low-income and subsistence agriculture, particularly in rural areas (Budds 2004). Indeed, peasants are usually unable to participate in the water market because their historical rights are not formalized according to the law; but in case they are, smallholders usually enter the market as rights sellers with a very weak bargaining power when it comes to the bilateral determination of the price (Budds 2004; Romano & Leporati 2002).

It becomes evident that the institutional framework under the 1981 WC is characterized by a vicious cycle of self-reinforcing elements that reproduce inequalities across actors and space and maintain unequal power relations over time. For this reason, Table 6 sums up the findings of the analysis of Chile's WC according to the CEJ framework.

Table 6: Critical Environmental Justice Framework Perspective on the 1981 Water Code – Source: author's own elaboration

Pillars	**CEJ**	**Human Communities**	**Environment**
1° Pillar	An intrinsic connection between vulnerable communities & ecosystems	Rural, peasant, and indigenous communities' cultural and economic lives depend on their local environment, and on water in particular (Macpherson & Salazar 2020).	
2° Pillar	Geographical and temporal reproduction of inequalities	Tensions arise particularly in areas characterized by scarce water resources and because of unsolved historical issues (non-recognition of traditional water rights & exclusion from the water market).	Water over-extraction is observed particularly in scarce regions, paving the way towards water exhaustion for future generations.
3° Pillar	Reproduction of inequalities through institutional processes	The rules and regulations since 1981 favor the export-oriented economy and exclude local communities from the Chilean growth model (Macpherson & Salazar 2020).	The rules and regulations since 1981 favor the export-oriented economy to the detriment of the environment and of natural resources, such as water.
4° Pillar	Indispensability of all communities and ecosystems	There is the recognition that peasants and indigenous are part of the identity of the country and that their inclusion in the development process is important for resilience (Boelens, Getches & Guevara-Gil 2010: 5).	There is the recognition that water is needed to ensure sustainable development in the future (Macpherson & Salazar 2020).

In conclusion, it can be said that "the Chilean model for water management has a strong economic leg and two weak social and environmental legs, making it unbalanced overall" (Bauer 2005: 161). The application of the CEJ framework on the functioning of the WC has made it possible to answer the first sub-research question *"Does the 1981 Water Code reproduce inequalities across time and space for both the human and natural worlds?"*, as the results show that the legal text reproduces unequal power relations over time and across the different regions of Chile for vulnerable groups in society, such as rural indigenous and peasant communities, and for water resources more generally, given their exposition to over-extraction. This finding is in line with Chile's overall history, which is characterized by an exclusionary growth process.

7.2 Econometric Analysis

7.2.1 Results[9]

Table 7 presents the results of the regression analyses of the three models, all having sixteen observations, except for Model (3) which only presents 12.

Table 7: Ordinary Least Squares Regressions Output – Source: author's own computation

Independent Variables	Dependent Variables		
	NPWP (1)	**PPWP (2)**	**OCPWP (3)**
Constant	**5.70***** (0.57)	**5.17***** (0.66)	-2.75 (2.93)
AGR	0.93 (1.09)	1.38 (1.26)	6.50 (3.69)
WA	0.0001 (0.000)	**0.0001**** (0.0001)	
WQ	**1.98**** (0.50)	**2.25***** (0.58)	**6.15**** (2.01)
MT	-0.002 (0.02)	0.02 (0.02)	**0.31**** (0.09)
AP	**-0.32***** (0.07)	**-0.29***** (0.08)	**-1.47**** (0.51)
PO	-0.88 (0.48)	**-1.05*** (0.55)	-2.80 (0.001)
PD	**-0.001**** (0.0002)	**-0.001*** (0.0003)	0.000 (0.001)
Observations	16	16	12
R^2	0.93	0.90	0.87
Adjusted R^2	0.88	0.82	0.72
Residual Std. Error	0.08 (df = 8)	0.09 (df = 8)	0.24 (df = 5)
F Statistic	16.38*** (df = 7; 8)	10.67*** (df = 7; 8)	5.83** (df = 6; 5)
Significance	* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$		

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[9] To provide a sensitivity analysis of the results, it seemed interesting to repropose the three models under different restrictions related to climatic factors, given their importance in the water prices determination (as will be seen in 7.2.1 Results). Therefore, it was decided to merge the sixteen regions according to the five climatic macrozones of Chile, namely Far North, Near North, Central Chile, Near South, and Far South. However, the already small sample of the current models shrunk even further to only five observations and led to the elimination of too many variables. For this reason, it was decided to not include it in this thesis.

The first thing that can be noticed is that our variable of interest is never significant in the three models even though the relationship between AGR and the dependent variables NPWP, PPWP, and OCPWP appears to be positive, as expected. Therefore, although the results have no statistical meaning, it seems that when the share of the agricultural sector is relatively higher, meaning that more water is extracted by agricultural industries, the prices of potables water are relatively higher as well.

Concerning WA and WQ two different outcomes can be observed. Concerning water availability, it looks like its contribution to the determination of prices of potable water is practically null, given that the coefficients in Model (1) and Model (2) are very close to zero. Moreover, it seems that this result is significant at the 5% level only for Model (2), where a one unit (measured in 10^3m^3/person/ per year) increase in WA is associated with a 0.01%[10] increase in PPWP. Concerning water quality, it results that WQ is positively related with all NPWP, PPWP, and OCPWP in an increasing way, indicating that when the quality of water is high, the prices of potable water are higher as well, especially in summer with more water scarcity. Statistically, the regression results are always significant at the 5% and the 1% level for Model (2). The interpretation for Model (2) for instance is that when WQ increases by one unit (measured in percentage), PPWP increases by 225% on average *ceteris paribus*. This effect is very large and is probably due to the small span of WQ's observations, which ranges from 77% to 99% of compliance with the optimal water quality.

Related to the variables about environmental conditions, MT seems to play an ambiguous role. While it is not significant in Model (1) and Model (2), when it comes to Model (3) average maximum temperatures are positively related to over-consumption water prices and are statistically significant at the 5% level. This means that when maximum temperatures increase by one unit (measured in Celsius degrees), OCPWP increase by 31% on average *ceteris paribus*. Concerning AP, it appears that average precipitation rates play a relatively important role for the determination of water prices, especially in summer for the determination of OCPWP. Indeed, the coefficients are always significant, at the 1% level for Model (1) and Model (2), and at the 5% level for Model (3). This indicates that when precipitation rates for example increase by one unit (measured in meters), NPWP decrease by 32% on average *ceteris paribus*.

Concerning socio-economic factors, it can be observed that poverty rates have a relevant negative coefficient, which is significant at the 10% level only for Model (2). In this case, one unit increase

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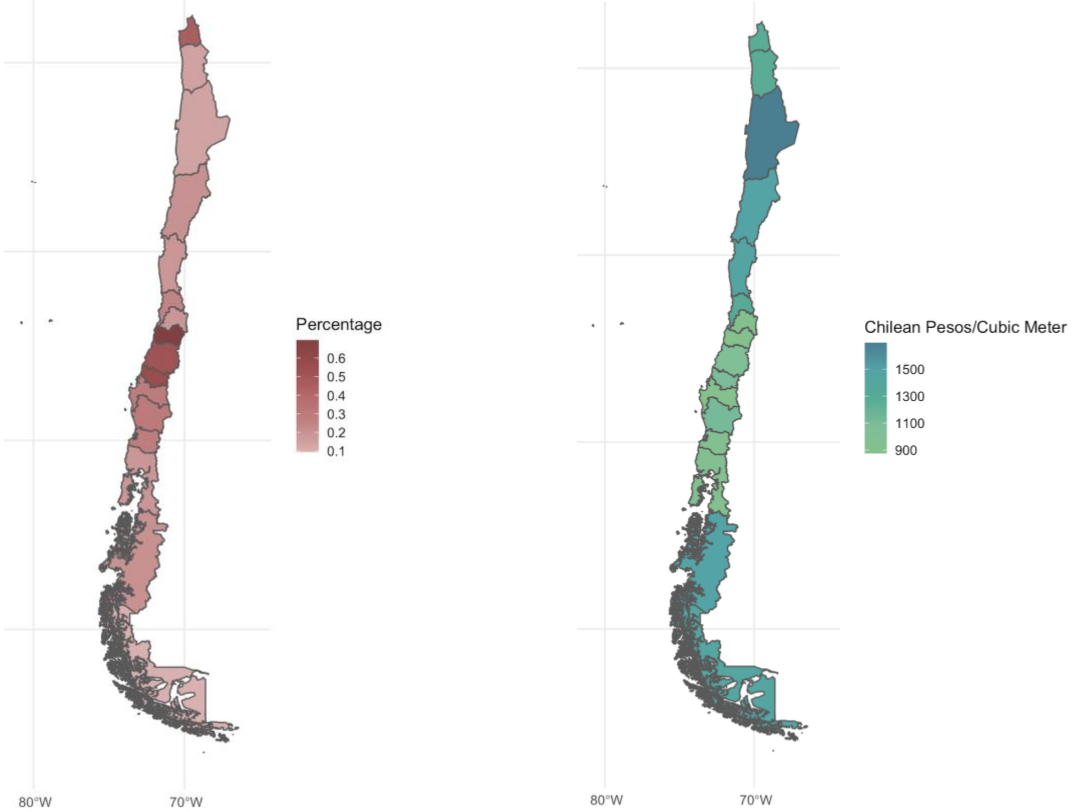
[10] It should be noted that the interpretation of the coefficients needs a transformation, given that the prices of potable water were logged. For log-lin relationships, one unit change in the independent variable changes the dependent variable by the explanatory variable's coefficient, multiplied by 100 and expressed in percentage (for ex. if $\beta_1 X$, the impact on the dependent variable will be of $100 \times \beta_1 \%$).

in poverty rates (measured in percentage) is associated with a decrease in peak potable water prices by 105% on average *ceteris paribus*. Finally, when it comes to PD its contribution to potable water price determination is negative and very limited, given that the coefficients are very close to zero. Nevertheless, they are significant at the 10% and the 5% level for Model (1) and Model (2) respectively, suggesting that when population density increases by one unit (measured in people/square kilometer), for instance NPWP decreases by 0.1% on average *ceteris paribus*.

Related to the other outputs reported in Table 7, the F-test specifies whether the independent variables are jointly significant in explaining the dependent variables (Wooldridge 2015: 153). It is evident that the variables are significant at the 1% level for Model (1) and Model (2), and at the 5% level for Model (3) in explaining NPWP, PPWP, and OCPWP. Based on the R squared, a goodness-of-fit measure for a given model, indicating the proportion of the dependent variable explained by the model (Wooldridge 2015: 80–81), it seems that Model (1) explains 93% of NPWP, Model (2) explains 90% of PPWP, and Model (3) explains 87% of OCPWP. Moreover, when looking at the adjusted R squared, which imposes a penalty for including additional variables that do not contribute to explain the dependent variable (Wooldridge 2015: 202), it results that the models are still quite robust although their explanatory power decreases to 88% for NPWP, 82% for PPWP, and 72% for OCPWP. Finally, the residual standard errors presented in Table 7, measuring the standard deviation of the residuals in the regression models (Wooldridge 2015: 100), are quite small for Model (1) and Model (2) and slightly larger for Model (3) indicating that the regressions fit the models well. Visual representations of the residual standard errors can be found in APPENDIX B.4. Moreover, the parentheses in Table 7 represent the standard errors of each variable and show that the values are smaller for Model (1) and Model (2) than for Model (3), indicating that each variable generally fits the nonpeak and peak prices better than the over-consumption prices.

7.2.2 Discussion

Overall, the expected effect of the independent variables was observed in the regressions' outputs. Indeed, our interest variable representing the proportion of regional GDP covered by the agricultural sector is positively related to potable water prices. This would suggest that the initial hypothesis could be true: where the agricultural sector operates more intensively water resources for sanitation companies are reduced, thus forcing them to set higher prices to account for increased water scarcity. However, as mentioned in the results section, the findings are not significant for any of the three models. These findings are somehow confirmed by the mapping of the four variables AGR, NPWP, PPWP, and OCPWP in Figure 4.



Agriculture's Share of Regional GDP

Nonpeak Potable Water Prices

Peak Potable Water Prices

Over-consumption Potable Water Prices

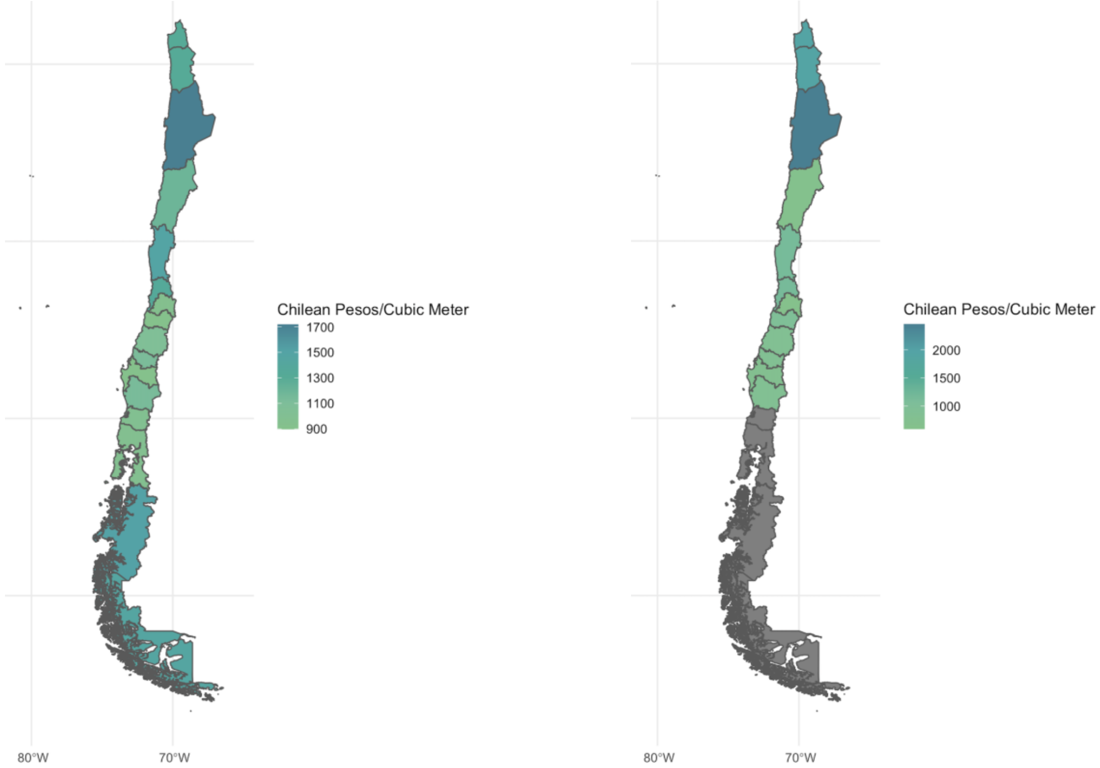
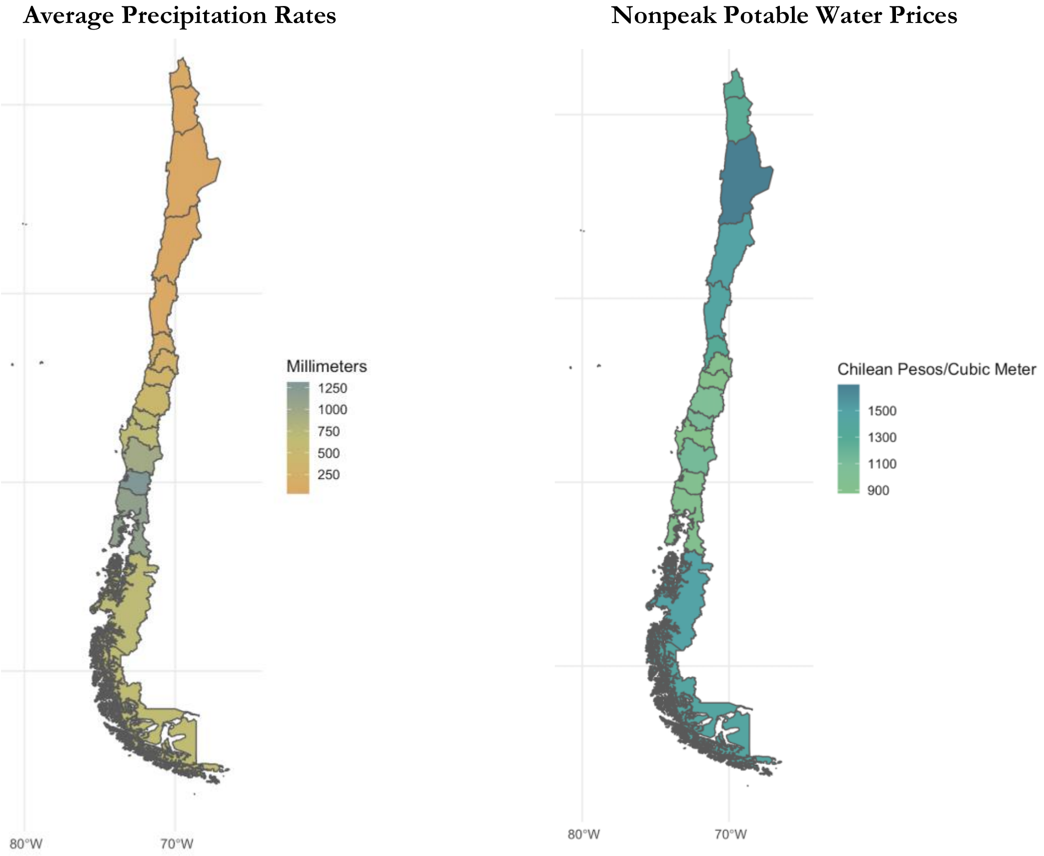


Figure 4: Mapping of AGR, NPWP, PPWP & OCPWP – Source: author's own elaboration

Indeed, it is visible that the patterns reported for the prices of potable water are opposite to the ones representing the share of the agricultural sector in regional GDP. While agriculture makes important contributions in the *Región de Arica y Parinacota* (XV) in the north and the economies in the central regions, with the *Región del Liberador B. O'Higgins* (VI) being the most significant one, potable water prices seem to reach their maximums in the northern areas and in the south of Chile, with the central regions being clearly those with the lowest potable water prices, no matter in what season.

When it comes to the variables included in the estimations to account for effects due to regional climates, both MT and AP resulted to be associated with the prices of potable water with the expected signs. In fact, one hypothesis was that where maximum temperatures are higher, a higher evapotranspiration rate applies, making water scarcer, thus forcing sanitation services to charge higher prices to account for the reduced availability. Interestingly, MT was significant only in Model (3), suggesting that it is an important factor determining over-consumption prices for potable water in the summer seasons, as suggested by the literature (Bjornlund & Rossini 2005; Pesic, Jovanovic & Jovanovic 2013). Similarly, AP's results reflect the hypothesis suggested in by several authors (Bjornlund & Rossini 2005; Macian-Sorribes Pulido-Velazquez & Tilmant 2015) that where average precipitations are higher, water recharging is larger, thus augmenting water availability, allowing sanitation companies to charge lower prices. Given that this relationship is significant for all the three models it is interesting to map the four variables AP, NPWP, PPWP, and OCPWP to see whether they follow a similar pattern across the regions. As can be seen in Figure 5, average precipitation rates are higher in the central regions of Chile, slightly lower in the south of Chile, and very low in the north. Interestingly, peak, nonpeak and over-consumption potable water prices follow a similar distribution, as the lowest prices are found in the central areas where it rains more, and the highest prices are present in the north, where average precipitation is the lowest.



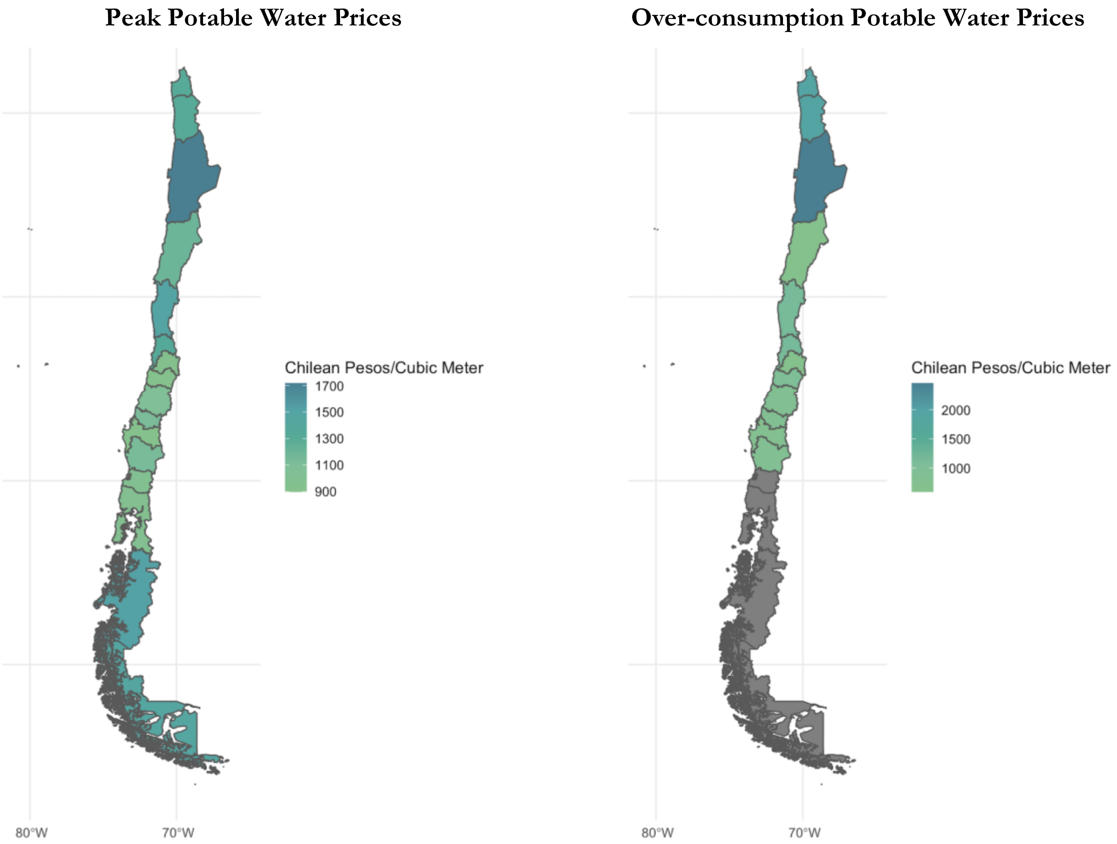


Figure 5: Mapping of AP, NPWP, PPWP & OCPWP – Source: author's own elaboration

Concerning water availability, the results section showed that WA has almost a null effect on the outcome variables, which is rather unexpected, given that the literature pointed to scarcity-based pricing as a key strategy (Donoso & Molinos-Senante 2017; Min 2007). In fact, the hypothesis was that where water availability per capita is higher, water is more abundant and, given the laws of supply and demand, prices should be lower. It is difficult to say why no meaningful association was produced by the regression analysis, but one limitation of the variable WA is that it only represents how much surface water is available in a region given its population density, without accounting for any water consumption resulting from agriculture, industry, urban centers, etc. thus not informing about real water stress, which would influence potable water prices. When it comes to the variable WQ, the expected effect was observed in all models at 5% significance levels, thus confirming the hypothesis that where the quality of water is better, sanitation companies can set higher prices because they have less cleaning and filtering costs, as suggested by Hollman and Boyet (1975). Moreover, WQ had the largest coefficient of all variables, indicating that potable water prices are very sensitive to changes in quality.

In terms of socio-economic determinants of prices of potable water, the regression outputs showed that the expected effects were confirmed only to a certain extent. While poverty is indeed positively associated with NPWP, PPWP, and OCPWP it is not significant, except in Model (2) at the 10% level, population density is mostly significant but seems to have no effect on the dependent variables in terms of magnitude. The reason behind these findings could be that potable water prices are not determined by socio-economic factors, as the equity and affordability principles of water tariffs are met through the household subsidies that apply as a result of unaffordable water prices (Hormazábal & Muñoz 2006).

In conclusion, the econometric analysis suggests that potable water tariffs are mainly based on the principles of economic efficiency and water conservation measures (Donoso et al. 2015: 90), given that peak, nonpeak, and over-consumption potable water prices all seem to depend on the climatic variables, namely AP and MT, especially for the summer season. To answer the second sub-research question *"To what extent is the agricultural sector's share of regional GDP related to drinking water prices in Chile's administrative regions in 2007?"*, the OLS estimation's results suggest that AGR is not significantly associated with potable water prices in the sixteen regions of Chile. A possible reason for this finding is that the scarcity of water resulting from human-caused over-extraction is not reflected in the AGR proxy because the GDP contribution of the agricultural sector is a relative measure of economic activity that does not necessarily give an indication of the volume of agricultural goods produced or of water extracted.

8 Conclusion

The aim of this thesis was to provide a more complete understanding of Chile's water management system, especially in terms of its socio-environmental outcomes. The contribution of the analysis relies in the adoption of a mixed-methods approach: on one hand, the 1981 Water Code was investigated through the lenses of the Critical Environmental Justice Framework to assess whether unequal power relations are reproduced in terms of access to water and degradation of water resources and on the other hand, an econometric estimation assessed a possible relationship between the degree of regional activity of the export-oriented agricultural sector and the prices of potable water faced by consumers. The analyses have allowed to answer the two sub-research questions:

> SRQ1: *Does the 1981 Water Code reproduce inequalities across time and space for both the human and natural worlds?*
>
> SRQ2: *To what extent is the agricultural sector's share of regional GDP related to drinking water prices in Chile's administrative regions in 2007?*

Indeed, the results of the qualitative analysis have shown that the Water Code reproduces historically rooted inequalities since 1981 with respect to vulnerable communities, such as indigenous people and rural peasant, in terms of their right to access water resources. Moreover, the Water Code also operates against a fair consideration of water resources, as they are subject to over-extraction even when signs of unfavorable future outcomes are present. However, the limitation of this analysis is that it is biased towards human claims about injustices, thus leaving less space for inequalities related to the environment, which could therefore be perceived as less important in this context. Furthermore, the findings of the quantitative analysis have shown that in 2007 potable water prices are not related to the degree of agricultural activity in the regions, thus not confirming the hypothesis that where the agricultural sector operates more intensively and extracts more water resources for production, prices of potable water are higher as a result of less resource availability. Nevertheless, the method used to assess this relationship was rather elementary and the data were probably not the most adequate proxies for this purpose, although they were the best that could be found. Still, together the results allow to answer the research question of this thesis:

RQ: *Does the Chilean water management system encourage over-extraction and discourage access to water resources for certain actors in society, while reducing affordability of potable water in water scarce areas?*

The analyses have shown that the current system under the 1981 Water Code does not prevent from – or even encourages – over-extraction of water resources for productive export-oriented activities that are the backbone of the Chilean economy. At the same time, the water market resulting from the legislation institutionally excludes some actors of society from enjoying access to water resources, particularly in rural areas, as for example indigenous communities and peasants. Nevertheless, the analysis could not confirm that the current system reduces affordability of potable water in water scarce areas, as no such trend could be identified. Still, the findings showed that potable water prices are tightly linked to climatic factors such as temperatures and precipitation rates, without however being significantly related to the condition of water resources in terms of availability or scarcity. In conclusion, the system clearly determines winners and losers and unsurprisingly operates to the benefits of the economy and to the detriment of the environment and vulnerable communities.

These findings have important policy implications. First, Chile's static, problematic and outdated Water Code should be replaced by a legal base encouraging Integrated Water Resource Management (IWRM), allowing for a more coordinated action across sectors and across the economic, social, and environmental pillars. Indeed, IWRM lays down a dynamic and adaptive process of holistic water resources management by including various stakeholders in the decision-making processes, resulting in a more bottom-up approach (Donoso 2014: 230–231). The equity and environmental problems of the Water Code have already been acknowledged by the Chilean government since its implementation, resulting in almost ten proposals for a reform of the legal text since 1981. However, reforms were either not progressive enough, or were opposed by economic interest groups formed by the agricultural, mining, and hydroelectric industries, by neoliberal economists, and by right-wing politicians (Budds 2004). This shows that it is not only the neoliberal system that has to be held accountable for the issues, but the Chilean government as well. However, the 2019 protests paved the way for a referendum of the 1980 Constitution, aiming for the first time to rethink the relationship between the Chilean society and its environment. The new Constitution has been drafted since 2021 and finally addresses topics such as the human right to water or inter-generational justice, marking an unprecedented historical opportunity for Chile (Parra Galaz 2020). The second policy implication relates to the findings of the determinants of potable water prices and suggests that the DGA and the SISS should better investigate the impact of extractive industries on the availability of water resources in the different regions of Chile to implement regulations guaranteeing water continuity for future generations, as it is unlikely that variables such as water availability or the degree of agricultural activity in a region are not linked to prices of potable water. Indeed, there is evidence that some rural villages depend on expensive potable water supply from trucks in summer during drought periods because no more water is available as a result of over-exploitation (Larrain 2012).

Concerning future research, the current thesis is a first attempt at evaluating the 1981 Water Code from a Critical Environmental Justice perspective and future studies should develop the understanding of socio-environmental outcomes of Chile's water management system further. Additionally, research about the determinants of potable water prices should focus more on water scarcity and availability related factors. Indeed, these still need to be investigated and calculated given that they currently only exist for eight AR for the year 2007 thanks to Aitken et al.'s (2016) publication. Moreover, future studies interested in the relationship between agricultural activities and prices of potable water faced by rural and urban consumers should try to assess a causal relationship, which has not been done in this study.

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A Background Information

A.1 Contribution of Chile's Exports to GDP

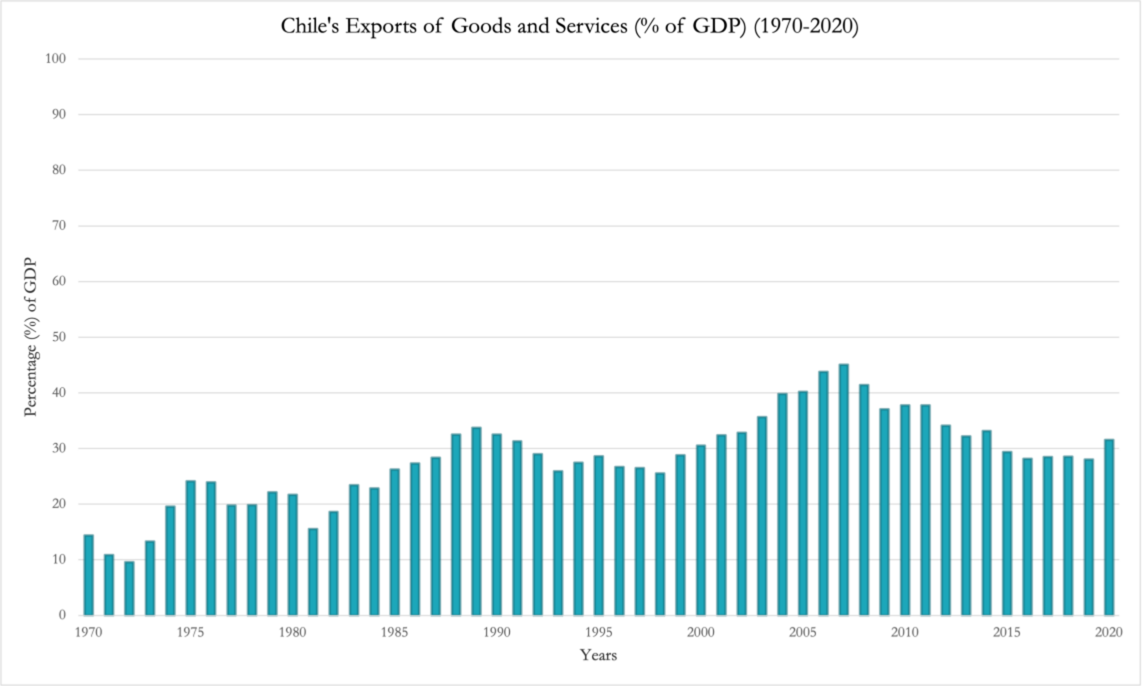

Figure 6: Evolution of the Share of Exports of total GDP – Source: author's own elaboration with data from The World Bank (2022)

B Econometric Outputs

B.1 Missing Values for Model (3)

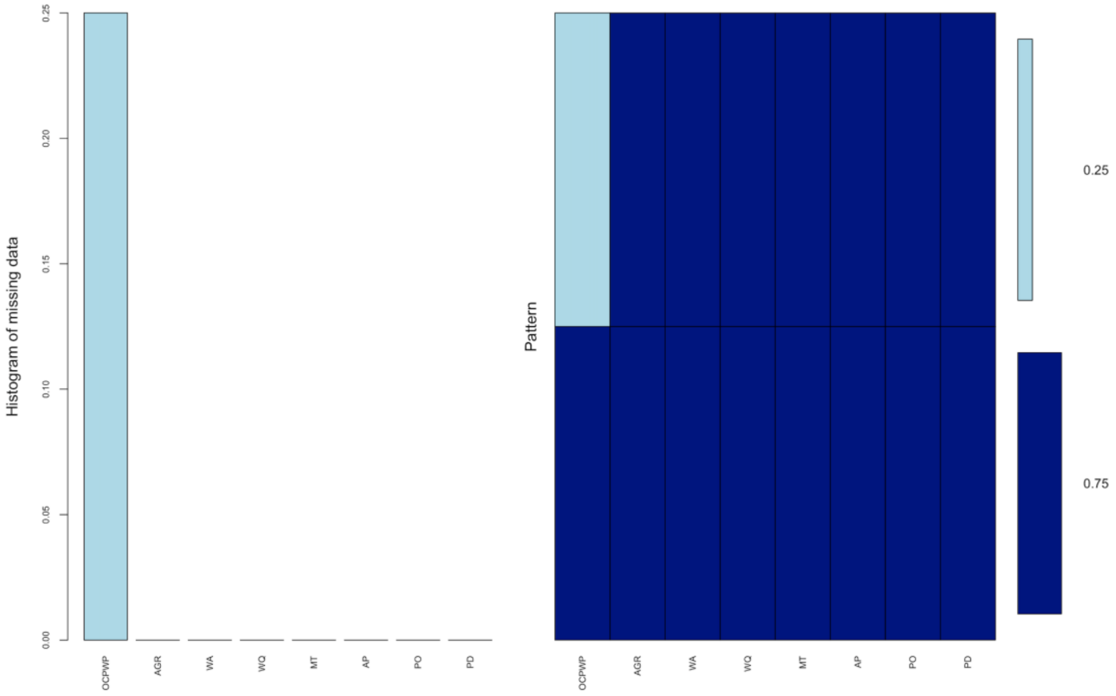

Figure 7: Missing Values for Model (3) – Source: author's own computation

B.2 Test of Multicollinearity Model (3) including WA

Table 8: Test of Multicollinearity for Model (3) including the variable WA – Source: author's own computation

Independent Variables	Model (3)
AGR	7.36
WA	14.21
WQ	4.02
MT	2.80
AP	13.46
PO	6.17
PD	2.29

B.3 Density Plots for Residuals

B.3.1 Density Plot – Residuals NPWP

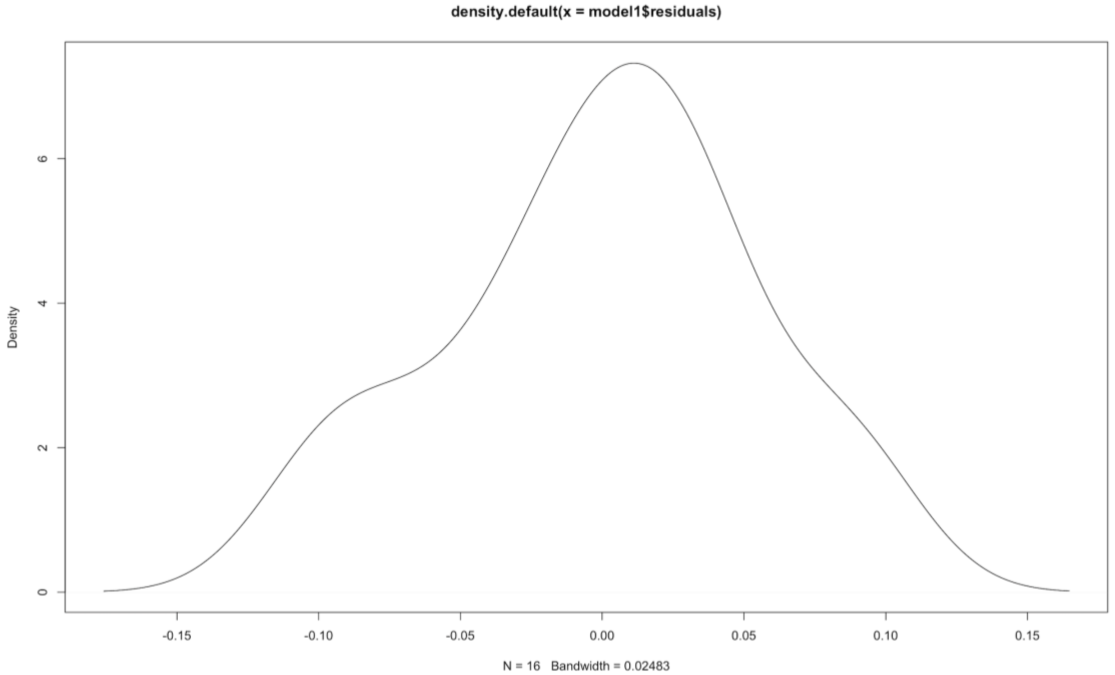

Figure 8: Density Plot for Residuals NPWP – Source: author's own computation

B.3.2 Density Plot – Residuals PPWP

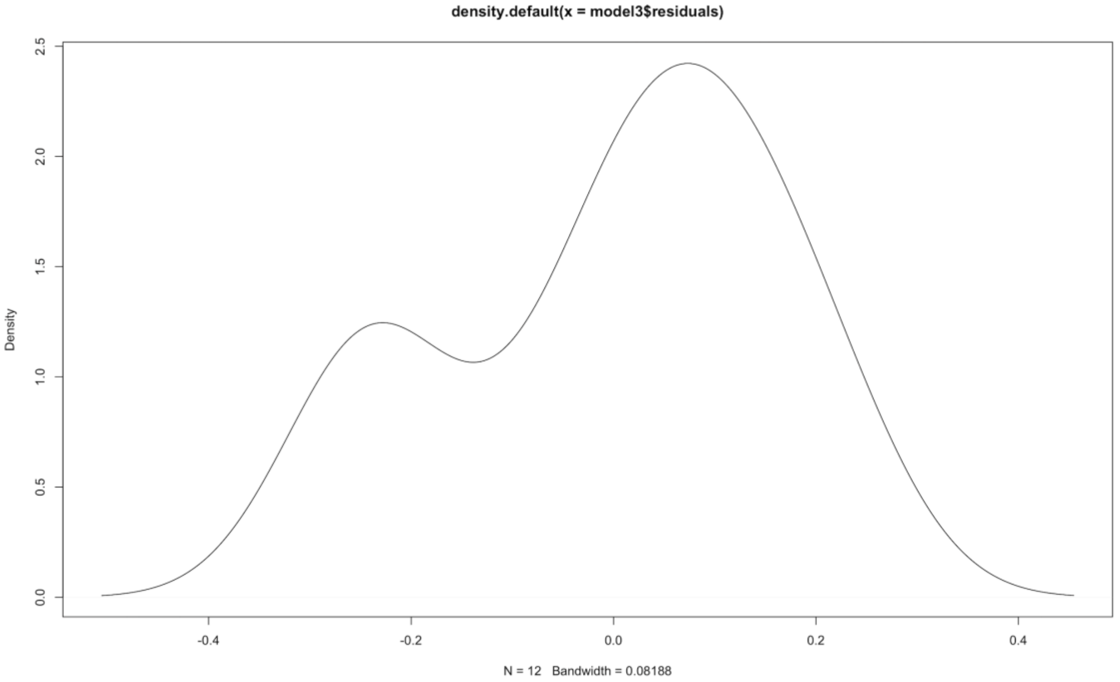

Figure 9: Density Plot for Residuals PPWP – Source: author's own computation

B.3.3 Density Plot – Residuals OCPWP

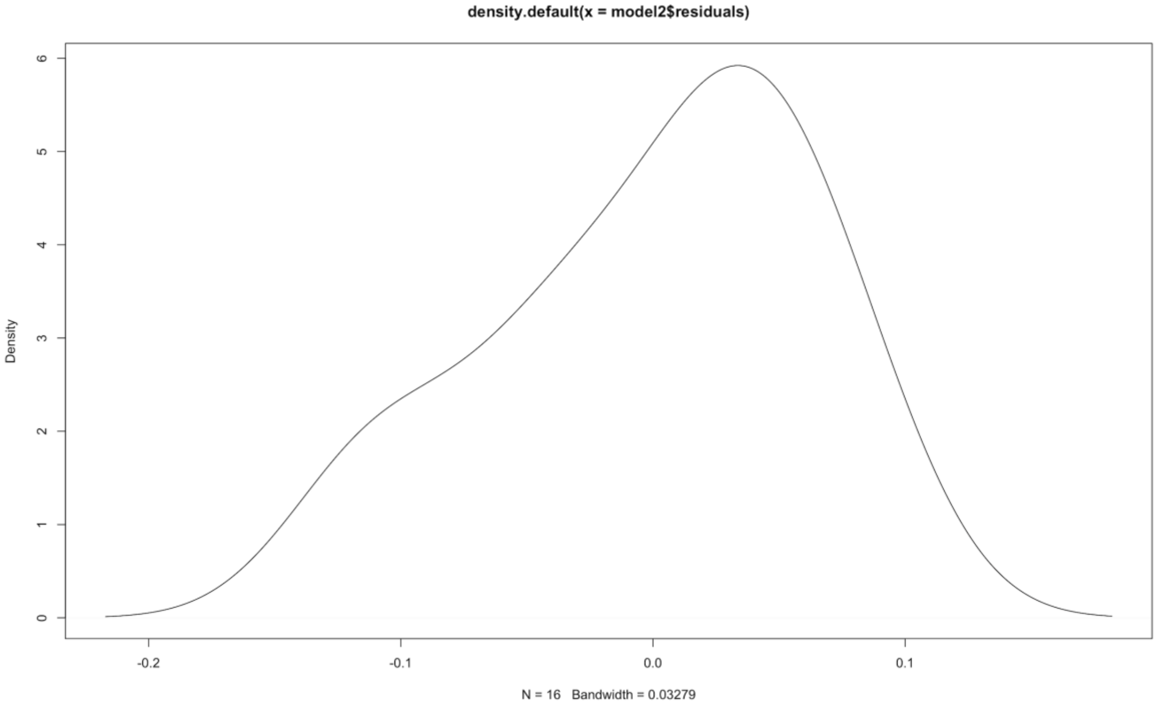

Figure 10: Density Plot for Residuals OCPWP – Source: author's own computation

B.4 Residual Standard Error Plots

B.4.1 Residual Standard Error Plots – Residuals NPWP

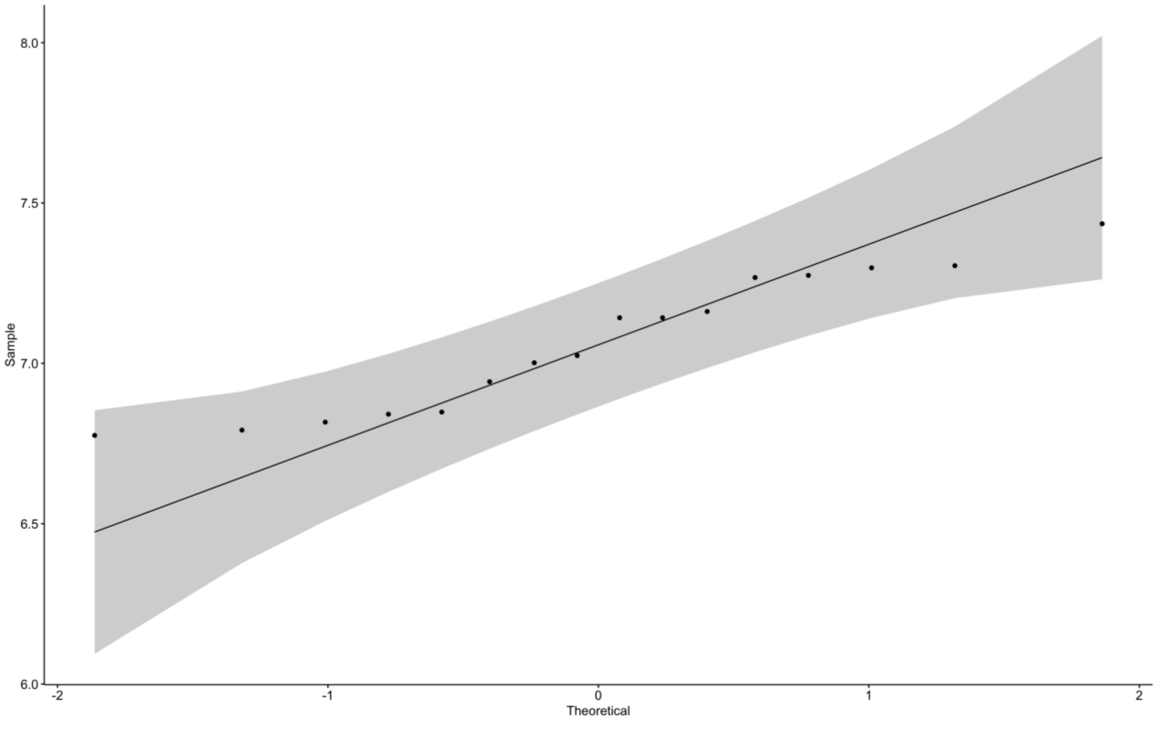

Figure 11: Difference between Predicted and Observed Values for Model (1) – Source: author's own computation

B.4.2 Residual Standard Error Plots – Residuals PPWP

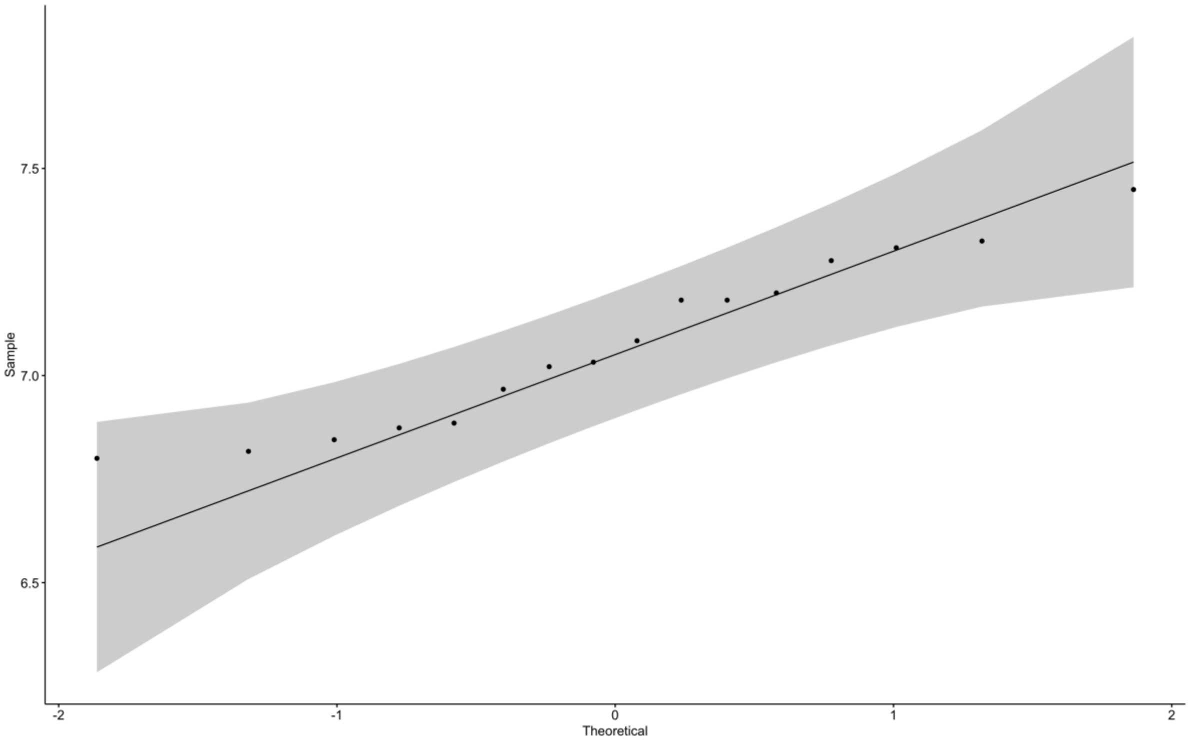

Figure 12: Difference between Predicted and Observed Values for Model (2) – Source: author's own computation

B.4.3 Residual Standard Error Plots – Residuals OCPWP

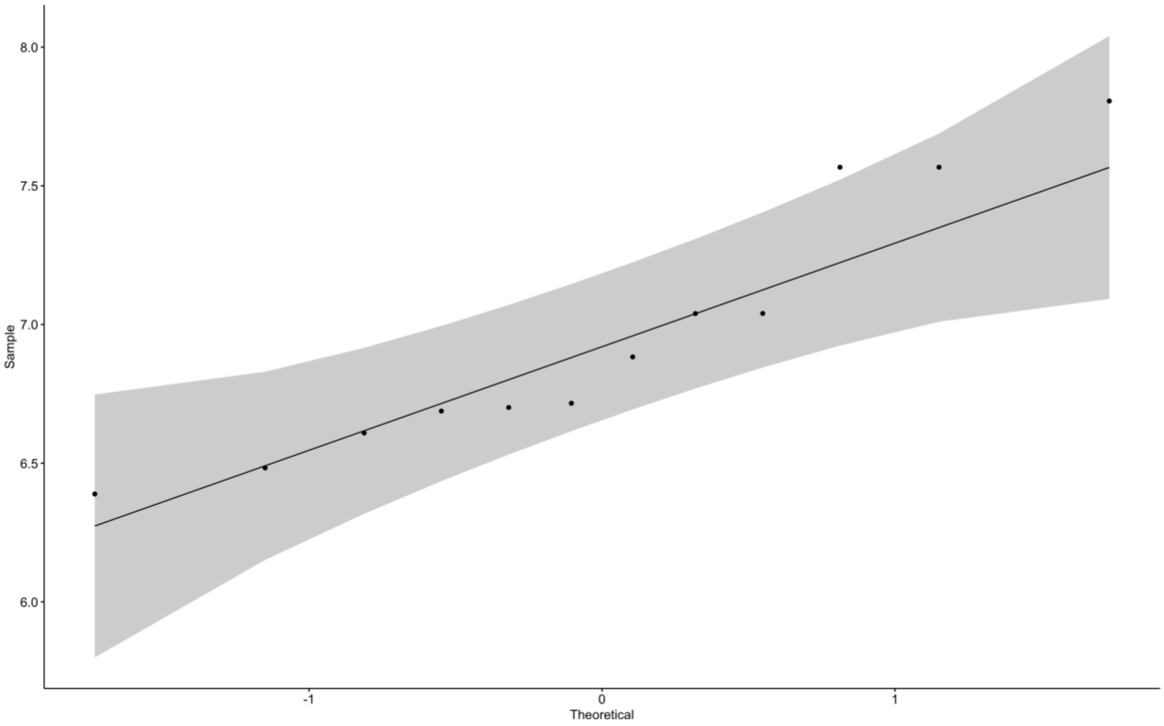

Figure 13: Difference between Predicted and Observed Values for Model (3) – Source: author's own computation