The Impacts of Corporatisation on the Efficiency of Water Utilities:

An Analysis of Water Supply in Jordan

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Abstract

Jordan is one of the most water stressed countries in the world. Thus, maximizing the efficiency with which the country supplies water is of paramount importance. However, the Jordanian water provision system has rarely been studied from an economic efficiency perspective. This thesis will address this gap in the literature, by appraising the impact of the corporatisation process on the efficiency of Jordanian water provision system. Jordan’s water provision system was entirely state-run until the late 1990s, but then a shift towards more corporate principles resulted in a mix of state-run and corporatised water providers.

This thesis will study how the shift from purely state-run to mostly corporatised water provision has impacted water supply efficiency in Jordan. This will be done using three techniques: Data Envelopment Analysis, Difference-in-Difference Analysis and Stochastic Frontier Analysis. Efficiency results vary considerably with each method used, and between water suppliers. While corporatised utilities do show high levels of efficiency, this is not uniform across corporatised suppliers. The state-run utility was also shown to be efficient, in relation to corporatised utilities. Finally, in order to analyse the differences in efficiency between corporatised suppliers, an analysis of their customer orientation was done. This analysis indicated that corporatised suppliers with greater customer orientation showed higher levels of efficiency than suppliers who were less customer oriented.

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Table of Abbreviations

ASEZA	Aqaba Special Economic Zone Authority
AWC	Aqaba Water Company
COVID-19	Coronavirus Disease
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DID	Difference-in-Difference
DMU	Decision Making Unit
DOS	Department of Statistics
GBD	General Budget Department
GDP	Gross Domestic Product
GLS	Generalised Least Squares
JD	Jordanian Dinar
JVA	Jordan Valley Authority
KPI	Key Performance Indicator
IMF	International Monetary Fund
MCM	Million cubic metres
MENA	Middle East and North Africa
Miyahuna	Jordan Water Company
MWI	Ministry of Water and Irrigation
NoC	Number of connections
NRW	Non-revenue water
OLS	Ordinary Least Squares
PPP	Public-Private Partnership
SFA	Stochastic Frontier Analyses
SOEs	State-owned enterprises
UPMU	Utilities Performance Monitoring Unit
USD	United States Dollar
VRS	Variable Returns to Scale
WAJ	Water Authority of Jordan
YWC	Yarmouk Water Company

Chapter 1. Introduction

Over the last thirty years, the efficiency of water provision systems has been studied using a wide range of methodologies. The efficiency of water supply is an especially pressing matter, due to increasing pressures on dwindling fresh water sources. As a result of population growth, climate change, environmental degradation and dilapidated infrastructure, every drop of water becomes more precious. Therefore, efforts to improve the efficiency of water supply are paramount; gaining more water per unit of input is especially important in arid countries, such as Jordan. Indeed, Jordan is the second poorest country in the world in terms of water supply (Namrouqa, 2014). This is compounded by the influx of refugees into the country from neighbouring conflicts, reaching 760,000 refugees by 2018 (UNHCR, 2018). Thus, there is great potential for studying the efficiency of water provision systems using various methods, as it relates to Jordan. To that effect, this thesis investigates the impacts of the corporatisation process on the efficiency of water supply in Jordan.

The Jordanian water provision system has rarely been studied from an economic efficiency perspective. This thesis will address this gap in the literature, by addressing the impacts of the corporatisation process on the efficiency of Jordanian water provision, primarily state-run and corporatised water providers. Jordan’s water provision system was entirely state-run two decades ago; there has been since then a shift towards more corporate principles. This thesis will study how the shift from purely state-run to mostly corporatised water provision has impacted Jordan’s water supply efficiency. This will be done using three techniques: Data Envelopment Analysis, Difference-in-Difference Analysis and Stochastic Frontier Analyses. By relying on three different methodologies, one can obtain a more nuanced picture, and avoid biased results that might arise from only one methodology. Finally, in order to analyse the differences in efficiency between corporatised suppliers, an analysis of their customer orientation was done. This analysis indicated that corporatised suppliers with greater customer orientation showed higher levels of efficiency than suppliers who were less customer oriented.

1.1 Brief Introduction to Jordan

Due to the rapidly increasing population growth in Jordan and modernising lifestyles, demand for water soon outpaced supply. By 2017, average water supplies amounted to 150 cubic meters per capita/annum, whereas the internationally recognised ceiling for absolute water scarcity is 500 cubic meters per capita/annum (Arsenault, 2017). In 2017, the nation's water deficit stood at 405 million cubic meters, and this water stress is set to increase for the foreseeable future (Namrouqa, 2018). Additionally, factors such as climate change made the collection of rainwater unpredictable. Existing water collection and provision systems became out-dated, as approximately half of water was lost between extraction plants and their final destinations. Different institutional arrangements adopted in Jordan have impacted water efficiency measures, such as supply to cost ratios and the number of connections to water networks.

Jordan has gone through roughly three phases of institutional arrangement in water provision: state-owned enterprises until 1999; a public-private partnership (primarily in Amman) up until 2006; and a corporatised water provision system up until the present. Initially, the state-owned Ministry of Water and Irrigation (MWI) was solely responsible for managing the supply of water to the nation until the end of the 20th century. The MWI leads the overall strategic direction of the Jordanian water sector and has two subordinate organisations: (i) the Water Authority of Jordan (WAJ), and (ii) the Jordan Valley Authority (JVA). The WAJ manages the day-to-day running of the sector, whilst the JVA is responsible for irrigation in the valleys. Recently, three new corporatised entities: Jordan Water Company (Miyahuna), the Aqaba Water Company (AWC) and the Yarmouk Water Company (YWC), have shared responsibility for water provision to the nation.

The development of corporatised entities in the 21st century was in response to the massive water supply challenges Jordan faces. 'Miyahuna' was created in 2007, to manage the water supply of the capital, Amman. This firm, along with the AWC and subsequently the YWC, were managed on private sector principles. These three companies combined manage the water supply of two thirds of the governorates of Jordan. This, in theory, aimed to improve the efficiency of water provision. However, whilst corporatised companies have improved the number of homes connected to water networks in most corporatised governorates, they have not improved efficiency in terms of supply output per unit of cost input.

1.2 Brief Introduction to the Literature

Globally, there has been an evolution in the discourse, regarding which institutional arrangements in water supply are perceived as the most efficient. Initially, state-owned enterprises (SOEs) were perceived to be the most efficient providers. However, throughout the 1980s-1990s, the discourse shifted to supporting privatised water providers. The trend has now reversed: corporatised and corporatised state-run water providers have become the standard for water provision (Dagdeviren, 2008); (Loftus, 2009). Indeed, there is a noticeable progression in the literature, moving away from the idea that outright privatization of water leads to increased efficiency in the sector (Hukka & Katko, 2003); (Estrin & Pelletier, 2018); (Araral, 2009).

Studies of the corporatisation of water show that corporatisation by itself is unlikely to significantly improve water supply efficiency in developing countries. Rather, Lobina and Hall (2014) show that in developing countries, the corporatisation of water should be implemented gradually and carefully, especially in contexts of weak regulatory mechanisms and underdeveloped markets. It requires complementary regulatory structures and systems, without which water corporatisation cannot bring about significant increases in supply and efficiency, especially in developing countries.

Some studies, such as Padfield et al., (2016) have found that corporatisation has improved the water provision sector's efficiency, across a wide range of indicators, including supply, non-revenue water (NRW) and revenue and expenditure ratios. Other studies, such as Hadipuro (2010) have shown that corporatisation significantly reduces supply, investment and efficiency. Some, such as Pigeon et al., (2012) go in a different direction, arguing that water provision should be 're-municipalised.'

1.3 Efficiency of the Water Sector in Jordan

The Jordanian water provision system has rarely been studied from an economic efficiency perspective. Instead, the focus has been on solving water shortages through demand-management, hydrological, geological and technological perspectives [see for example (Hadadin, Qaqish, Akawwi, & Bdour, 2010) and (Al-Ansari, Alibraheim, Alsaman, & Knutsson, 2014)]. Also, it is only within the last decade that the water provision system in Jordan was studied through a political-economic lens (Mahayni, 2015); (Hussein, 2018); (Yorke, 2016); (Mustafa, 2016); (Zeitoun, Allan, Al-Aulaqi, Jabarin, & Laamrani, 2012). However, the discourse has only occasionally addressed the impacts of different modes of ownership on water supply in Jordan, especially using frontier techniques (Al-Assa'd & Sauer, 2010); (Al-Theeb, Smadi, & Obaidat, 2019).

Telfah, Halalsheh, Ribbe and Roth (2017) examine Miyahuna, the water utility for Amman, the capital. The authors find that adopting corporate principles improved the performance of Miyahuna, especially in the case of NRW, which went from 47% in 2000, to 33% in 2011. The authors then compare the performance of Miyahuna to international standards, specifically the median performance levels of international utilities. They find that Miyahuna's billed water operational unit cost was 160% of the international average for 2007-2013. When comparing against other Middle-East and North Africa (MENA) utilities, Miyahuna showed 190% greater costs for 2007-2010. However, Miyahuna billed 140% higher revenues than the international average, between 2007-2013. Median international NRW was 28% from 2009-2011, while Miyahuna's was 33%. The authors conclude that the implementation of corporatisation was successful in Amman. However, this is only correct when examining Miyahuna's progression across the years. The authors' own data shows that, when compared to other countries' utilities, Miyahuna still has significant progress to make in efficiency. Specifically, between 2007-2013, its revenues were 140% higher than the international average, but its costs were 160% higher. The authors also deem Miyahuna's financial position as 'satisfactory', which is questionable as Miyahuna cannot cover its operational costs, let alone its capital costs.

Chapter 2. Literature Review: Discussing the Theories Behind the Adoption Private Sector Principles in Public Utilities

There are many ways for water utilities to adopt private sector principles, without undergoing a form of privatisation. The primary ways for water utilities to adopt private sector principles are: corporatisation, marketisation and commercialisation. This section will discuss the concepts of corporatisation, marketisation and commercialisation, in regard to increasing the efficiency of water supply. As this section of the Literature Review will show, there is some confusion in the literature regarding the usage of such terms. This is because corporatisation, marketisation, and commercialisation all fall under the broad umbrella of publicly owned bodies adopting some measure of private sector attributes. As these terms share some similarities and overlap in some ways, this may lead to confusion in usage. Thus, this section will attempt differentiate between these when applying them in this thesis. However, before defining these terms, this section will discuss the concept of an SOE. In order to understand the impacts of corporatisation, marketisation and commercialisation, it is necessary to understand the type of organisation they will be impacting.

2.1 State-Owned Enterprises

SOEs were the predominant method for state-led growth in the MENA region, from the 1950s up until the mid-1970s. However, by the early 1990s, this doctrine had been supplanted by privatisation and commercialisation. Even though there are few current proponents of the SOEs paradigm (especially in the International Monetary Fund (IMF) and the World Bank), this paradigm not only laid the foundations for much of the modern MENA region, but with the current tides of nationalism and disillusionment with privatisation that are prevalent in the MENA region, SOEs may one day again become a significant force in the region.

It should be noted here that when discussing SOEs, there are many structures under which the SOEs can perform. For example, the SOEs can follow the traditional model of soft budget constraints, artificially low interest rates on government loans, over-employment, subsidised prices, political as opposed to economic decision making and so on. However, the modern trend veers towards that of the corporatised SOEs (which is the case in Jordan today), whereby the company, while technically still owned by the government, is legally a limited liability company, and is thus managed (adhering to a hard budget, obtaining loans at full interest rates, making use of Public-Private Partnership (PPP) to outsource and delegate projects, and charging market prices for services).

The supposed advantages of SOEs include the fact that, as they are not beholden to market pressure, they will not engage in short-term thinking and planning, instead engaging in long-term planning (reducing speculation and other adverse behaviours). Also, revenues are re-invested in the firm, as opposed to going to dividends and stock buybacks, and it is highly unlikely to engage in mass layoffs, price hikes, and other actions which are not in the public interest. Also, they can prevent strategic sectors/activities within the economy being owned and controlled by private entrepreneurs, especially overseas investors.

Essentially, the primary argument for SOEs is to compensate for a 'market failure,' whereby the public sector can offer goods and services at a price that the private sector cannot match, perhaps due to the sheer scale of the operation (water network or electric grid), or the importance of it (national security), or if it is a vital service that must be offered even to those who cannot afford it (policing) (Greene J. , 2014).

However, in practice, many SOEs have not shown the same levels of efficiency, or returns on investment, that private firms have. Thus, powerful global organisations such as the IMF decry SOEs, delineating all their potential negative effects and inferiority, compared to commercialised or private firms (Dinavo, 1995). However, such a viewpoint almost entirely ignores the wide-ranging success stories of SOEs, though these are to be found elsewhere. The most successful SOEs are to be found in South-East

Asia, principally Japan, China, South Korea and Singapore. The SOEs in these countries have shown massive successes, defying common orthodoxy. They have not only generated massive revenues for the state, helping with budget and fiscal deficits, but have shown great levels of innovation, efficiency and productive employment (Chang, 2012). However, in praising the SOEs of the South-East Asian Tigers, it is important to be careful, as they are unique to a particular economic context (the 'Economic Miracle' of these countries). In the last two or three decades, these countries also underwent extensive privatisations, the most recent being the example of China, where a debate is currently being held, regarding the merits of SOEs and privatisation (Wildau, 2015).

Ultimately, the theory that purely state-run SOEs are inherently more inefficient due to soft budget constraints, political prices, overemployment, inefficiencies and incomplete contracts is not borne out by the facts, with many privatised firms also showing high levels of inefficiency, poor quality goods/services and other problems.

2.2 Corporatisation

This section will offer a brief definition of corporatisation. The World Bank offers a checklist of the conditions needed for a water utility to be considered 'corporatised'. These include its status as legally distinct from the government (including assets and liabilities), with its own decision-making autonomy. It must also show independent revenue streams, management and staffing, while being fully transparent, including in its accounting (World Bank Group, 2020). However, the World Bank's checklist leaves little room for local contexts or nuance. As this section will show, the term is actually more ambiguous in the literature, with more dimensions and flexibility in its interpretations.

Walby and Lippert (2020) show that corporatisation is more about how an organisation is run (to increase efficiency), rather than changes in ownership. A utility can be corporatised in a variety of ways. However, what they usually have in common is that the utility is run like a for-profit private sector firm, including in terms of organisational structure, management practices, and financial viability. A typical corporatised entity's management, or Board of Directors, are entirely independent of governmental control. This arrangement requires that the corporatised entity itself should have a unique legal status stipulating its corporatised organisational structure with public ownership status.

Nasrulddin (2020) offers a similar definition. The author maintains that corporatisation is essentially a process whereby management is disconnected from the firm's ownership (the government). Indeed, the public sector delegates only management powers to the corporatised entity, while still preserving full ownership. Corporatisation is not necessarily a component of privatisation, though it may be a prelude. Corporatisation is also seen as a method of enhancing the utility's efficiency, while avoiding the some of the disadvantages of outright privatisation, by introducing more autonomy for the utility, with a concurrent reduction in bureaucracy, and more incentives for improved performance and financial viability. Ultimately, as Nasrulddin correctly points out, the degree of success of corporatisation is directly related to the degree of sophistication of a country's markets, regulatory frameworks and institutions. The more mature these elements, the more likely corporatisation is to succeed.

Andrews et. Al. (2019) show the advantages of corporatising public sector bodies. By re-orienting them to more commercial principles, they can increase revenue streams for governments, as well as promote flexibility in labour and human resources. However, one disadvantage of corporatisation is that revenue streams based on selling goods and services, as opposed to simple taxation, are more likely to be unpredictable. Also, it may obscure the true extent of fiscal spending, as corporatised entities are treated as separate entities for accounting purposes. Additionally, there are some features which are not clearly an advantage or problematic. For example, the authors consider it an advantage that corporations can hire labour while avoiding government regulations and trade union demands. Although this might help reduce the corporatised company's costs, it is not immediately clear that it is beneficial overall, as many employees are put in an economically precarious position.

Stiel (2022) points out that much of the literature is focused on the contrast between privatisation and state-owned enterprises. The literature on how SOEs themselves operate, or how they are internally organised (or how they can be brought more into line with private sector principles), is less extensive. Thus, careful study of how SOEs function internally, and how they can be made to improve efficiency, is warranted. The author points out that corporatisation can impact efficiency in many ways. By developing a new governing structure between the owners of the company (the government) and the managers, the company has (theoretically) more autonomy, and is forced to make policies based on tighter budgets, thus promoting efficiency. On the other hand, this might increase transaction and monitoring costs for the owners. Also, while efficiency may grow, as a result of applying best business practices, the social impacts may be negative, with potential price increases and other restrictions on once free goods and services. Corporatisation frequently requires the replacement of the company's management, with government bureaucrats replaced with experienced business professionals. As with Andrews et. Al. (2019), Stiel shows that corporatisation often leads to reforms in human resources, including an increase in temporary contracts and salaries that are more based on performance.

Kirkpatrick et. Al. (2017) discuss corporatisation as a process whereby publicly owned companies adopt corporate structures, in so doing mirroring the private sector. Indeed, this has given many public sector companies, which had previously no real organisational identity or culture of efficiency, effectively a new identity. Corporatisation has also led to the growth of a managerial class in public sector bodies (including middle management), out of a need for increased coordination and administration. However, the authors are not clear as to whether, on the whole, this may in fact be a disadvantage, as increased levels of middle management may in fact impede communications, and therefore increase inefficiency. While they do discuss this possibility, they contradict it later by stating that institutional constraints, such as intense media scrutiny, will push the corporatised firms towards increased efficiency. Ultimately, it is not clear that media scrutiny, and other intuitional constraints, can overcome the possible disadvantages of increased bureaucracies, layers of middle management, and the potential ensuing communications problems.

In summary, the corporatisation is a process of converting the publicly owned entity into autonomous entity, with unique legal status, in order to incorporate market principles that will enhance the public entity's efficiency and financial viability.

2.3 Marketisation

Having defined corporatisation, this section will now offer a definition of marketisation of public services. Walby and Lipert (2020) cite Whitfield (2006) to show that marketisation is the application of market mechanism to public goods and services, while still maintaining public ownership. This process has many features, including but not limited to, the commodification of goods, services, labour and infrastructure, adopting the goals of profit maximisation, business interests, and implementing market mechanisms. In other words, it is the replacement of the public sector with a more business oriented dynamic and paradigm, where 'citizens' are replaced by 'consumers.'

Bhattacharya (2020) concurs that marketisation involves the transformation of public goods and services to market goods and services for consumers, and the liberalisation of such goods and services to establish or increase competition in a market, which allows multiple entities to operate in the market, to benefit from the efficiency gains from the competition and market-based principles. The core elements of marketisation are, in the author's opinion, 'choice and competition.' Theoretically, marketisation will bring about greater incentives for performance, with the threat of bankruptcy for weak performers. It will also improve equity by giving poorer communities more access to high quality goods and services. Finally, the transformation of citizens into customers can empower public, including marginalised communities, as they wrest control over their goods and services from the government (Bhattacharya, 2020). However, in practice, many of these points are misleading. By turning citizens into consumers, it can actually be disempowering, with public no longer guaranteed access to certain essential goods and services. Rather, access to goods and services is now limited to those who can afford. In other words, their role as democratic agents is removed, their access to goods and services limited to their purchasing power (which will increase inequity, not decrease it).

Bradley (2021) takes issue with the aforementioned definitions of marketisation and argues that marketisation imposes market-based rules to non-market public goods and services and forcibly creates imaginary markets for non-market goods and services through aggressive liberalization, removing regulations and commodifying public goods and resources by setting "market prices". The author argues that the marketization may look successful in the accountancy practices, such as key performance indicators, but it may not lead to the improvement in the public service and inclusive service provision.

In overall, marketisation is a process to introduce market-based mechanisms and competition into the public entities, which aims to benefit from the efficiency gains from the market mechanisms, such as market pricing, and competitions. However, it should be noted that marketization may not be an effective tool to enhance efficiency of public entities as some public goods and services, such as water, needs regulated price and may not be feasible to be traded at a market price in order to reach the marginalised customers.

2.4 Commercialisation

Having examined corporatisation and marketisation, it is possible to discuss another mode of managing water systems: commercialisation.

Commercialisation can be defined as the process by which an SOEs adopts private sector values and practices, focusing on generating profits and efficiency. This involves full-cost pricing (setting prices at market value, in order to recover costs incurred) and economic equity (users pay for all the water they consume). Thus, the utility operates according to corporate law, as opposed to state-led practices. The commercialised utility is run by a management board and operates like a private firm, with the government in the role of shareholder (NNEWH, 2009).

The impetus to move away from purely state-run firms partly came about partially due to poor management of governmental utilities, rapid urbanisation and inadequate investment. This in turn weakened the ability recover costs, limited productivity, service quality and network reach. Thus, in theory, commercialised water entities will help in overcoming these obstacles. This is primarily because commercialised entities are autonomous and strive towards cost recovery (Tutusaus & Schwartz, 2020). In their review of the literature, Tutusaus and Schwartz (2020) discuss the tenets of commercial, as delineated by their peers. These tenets of commercialisation include: cost recovery (with three out of five authors insisting on full cost recovery); commercialised entities have to be autonomous (again, three out of five scholars agree); operations based on profit maximisation; flexible management; direct accountability and performance management.

Tutusaus and Schwartz (2020), in studying the National Water and Sewerage Corporation of Uganda, show that even within one utility, there can be competing definitions of commercialisation. That is, while the utility strives to follow the tenets of commercialisation, what happens in actuality, when confronted with facts on the ground, is quite different. According to the authors, the utility has to maintain an image of commercialisation, so as to continue receiving funds from the Central Government and international donors. However, at the same time it has to continually supply water to small, rural areas. This requires extensive new investment in delivery systems to these areas, at great cost and uncertain return on investment. Also, the company eschewed a policy of raising water tariffs, a frequent practice for commercialised water utilities elsewhere. In fact, servicing small rural areas can be over twice as expensive as servicing large urban areas in Uganda, so the company instead focused on cost cutting. The utility cut costs in water treatment and network maintenance, and labour costs by having one specialist serve multiple locations. Additionally, connecting remote areas with small customer bases negates economies of scale and density, which in turn prevent profitability. Finally, profits from well-paying urban areas are used to cross-subsidise poorer and more remote areas that cannot cover their costs. This whole process has been dubbed 'organised hypocrisy.' This is a situation whereby an organisation has to espouse certain values, but in reality pursue different values if efficient targets are to be met. Furthermore, these inconsistencies exist at the structural level, making the dissonance institutional (Tutusaus & Schwartz, 2020). The authors' study of Uganda can be applied to many countries, where water commercialisation was adopted, but implemented sporadically due to local realities and context.

Tutusaus, Surya and Schwartz (2019) offer a comprehensive re-evaluation of the term 'commercialisation,' in their study of Lamongan Regency, Indonesia. The multiple ways this concept can be implemented on the ground, depending on environmental context, shows that the term should be re-examined. By the time a utility is commercialised, local contexts and interests render it extremely different from the theoretical definition found in the literature. The authors argue that these differences are rarely touched upon in the literature, and in light of this chapter's literature review, this is a sound assessment. When discussing commercialisation, the literature sticks to a preconceived notion, rarely qualifying it with environmental contexts and realities.

Ultimately, Tutusaus, Surya and Schwartz (2019) argue for an entirely new vocabulary to delineate the many iterations of commercialisation. As the authors (correctly) point out, opponents of commercialisation believe that it promotes efficiency as opposed to equity. They then examine this belief. They show that commercialised entities exist in a strange limbo. On the one hand, if the utility is successful, then governments and donors will argue that it is because they stuck to commercial values. However, the actual running of the utility can ignore or re-interpret such values significantly. In their study of Lamongan Regency, they show that, in accordance with commercial theory, the utility should have cut off water access to delinquent payers. Instead, due to tight bonds within the community, this was rarely enacted. Instead of cutting off water to non-payers, the utility extracted revenue from well-regarded local institutions, such as mosques or committees. The average salary in the utility is low, with personnel costing only 11-30% of revenue. This is because most of the staff have other sources of income, and volunteer at the utility during spare time.

2.5 Distinguishing definitions of corporatisation, marketization and commercialisation

In principle, all three policy tools are aimed to bring about efficiency in the public entities. However, in terms of social equality of service provisions that, corporatisation and commercialisation may be more effective tool balance the financial viability with equitable service provisions than marketization. In terms of the definitions, the corporatisation is a process of transforming the publicly owned entity into autonomous private sector led entity, with unique legal status, in order to incorporate market principles that will enhance the public entity’s efficiency and financial viability. The corporatisation requires robust legal framework to operate independently from the political interference. The marketisation is a process to incorporate market-based mechanisms and competition into the public entities, to leverage efficiency gains offered by the market mechanisms, such as market pricing and competitions.

This section attempts to form coherent distinctions of the terms: corporatisation, marketisation and commercialisation. These terms have similar over-arching themes and aims (replacing the public service provision with some form of market dynamic). However, because these terms overlap in certain ways, they are sometimes used interchangeably. This section will clarify and differentiate these terms, allowing for precise usage in this thesis.

Walby and Lippert (2020) offer a clear breakdown of these terms. The authors correctly argue that the terms 'corporatisation' and 'marketisation' are frequently used interchangeably, thus incorrectly. Indeed, there is a key difference between corporatisation and marketisation. Corporatisation is about the development of new types of management in the public sector. That is, the ultimate result of corporatisation is the development of public sector companies with new, independent management under its unique legal status. Such management is focused exclusively on the running of the company, as if it were simply an independent, private company. There is a transformation in management and authority, but not in actual ownership; corporatised firms are still public entities. It involves the adoption of market friendly strategies *in the public sector itself*. It can involve key performance indicators for both employees and management, new revenue streams or re-orientation to focusing on profits. It can involve new legal settings whereby the firm is independent of governmental influence, with apolitical management. Finally, it can take the form of PPP, or other arrangements which bring the private sector into managing public utilities.

McKenna (2000) differentiates between commercialisation and corporatisation. Commercialisation is the restructuring of public sector utilities and other sectors in order to increase economic *efficiency*. However, corporatisation is the transformation of public sector functions into government owned companies, based on private sector models.

Ultimately, the difference between the terms is as follows: marketization is about introducing market dynamics to a *product*, and commercialisation is the introduction of private sector principles to a public *organization*. Corporatisation goes one step further and *transforms* the legal status of the public organization into a separate entity. None of these (necessarily) entails privatisation, which is the transferring of goods or organisations into the private sector.

Chapter 3. Impacts of Running Utilities on Corporate Principles

Having discussed the theory behind corporatisation, marketisation, commercialisation and SOEs, this paper will now examine the impacts of such policies.

3.1 Impacts of the Corporatisation of Water Utilities

After ascertaining a theoretical understanding of corporatisation and other methods of imposing corporate principles on a utility, one can begin to examine its impacts. In examining the impacts of corporatisation in the real world, one can begin to understand where theory fails, and what is needed to make theory work.

One of the early papers to address the impacts of corporatisation on water utility, proclaiming the process to be a success, was Martin (2004), which discussed Australia's experiences. In corporatising water utility, the utilities adopted key performance indicators (KPIs), distanced themselves from the local government, increased transparency and adopted more commercial outlooks. This resulted in increased revenues, efficiency and accountability. Operating costs dropped between 20-35%, and savings were re-invested into infrastructure (Martin, 2004). As noted by Nasrulddin (2020), the marketization will likely succeed in mature markets as in this case of Australia.

Indeed, a paper that attempts to address the topic of whether corporatisation can be applied to developing countries is that of Lobina and Hall (2014). The authors posit that the main goal of corporatising water utility is maximising supply efficiency, achieved by putting distance between the utility's managers and the government, which owns the utility. Such distance between the managers and the government is meant to minimise political interference in decision making, giving managers more independence than typically found in public entities. The authors then show that there are varying degrees of corporatisation, with some utilities having financial but not decision-making independence, and are not legally distinct form the government. Other utilities have both financial and decision making independence and are legally independent. In analysing the consequences of corporatisation, the authors find that adopting corporatisation elements in a phased approach is the most suitable form of corporatisation for developing countries. This is especially the case in countries with immature markets, legal frameworks, institutions, and infrastructure.

Mcdonald (2016) also questions the impacts of corporatisation in developing countries. He shows that the growing corporatisation of water utilities is influenced by neoliberal philosophy. However, he also argues that the corporatisation of water does not *necessarily* entail neoliberal underpinnings. That is, there have been instances of corporatised utilities avoiding market dynamics and providing water based on social equality. While corporatisation may be the first step in outright privatising a utility, it may also be the opposite; an attempt to improve efficiency by applying business best practices and market dynamics, without the socio-economic risk of full privatisation, which may not prioritise servicing marginalised communities.

Furlong, Acevedo, Arias and Patino (2018) go further, showing that even the origins of the concept of corporatisation are misunderstood. Its current perception is that of a 'solution' thought up by the developed countries and foisted on developing countries. It is also thought of as being one step away from privatisation, a compromise between the private sector and the government. The reality is far more complex. In Colombia, much of the water service has been corporatised since the beginning of the 20th century which challenges the conventional notion of corporatisation is a product of a neoliberal policy. This situation came about due to negotiations between the Colombian public and private sector interests where private sector sought to protect its substantial investments in the water supply infrastructure and the municipal government sought to tackle inequality in the water supply (high consumptions by wealthy households and commercial users) through granting the private sector more decision-making authority to improve the service provision. As the authors convincingly argue, the corporatisation of Colombian water utilities did not come about to replace the public sector. Rather, the corporatisation aimed to reduce the political interference by adopting technocratic and private sector led management of the water utilities. Corporatised suppliers increased prices on affluent and industrial and commercial consumers after engaging in lengthy negotiations with all the stakeholders. The private sector continued to invest, regulate and manage many components of water services. However, this autonomy was subject to long negotiations with stakeholders and the corporatisation itself evolved overtime.

As this section shows, corporatisation of water utilities is likely to succeed in mature markets. However, in less mature markets the corporatisation of public entities should be carried out in a phase-wise manner, taking account of local circumstances, legal frameworks and institutions. Corporatisation does not necessarily mean to transform the water utilities into for-profit only entities, but it is a tool to enhance the utilities' efficiency and improve the social equality of water supply by reducing political interference through its unique legal status. Corporatisation is a process that will take a significant amount of time accompanied by constant negotiations with stakeholders.

3.2 The Impacts of Water Utility Marketisation

This section will offer an overview of the impacts of the marketisation of water utilities. Harris (2013) in discussing the marketisation of water utilities, makes some key observations. The costs of water markets are not applied evenly among stakeholders, with private sector polluters not needing to compensate communities for their pollution. This is from the very same communities who have to pay the utilities in the first place. Despite this and other disadvantages, marketisation remains one of the most consistently adopted measures in water utilities.

Yining (2013) also finds flaws in water utility marketisation. The author analyses the marketisation of water utilities in China. The author shows that water markets alone will not guarantee efficiency or fairness in supply. Rather, government policy, informed by consultation with affected communities and stakeholders, can maximize efficiency and equity in water markets.

Chen, Ai, Zhang, and Hou (2019) also discuss the marketization of water utilities in China, but come to a different conclusion than Yining (2013). The authors, using econometric techniques, maintain that marketisation had a positive impact on the efficiency of water use in China, as well as a positive spatial spill over effect (that is, impacts on surrounding areas).

Grafton, Horne and Wheeler (2016) also find water marketisation to have had positive impacts. By studying the Murray-Darling Basin in Australia, the authors show that water utility marketisation, backed by sound institutions and regulatory frameworks, such marketisation adoption can have positive impacts. That is, they can deliver water in environmentally conscious ways, improve efficiency, and allocate water supply in equitable ways.

In conclusion, the marketisation of water utilities requires a strong set of regulatory mechanisms and institutional frameworks, for it to be equitable. Otherwise, marketisation could in fact hurt the most vulnerable members of the community.

3.3 The Impacts of Commercialisation

This section will analyse the impacts of commercialisation on the efficiency of water supply in developing countries. It should be noted that 'commercialisation' does not have one fixed definition, and different studies hold different meanings of the term. This is elaborated upon in the 'Defining Commercialisation' Section above.

Commercialisation has many theoretical advantages. One of the main advantages of this mode of ownership is that it supposedly encompasses the best of privatisation and state-run enterprises. As they are still owned by the state, they are unlikely to engage in practices which will harm the citizenry. That is, they are unlikely to hike prices or disconnect services to non-paying customers. This has the added benefit of making commercialised entities more politically viable.

At the same time, they are run on private sector principles, so they will strive to maximise efficiency, through the use of best business practices. As these firms are run by a supposedly independent board of directors, they will not be beholden to the whims of electoral politics.

Indeed, towards the beginning of the 21st century, much of the literature still supported the idea of water commercialisation in developing countries. This essentially replaced water privatisation, as the 'solution' to the water woes of developing countries. For example, Van Rooijen, Spalthoff, and Raschid-Sally (2008) examine the challenges facing the water sector in Accra, Ghana. The authors examine areas of the city with lower-than-average access to water. They maintain that commercialisation of the city's water can substantially improve access, therefore disrupting existing monopolies and reducing tariffs. Commercialising Ghana's water sector was attempted however, and the results are ambiguous. Adu-Ampong (2014) shows that commercialisation in fact resulted in steadily increasing tariffs, in an attempt to achieve cost recovery. However, these increased tariffs did not translate into improved water quality or reach of the supply network. Also, raising tariffs before increasing the reach of the supply network exacerbates water inequality and poverty. Although 59% of urban homes are connected to water, in the most deprived neighbourhoods this figure drops to 20% (and down to 5% in the worst neighbourhoods). Thus, while Van Rooijen, Spalthoff and Raschid-Sally (2008) argued that commercialising Ghana's water would result in improvements to the network, Adu-Ampong (2014) showed that few of the intended benefits materialised. Indeed, the government of Ghana even declined to renew the management contract with the supplier.

This shows that, in reality, many of the aforementioned advantages do not materialise, partially due to local contexts and partially due to the nature of commercialisation. This is demonstrated well in a study by Odeny (2006), which contends that water commercialisation decreased water supply to certain communities in Zimbabwe. Also, commercialisation did not increase the amount of pipes going to these communities, as providers insisted that consumers pay for the cost of establishing these pipelines.

Another study which shows the impacts of commercialisation on the reach of water is Dagdeviren (2008). This paper analyses the commercialisation of urban water in Zambia, and the dilemma between cost recovery and increasing home connections to remote areas, especially in a context of reduced investment and soaring prices. In developing countries, with extensive infrastructure and poverty challenges, increasing prices for cost recovery purposes might price water out of reach for many consumers. Thus, the policy objective of increasing access to water may in fact *decrease* access to water. The author pinpoints three areas where commercialisation can help, the first being in reducing operational inefficiencies. This happens through altering management or organisational systems, removing excess staffing, or increasing bill collection. The second method makes use of economies of scale, reducing production costs and NRW. The third method sees increasing prices, to increase revenue. However, in reality, the commercialisation of water in Zambia, realised in price increases and slashing capital expenditure, did not have the desired outcomes. Most Zambian water providers still have not achieved cost recovery, and although water tariffs are still low, they are still priced beyond the reach of most customers. Also, water quality dropped, with less household access to clean drinking water. Also, less homes have access to water through pipelines, instead depending on wells, boreholes and taps.

This issue (of water supply equity in Sub-Saharan Africa) is studied in more depth by Marson and Savin (2015). They analyse 25 Sub-Saharan African nations, from 1996-2012. The authors find that while on average more affluent areas get more water, it is not a clear-cut relationship. Some areas with weak cost recovery actually have greater access to water, although this is not the norm. Ultimately, the authors offer support for the mainstream of the literature, that commercialization creates a divergence between water supplies and financial stability. This finding is further buttressed by Kitonsa and Schwartz (2012), who study the impacts of commercialisation on the Ugandan and Zambian water sectors. The authors point out that water commercialisation results in reduced accountability and equity to citizens. However, where Kitonsa and Schwartz (2012) differ from previous cited studies is that such policies resulted in increased operational scales, in order to achieve cost recovery. This has led to horizontal integration of water supply, meant to increase economies of scale and let utilities operate in more 'profitable' ventures.

While the cited examples discuss cases how water commercialisation resulted in less water reaching poorer and remote communities, it should be remembered that this is not always the case. There are instances of 'organised hypocrisy', discussed in Tutusaus & Schwartz's (2020) examination of the commercialisation of water in Uganda. As described above, in the 'Defining Commercialisation,' section, the authors found a situation which they termed 'organised hypocrisy.' This came about from the contradiction between the utility's stated objectives, and the realities on the ground. For example, while the company professed cost minimisation, this clashed with the need to connect households in poorer, rural areas. However, the utility did increase the reach of the network to these areas, even if it was not cost efficient, and the return on investment was doubtful. The commercialised utility did have many notable successes. Between 1998 and 2010, the company increased: service coverage from 48% to 74%; the number of connections from 34,300 to 246,500; and collection efficiency from 71% to 98%. It also reduced water loss from 49% to 33.3%, and the number of staff per 1000 connections from 36 to 6 (thus increasing productivity).

Tutusaus and Schwartz (2020) examine the impacts of water commercialisation on rural areas in Uganda. The authors find that there are many interpretations of the impacts of commercialisation, even when examining the same data. Indeed, while the supplier is supposedly run on commercial principles, in reality suppliers often fall far short of this, preferring a hybrid model of state-run and commercial elements. The authors show the dichotomy between commercialisation meant to raise investment from international donors, but simultaneously provide water to struggling communities. The authors label this phenomenon 'organised hypocrisy.' The authors show that during commercialisation NRW dropped from 49% in 1998 to 33.3% in 2010.

3.4 Conclusion

Whilst the literature shows mixed results, pertaining to the privatisation and commercialisation of water services in the MENA region and the developing world, it is clear that there have been numerous problems with these processes, both in implementation and results. The focus on recent years has been to push for corporatisation, marketisation or commercialisation, in order to ensure that SOEs adopt the rigorous and efficient business practices of the private sector. However, even water corporatisation, marketization and commercialisation have been a far cry from unambiguous success, with many of the problems of privatisation still plaguing commercialised suppliers.

Chapter 4. Literature Review iii) Theoretical Background

In order to study the efficiency of Jordanian water providers, this section will outline the analytical framework of the thesis. First, this section will focus on 'production,' then delineating the analytical framework of 'efficiency.'

4.1 Frontiers and Efficiency

Conventional economic theory, for example neoliberalism, has not been able to solve the problem of water shortages in Jordan. As in all cases when demand exceeds supply, questions of efficiency arise, so as to extract the maximum possible amount of water, with limited inputs. This is especially pertinent in countries with limited amounts of water and financial resources, such as Jordan. Thus, an approach examining efficiency may be more suitable to examining Jordan's water shortages. This framework will also examine whether corporatisation is a more efficient method of running a utility, than being purely state-run.

However, in order to utilize an 'efficiency' approach to water scarcity in Jordan, it is first necessary to outline what is meant by 'production,' especially as it pertains to measuring efficiency. The production is the process whereby inputs are taken and used to create outputs (Sealey & Lindley, 1977). This applies to both physical products and services. While the concept is intuitive regarding physical production (for example, constructing buildings, creating a computer), it is more ambiguous with services. For example, regarding banking, it is not always clear how inputs/outputs should be measured. This issue is also pertinent when discussing the extraction, purification and transportation of water. Thus, selecting the correct inputs and outputs to be used is always essential.

Once inputs/outputs have been determined, a production frontier is created, so as to gauge efficiency. One of the originators of production frontiers is Farrell (1957), who is discussed in Parman and Featherstone (2019). The authors show that Farell used linearization to envelope production amongst firms, thus creating the production frontier. All firms are either on or beneath the frontier, with firms on the frontier being efficient, and those under the frontier inefficient. Those firms on the frontier were producing output with the minimum possible input, and thus were efficient. Conversely, those firms within the frontier were using more inputs than was required to produce a certain output. Thus, the distance from the inefficient firm to the production frontier is the scope for improving efficiency. Eventually, the restriction of constant returns to scale was dropped. At first, cost functions were parametric with two sided errors, exemplified in Ordinary Least Squares (OLS). In this method, firms showing higher than average efficiency were below the frontier, and less than average firms above the frontier. This did not lend to a simple 'above or below' frontier methodology, so various attempts were made to correct it, including the Corrected Ordinary Least Squares method (Parman & Featherstone, 2019).

Parman and Featherstone (2019) show that, in order to correct for various challenges with the OLS methodology, Stochastic Frontier Analyses (SFA) was developed. With this methodology, there is only an upper or lower limit, and firms can only fall either on the frontier, or to one side of the frontier.

This is an example of a parametric frontier, whereby a functional form is created regarding outputs and inputs, and the parameters are calculated (with specific assumptions regarding the distribution of residuals). However, an example of a non-parametric frontier method is the Data Envelopment Analysis (DEA) method. Non-parametric methods calculate the frontier using data, instead of using a specific form of frontier at the outset (Read, 1998).

4.2 Measuring Efficiency Without Frontier Methodologies

In order to explore different avenues of assessing efficiency, a methodology which does not rely on frontier analyses should be discussed. In this case, a Difference-in-Difference (DID) analysis can study the impacts of policy changes, including how such changes impact efficiency. Rather than developing a frontier, and gauging distance from the frontier, DID compares changes in two sample populations.

For example, water supply can be measured before and after corporatisation, to see how much supplies have changed. However, how much of that change came about specifically because of corporatisation, or other external factors, is not immediately clear. To solve this, corporatised regions are compared to regions where corporatisation did not happen. The populations should be as similar as possible, with the one main difference being one population experienced corporatised water, and the other did not. Trends in the variable should have been going in similar directions in each group before the policy implementation, and only diverge after implementation. The methodology measures the change in each group over a period of time, after which these two results are subtracted, thus obtaining the difference between the two differences. Thus, it is clear how much of the change in a variable is the result of the policy implementation specifically, as opposed to other external factors (Schwerdt & Woessmann, 2020). This shows how much water supply changed in a corporatised region, and to what extent these changes are a result of the new policy, and not exogenous forces.

Thus, this thesis will use one parametric method, one non-parametric method, and one non-frontier method. This thesis will study the same sector (water), in the same country (Jordan) over roughly the same time period (2008-2018), using the three different methodologies. By studying a policy from three different angles, and drawing comparisons across methodologies, a more accurate understanding of its impacts can be reached. If the results of the methodologies are significantly different, then this can shed light on the efficacy of the methodologies themselves. It can allow for a discussion as to why studying the same issue using different methods results in such different outcomes, and what it means for the study of efficiency.

4.3 Analytical Framework

Before going further, it is crucial to explain what is meant by 'efficiency,' as this is the main focus of the thesis. The study of efficiency began as far back as 1957, in Farell (1957). Certainly, "It is important to know how far a given industry can be expected to increase its output by simply increasing its efficiency, without absorbing further resources," [Farell (1957), quoted in Mandl, Dierx, and Ilzkovitz, (2008)]. However, the analysis of public sector efficiency remains elusive, due to the multiple, sometimes conflicting, goals of public sector spending (Mandl, Dierx, & Ilzkovitz, 2008).

Financial and non-financial resources (inputs) are used to develop an output. The amount of output, per unit of input, depends on both allocative and technical efficiency (Mandl, Dierx, & Ilzkovitz, 2008). Allocative efficiency signifies how various inputs are used to create different outputs, whereas technical efficiency discusses how to maximise outputs with minimal costs (Akazili, et al., 2008).

It should be noted that there is a key difference between 'efficiency', 'productivity' and 'effectiveness.' Both 'efficiency' and 'productivity' use the idea of inputs to outputs ratios. However, efficiency uses the concept of the production possibility frontier, which shows the maximum possible levels of output per unit of input. That is, if output increase while inputs remain constant, efficiency increases. Also, if output remains constant, but inputs decrease, then efficiency increases. Conversely, productivity merely shows the ratio of output to input. Effectiveness, on the other hand, discusses how efficiency has contributed towards the achievement of the ultimate objective. This is influenced not only by efficiency but by the environment, also known as 'exogenous factors.' (Mandl, Dierx, & Ilzkovitz, 2008).

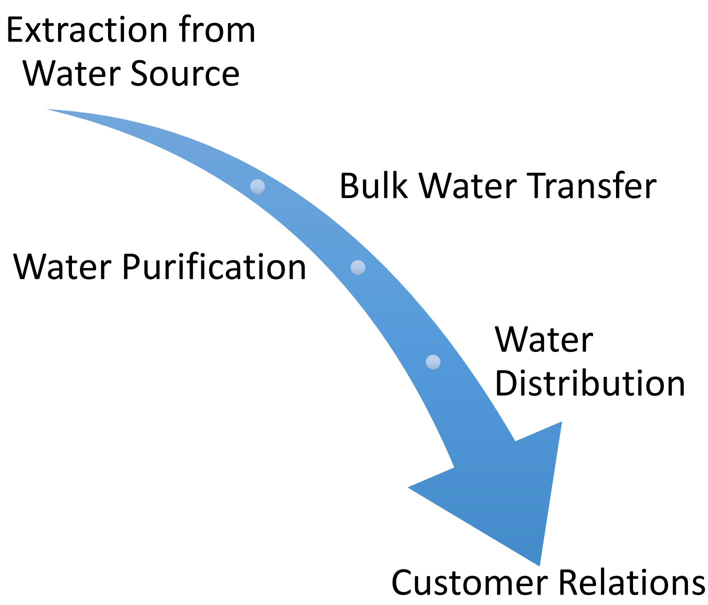
4.4 Production and Efficiency of Water

Having outlined the general theory of production and efficiency, it is now necessary to examine the literature regarding the production and efficiency of water. The study of production and efficiency in water is meant to understand how efficient water production is, examining how much input is needed to deliver a unit of water. As climate change and population growth makes fresh water an increasingly rare commodity, increasing the efficiency of water supply becomes ever more necessary. Frontier methodologies, and other statistical techniques, can show how much more water can be obtained, without an increase in inputs. Also, many of these techniques are able to delineate the main causes of inefficiency, and whether the inefficiencies are caused by internal or external factors. Before discussing this, it is necessary to briefly outline the structure of the water supply sector.

The water industry is structured differently across countries/regions, due to issues of geography, resources, customer base, competition and regulation structure (Abbott & Cohen, 2009). For example, the sources of water will determine sustainability (surface water is more renewable than ground water). Technology is also similarly affected, with oil rich countries being able to afford to desalinate their water (an option not available to income-deprived countries).

In most countries, especially markets with small/medium customer bases, the water sector is a vertically integrated, geographical monopoly. This is partially due to extensive capital costs, with such networks showing scale economies which result in natural monopolies. It is usually in larger, more developed urban locales, with varied water sources, that several vertically integrated players vie for market share. Water has low value added against delivery costs, making delivery expensive, which in turn makes competition less likely, because of the costs involved in constructing new distribution networks. Also, the importance of water as a public policy question necessitates government intervention, due to its scarcity and health externalities arising from water quality. Regulation is important, and public provision frequently a necessity, as consumers generally cannot test water for quality, and require affordable prices (Abbott & Cohen, 2009). A summary of the water sector can be shown in the figure below:

Figure 1 Water Supply and Waste-Water Supply Process



Source: Adapted from Abbott and Cohen (2009)

As Figure 1 above shows, water is collected from a source, then transferred to a bulk storage facility. There, it is treated and purified, then distributed to other storage facilities, then to the final customer. At each stage of the process, inefficiencies arise, for example, water lost as NRW. Even though water is free, the costs of each step combined make the provision of water an expensive and formidable task, especially to remote areas.

4.5 Economies of Scale and Scope

Having discussed the overall structure of the water sector, this section will examine the concept of economies of scale, scope and density. These concepts are important parts of the water efficiency discussion. Economies of scale are the cost savings obtained by increasing production. Economies of scope are when the production of one good results in lower production costs for another good. Economies of density are savings arising from customers/producers being in close proximity to one another (Nauges & Van den Berg, 2008).

There is a debate in the literature, regarding whether the water sector benefits from economies of scale. Ferro, Lentini and Mercadier (2011), in analysing many countries, find wide differences in economies of scale. That is, for economies with between 100,000 to 1 million customers, there are significant economies of scale. As the customer base increases, the results show CSR, and at even higher populations, decreasing returns to scale. Thus, according to the authors, economies of scale do exist, only up to a certain point and in certain contexts. The idea of economies of scale existing only in specifically sized water suppliers is also found in Worthington and Higgs (2011). The authors analyse 55 Australian water utilities between 2005-2009. They find economies of scale present at modest levels of production (when production reaches 50-75% of mean production). The authors find that operational costs can be reduced by increasing home connections, and both operational and capital costs by minimising NRW.

Saal, Arocena and Maziotis (2013) continue this trend. This paper also finds evidence of economies of scale, in the water sector, at certain levels of output, as well as diseconomies of scale beyond such output. Although, what that ideal level of output is varies substantially between countries. The authors also find vertical economies of scope, between upstream water extraction and distribution. There is however less clear evidence of economies (or diseconomies) of scope between the water and sewage sectors.

These issues are explored more deeply in Wenban-Smith (2009). The author finds that the unit cost of water distribution does exhibit economies of scale with different volumes. Although, the unit cost of water distribution shows diseconomies of scale with distance from the consumer. This implies that the denser a population is, the lower unit distribution costs are. In fact, denser populations show economies of scale in both production and distribution. Also, expanding settlement sizes either results in constant returns to scale or diseconomies of scale.

Guerrini, Romano and Campedelli (2013) study 64 Italian water utilities, using DEA methodology. The authors find evidence for economies of scale, scope and density, although not uniformly. Using Variable Returns to Scale (VRS), over half of Italian water utilities showed a score ranging 0.9-1. When analysing the difference between the VRS and Constant Returns to Scale (CRS) frontiers, over three-quarters of Italian water utilities are efficient. Only 16% of utilities scored 0.3-0.5. A Tobit Regression is used to analyse how different variables (including how differentiated are investments, utility size and customer density) affect efficiency. They find that the degree of differentiation in investment showed little effect on efficiency. However, there was a robust link between population density/km and efficiency, with denser regions showing greater efficiency. Regarding utility size, large utilities showed more technical efficiency than either small or medium utilities. Utilities generating at least 50 million Euros exhibited greater economies of scale (such as purchasing capacity). However, utilities generating between 10-50 million Euros showed the best organisational efficiency.

In contrast to the previous studies, Nauges and Van Den Berg (2009) study the economies of scale in the water supplies of more than one country. Specifically, the authors employ panel data to study economies of scale, scope and density of water in Vietnam, Brazil, Moldova and Romania. The authors demonstrate economies of scale in the water sectors of Moldova, Romania and Vietnam. The authors' findings are in line with other literature reviewed so far, in that economies of scale drop with the size of the utility. This is true both within and between the sample countries. The authors also find economies of producer/customer density, except for economies of customer density in Brazil.

While the size and distribution of the consumer base is important, policy can also have a significant effect on economies of scale. Sauer (2005) in examining Germany's rural water sector, finds none of the water producers to be of efficient size. Rather, the ideal firm size was, on average, three time larger than current firm size. This is because legislation bounds specific suppliers to a locale by administrative policy, not economic capability. Thus, overcapitalisation leads to diseconomies of scale in the long-term.

4.6 Identification of Literature Gap

This thesis aims to contribute to the literature by making novel contributions to the theory of production and efficiency. Specifically, this thesis will explore how the corporatisation of Jordanian water impacts efficiency, and whether one corporatisation is clearly more efficient than being purely state-run. Also, this thesis explores whether there is a method of studying efficiency (DEA, DID or SFA) that is more accurate or informative than the others. Thus, this thesis will contribute to the literature by filling gaps in said literature. Primarily, it will contribute to the study of efficiency and frontier analysis in economics, by comparing the results of DEA, SFA and DID analyses. This thesis will also provide real-world, practical benefits, as many countries (such as Jordan) suffer from significant inefficiency in their water sectors. It will contribute to the literature, as there are only two studies of Jordanian water efficiency using DEA. However, my study contributes to the study of Jordanian water efficiency, using DEA, in unique ways (as will be shown in the DEA chapter). Also, this thesis will be the first to apply SFA and DID analyses to Jordanian water efficiency.

This thesis will focus on Jordan for many reasons, the main one being it is one of the most arid countries in the world. Also, Jordan is a developing, middle-income country with significant shortages in resources, financial and material. Thus, efficiency in the Jordanian water sector is of paramount importance to the country.

4.7 Research Questions and Hypotheses

Research Questions

1. How has the corporatisation process impacted the supply efficiency of the Jordanian water sector?
2. Which is the more efficient mode of running a utility, corporatised or completely state-run?
3. Are the sources of inefficiency internal or external?

Hypotheses

1. The corporatisation process has improved the efficiency of Jordanian water supply significantly, but less so the overall supply.
2. The corporatised firms will show increased efficiency over state-run firms.
3. There are substantial savings to be made, by improving efficiency.
4. The causes of inefficiencies will be mostly external.

Chapter 5. Research Methods and Methodology

5.1 Methodological Approach

This thesis has so far outlined a broad theoretical outline of the various issues regarding corporatisation, and how they relate to water. This paper will now discuss the methodology to be used for the data gathering.

The methodology for this thesis contains both qualitative and quantitative aspects. A quantitative approach has the advantage of allowing one to make assertions based on data (although when analysing data, caution must always be employed, given the propensity for errors and sample bias). The qualitative approach allows for deeper insights into specific issues, that cannot be strictly measured by indicators.

This approach will be more empirical, as opposed to theoretical, as it will be more focused on gathering data, instead of testing theories. Specifically, the thesis will be based largely on the data gathered through statistics on water supply. These statistics were derived from the Ministry of Water and Irrigation, which is the main source of water information in Jordan. The results will be checked against existing theory.

5.2 Quantitative Research

The data obtained includes, but is not limited to:

- Water supply by the different governmental organisations, over the last 20 years
    - MWI
    - WAJ
- Water supply by the different corporatised utilities
    - Miyahuna, from 2007 until today
    - AWC
    - Yarmouk Water Company
- Revenues and costs of each of the above organisations and companies, going back 10 years (or as long as possible)
- The amount of investment into each of the above organisations, companies and water plants, going back 10 years (or as long as possible)

- NRW, across time (preferably the last 10 years), according to each organization and company
- Connection to water pipes, that is, which parts of Jordan did the above organisations (and companies and water plants) connect with water pipes, and which parts could not be reached (over the last 10 years)

In order to obtain this data, I will contact various officials in the MWI, the WAJ, the Department of Statistics, as well as other relevant authorities.

After contacting a representative from each organisation over the phone, I met the representative in person. Once the statistics are gathered, special attention has been paid to 'outliers,' answers which appear to be outside the spectrum of reasonable opinion.

5.3 Data Envelopment Analysis

Once the quantitative data is collected, this thesis will then use econometric methods to analyse such data. These techniques allow for a deeper analysis into the efficiency of the Jordanian water sector, beyond simple graphs showing output and costs. This section will provide an overview of these methods, and each empirical chapter will discuss the methodology in greater detail.

The first method will be Data Envelopment Analysis (DEA). This technique examines the inputs and outputs of the Decision Making Units (DMUs) in a sample. The theoretical maximum efficiency of the sample is derived from the most efficient DMU (that is, the DMU with the most output per unit of input). This is used to create theoretical frontier, with the most efficient DMUs on the edge on the frontier. The efficiency of other DMUs are then ranked in relation to the most efficient DMU, and thus the efficiency of each DMU is attained.

For the DEA, software from "Data Envelopment Analysis Online Software," was used. The data, including DMUs, inputs and outputs can be input directly into the software, and the efficiency and rank of each DMU is then found.

There are many advantages to this methodology. The main reason for using this method is that it is possible to measure efficiency using multiple inputs and outputs (Kohl, Schoenfelder, & Fügener, 2019). This is in stark contrast to simple efficiency ratios (for example, the ones used in Section 7.6) which show only the relationship between one input and one output. Also, it is not necessary to specify the production function (Stefko, Gavurova, & Kocisova, 2018). By ranking DMU efficiency, based on multiple inputs and outputs, a more holistic image of the firm is created. Thus, not only can DMUs be ranked, but suggestions can be made to improve efficiency in under-performing DMUs.

Another advantage is that there is no strict need for input or output pricing, although it can improve models in certain cases (Kuosmanen, Cherchye, & Sipilainen, 2006). This is particularly advantageous in the water sector, as it is frequently affected by price caps, subsidies and monopolies, all distorting market prices.

5.4 Difference-in-Difference

After the DEA, this thesis will utilise Difference-in-Difference (DID) analysis. When examining how a policy affected a sample, researchers can simply measure how a specific variable changed in that sample before and after the policy. However, it is not immediately clear whether the change in the variable is due to the new policy, or to exogenous factors beyond the policy. Thus, one can find a different sample in the same population, which grew in parallel trends before the policy was implemented. After examining how each population grew, researchers can then find how the two populations grew after the policy was adopted. Hence, one finds the 'difference in the difference,' which allows one to separate the impacts of policy from exogenous factors.

Specifically, the DID method examines the causal effects of a policy on a variable by comparing two differences: the first being the difference in outcome between the treated and control group; and the second being the difference in outcome before and after the implementation of policy.

This is the reason for choosing this methodology: the ability to examine a trend in a population, and to understand to what extent that trend is a result of policy changes or exogenous variables.

However, for a DID analysis to be precise, certain assumptions must be met. Specifically, the parallel trend assumption states that in the absence of the policy implementation, the gap (in the variable to be studied) between treatment and control groups is consistent in the long-term. That is, there are no significant unobserved differences between the treatment and control samples other than the policy implementation. This assumption is essential to DID methodology; that the parallel trends between the two groups would have persisted, had the policy implementation not occurred. This methodology is further expanded upon in Chapter 9.

5.5 Stochastic Frontier Analysis

The third and final quantitative method to be used in this thesis is Stochastic Frontier Methodology (SFA), examining the costs of Jordanian water utilities. While a simple cost function could have been used, an SFA was chosen because an SFA can split costs into endogenous and exogenous factors. SFA is a parametric technique, analysing technical efficiency by creating a production frontier, based on the performance of the best utility. The most efficient utilities fall on the frontier, and other utilities will fall within the frontier, hence comparisons can be made, relative to the best utility. Leite, Pessanha, Simoes, Calili and Souza (2020) discuss how, in deterministic frontier models, such as cost functions, any distance away from the frontier is due to inefficiency. However, such models do not account for the likelihood of random shocks beyond the control of the utility. Therein lies the key difference between a stochastic frontier and a regular cost function. Indeed, with SFA, one can distinguish inefficiencies caused by either the utility's own practices, or exogenous shocks beyond the utility's control. Hence, the SFA separates the error term into two distinct parts, containing both endogenous and exogenous causes of inefficiency (Leite, Pessanha, Simoes, Calili, & Souza, 2020). This allows for a deeper understanding of the sources of inefficiency in water utilities. This is further buttressed by Cornwell and Schmidt (2008) who show that deterministic frontiers do not factor in the randomness of real-world economics. This is the key difference between SFA and DEA; in SFAs, random noise and efficiency are separated, whereas in DEA, the noise is part of the efficiency result (Nguyen & Pham, 2020).

The SFA technique allows analysts to examine how each variable impacts the costs of the utility. It also allows for a separation of the causes of inefficiency, into exogenous and endogenous factors. Thus, if the analysis shows that inefficiency is a result of internal factors, such as managerial, technological, or other faults, firms can address such faults. Conversely, if the analysis shows that inefficiencies are caused by external conditions, the firm can take steps to adapt to the external environment. Also, variables must be chosen carefully, so as to avoid correlation of independent variables with the error term. This could be due to simultaneity, measurement issues or omitted variables. SFAs are logged and outcomes are interpreted as elasticities. This methodology is further expanded upon in Chapter 10.

5.6 Customer Orientation

This qualitative section of the thesis examines the customer orientation of Jordanian water suppliers, and the relationship between customer orientation and supplier performance.

Specifically, this chapter studies how customer oriented Jordanian water suppliers are. That is, it will show to what extent Jordanian water suppliers engage in policies that are in line with customer needs and desires. These include, but are not limited to, engagement with the supplier, dependence of the supplier on customer revenue, and how suppliers tackle NRW. Once this data has been collated for each supplier, the data is analysed, to see not only how customer oriented the firm is, but in what ways the firm is oriented, and how such orientation is related to the firm's performance.

5.7 Ethical Issues

The ethical issues which arise include, but are not limited to:

- Guaranteeing the anonymity of participants
- Potential political fallout of participants

In order for my research to be ethical, I will ensure that:

- All participation will be voluntary
- All participants will be made fully aware of the nature of my research, and what it entails
- All participants will be fully anonymous (that is, they will be codified)

5.8 Limitations of the Research Methods

As with any attempt at research, there are going to be shortcomings, which may prevent the work from being as comprehensive and insightful as possible. For example, the DEA may benefit from a secondary-stage econometric analysis, such as a Tobit Regression or a Malmquist Index. Additionally, more DMUs could have been added, either by increasing the range of years to be studied or including water suppliers from other Middle-Eastern countries. Also, increasing the number of variables used in each of the statistical methods would have allowed for greater exploration of the factors affecting Jordanian water supply efficiency. These steps would increase the rigor of the findings in the statistical methods sections.

This thesis depends, to a significant degree, on the government's statistics for water supplies, as they are the sole supplier of water in the country, and have control over water-related statistics. Thus, any errors the government made in their statistics (whether due to technical error, bias, errors of omission or commission) may be reflected in the thesis.

Also, this thesis will not include a detailed analysis of the geo-political causes of Jordan's water shortages, that is, its relations with neighbouring countries. This may weaken the thesis as Jordan's relations with its neighbours may significantly limit the amount of water Jordan receives, but this is beyond the scope of this thesis.

Chapter 6 Water Scarcity in Jordan

6.1 Introduction

This chapter provides an in-depth background to Jordan, specifically the available data pertaining to its water situation. This chapter analysed Jordan's water supplies and demand, as well as the resulting water deficit. The chapter also analysed other economic considerations, related to water, such as pricing policies.

This chapter also looked at each of the primary sources of water in Jordan, as well as the degree to which they are exploited. It examined these trends across a time series, as well as the causes for water over-exploitation. Thus, this chapter analysed the government's various attempts at combatting water shortages, as well as the impacts such strategies have had.

The chapter finds that Jordan is in water deficit by 400 million cubic metres (MCM) per annum, and that this gap is growing rapidly, to the point where Jordan might not have any local water supplies by 2030-2050. The primary causes of this crisis include, but are not limited to: a rapidly increasing population (exacerbated by waves of refugees from neighbouring conflicts), modernising lifestyles as a result of increasing incomes, the adverse impacts of climate change, a water delivery infrastructure desperately in need of renovation, repair, investment and modernisation. Agriculture is the main component of Jordan's water consumption, although domestic and municipal water consumption is rapidly increasing its share of water consumption in the country.

6.2 Jordan Brief

This section offers a brief introduction into Jordan's history, politics and socio-economic context.

<u>*Population*</u>

Jordan's population in 2019 amounted to 10.1 million people, including foreign refugees, whereas in 2000, the population was 5.1 million individuals (World Bank, 2021). In other words, the population doubled in the last two decades, or grew at an annual average growth rate of approximately 5%, which gives Jordan one of the fastest population growth rates in the world. For comparison, the global annual average population growth rate over the past two decades was approximately 1.3% per annum (World Bank, 2021).

Out of the 10 million people in the country, 2.9 million are foreigners (or approximately three in ten individuals). Excluding the foreign population, Jordan's population growth rate has in fact slowed down in recent years, due to modernising lifestyles and increasing costs of living, from families of 6.7 members in 1979, to 4.8 members in 2015 (Ghazal, 2016).

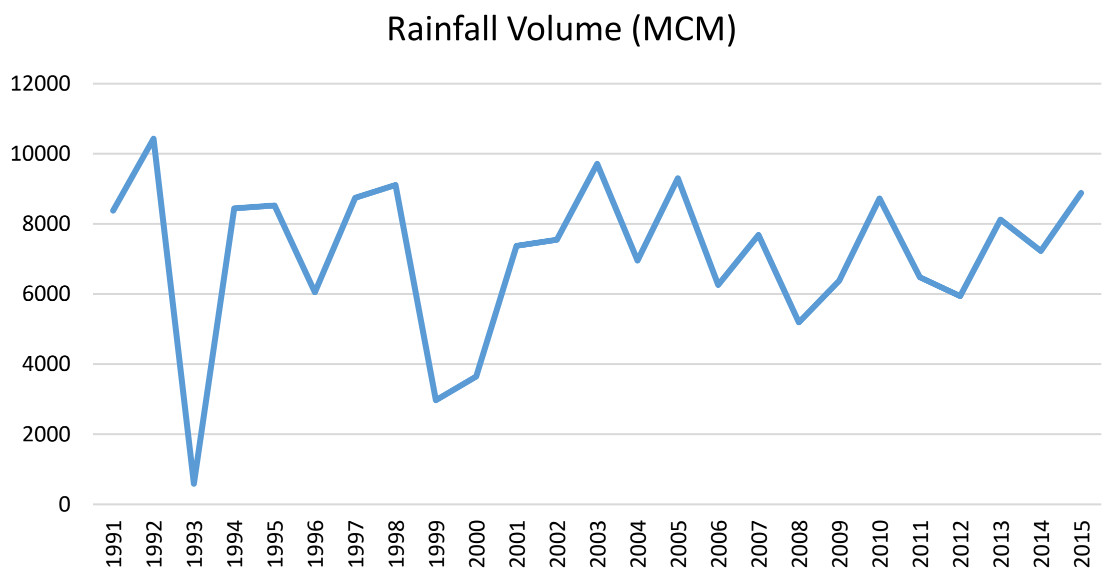
As of February 2021, Jordan had over 753,000 refugees, (88.2% of which are Syrian) amounting to 75 refugees per 1000 inhabitants (a drop from the high of 87 refugees per 1000 inhabitants in 2017). This makes Jordan one of the countries with the highest rate of hosting refugees, both as an absolute number and as a percentage of the population (UNHCR, 2021).

The impact of this rapid population growth in Jordan has rapidly increased the demand for water, putting extensive strain on the nation's water resources, as will be discussed further in this chapter.

Climate

Jordan has a very dry, arid climate, with temperatures ranging from an average of 28.4 degrees Celsius in the summer (although it can reach upwards of 35 degrees), to an average of 9 degrees Celsius in the winter. Jordan has practically no rainfall between June and September, and receiving on average, 96 mm annually (CCKP, 2021) (the global average is 600 mm to 1000 mm annually).

Figure 2 Rainfall Volume, Jordan, 1991-2015



Source: MWI (2013); MWI (2015)

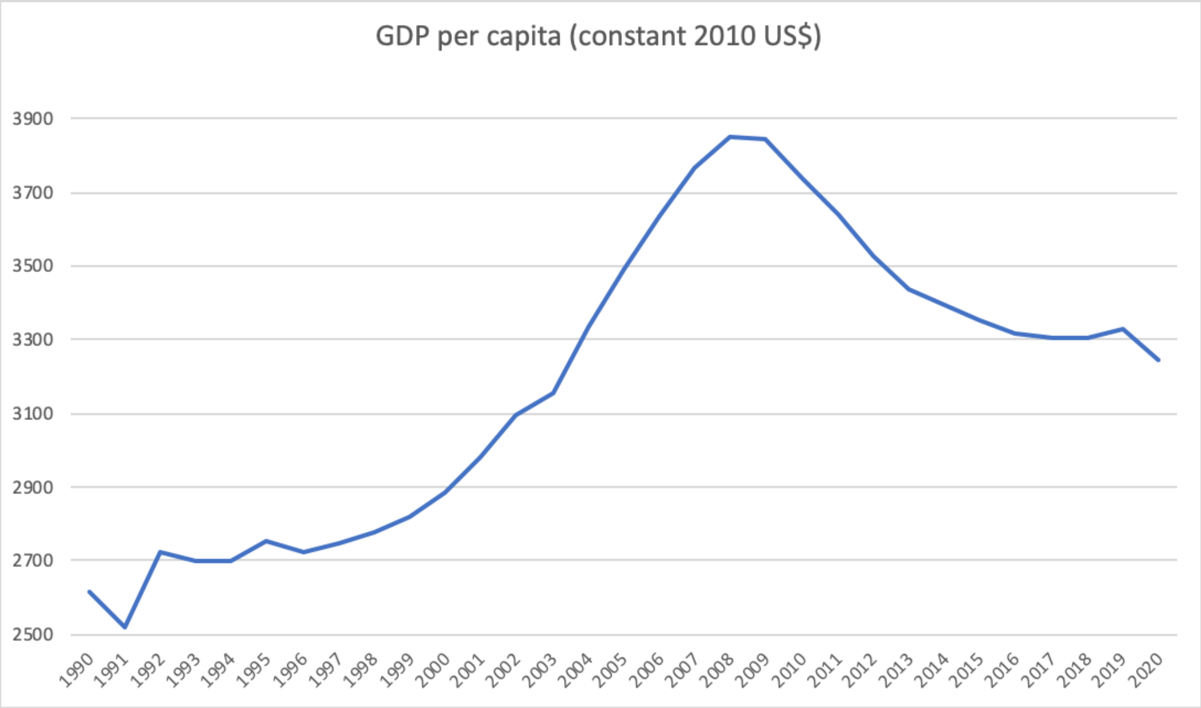
As Figure 2 above shows, rainfall in Jordan is showing an overall declining trend, although still quite erratic. However, the annual fluctuations in rainfall in Jordan have been narrowing, in recent years fluctuating between 6 billion and 9 billion cubic meters. Jordan received 8.9 billion cubic meters of rainfall in 2015. It should be noted that this was only the third time in the preceding decade that rainfall exceeded expectations, with most years showing less rainfall than the long-term average. Jordan's rainfall, between 1991 and 2015, ranged from a low of 589 MCM in 1993 to a high of 10.4 billion cubic meters in 1993. Also, this indicates that, should the nation make better use of technologies to harvest rain water, it may significantly improve the nation's water deficit problems.

It should be noted that Jordan's already limited rainfall has been exacerbated by climate change. While rainfall has not decreased significantly over recent years, as indicated in Figure 2 above, rainfall has in fact become more concentrated, now occurring primarily between November to February, whereas in the past rain occurred between October and April. This concentrated rainfall makes it harder to collect rain water, thus reducing overall available water supplies.

Socio-Economic Conditions

The average wage in Jordan is approximately 637 United States Dollar (USD) per month, while the average expense for a person is 676 USD/month (Azzeh, 2017). The fact that people are spending more than they are earning is a trend that has persisted over the past few decades, with families trying to cover the gap either through increasing debt, cutting consumption or assistance from friends and relatives (a large portion of income in the country is remittances from Jordanians working abroad).

Figure 3 GDP/Capita, Constant 2010 USD, Jordan, 1990-202



Source: "World Development Indicators," World Bank, 2021

Jordan's gross domestic product GDP per capita, in constant 2010 USD, was 3,200 USD/capita in 2020, whereas in 1990 it was 2,600 USD/capita, a growth rate of 23.1%, or an annual average growth rate of 0.8%. However, Jordan's GDP grew by 254.5% during this period, or an annual average increase of 8.5% (World Bank, 2021). This implies that the drop in GDP/capita was more a result of soaring population growth, which in turn was caused primarily by the waves of refugees escaping regional instability. These increases in income allow for more modern, water intensive lifestyles, which exacerbates Jordan's water deficits.

Table 1 Surface Water Budget*, MCM, Jordan

	Rainfall	Evaporation	Runoff	Recharge
2000	3651	3474	75	102
2001	7375	7063	148	164
2002	7545	7012	162	371
2003	9708	9026	275	406
2004	6951	6551	134	266
2005	9304	8671	270	364
2006	6258	5813	157	289
2007	7683	7201	195	288
2008	5194	4869	115	209
2009	6379	5903	127	349
2010	8728	8092	210	425
2011	6073	6477	119	285
2012	5943	5535	139	269
2013	8120	7689	187	244

Source: MWI (2013)

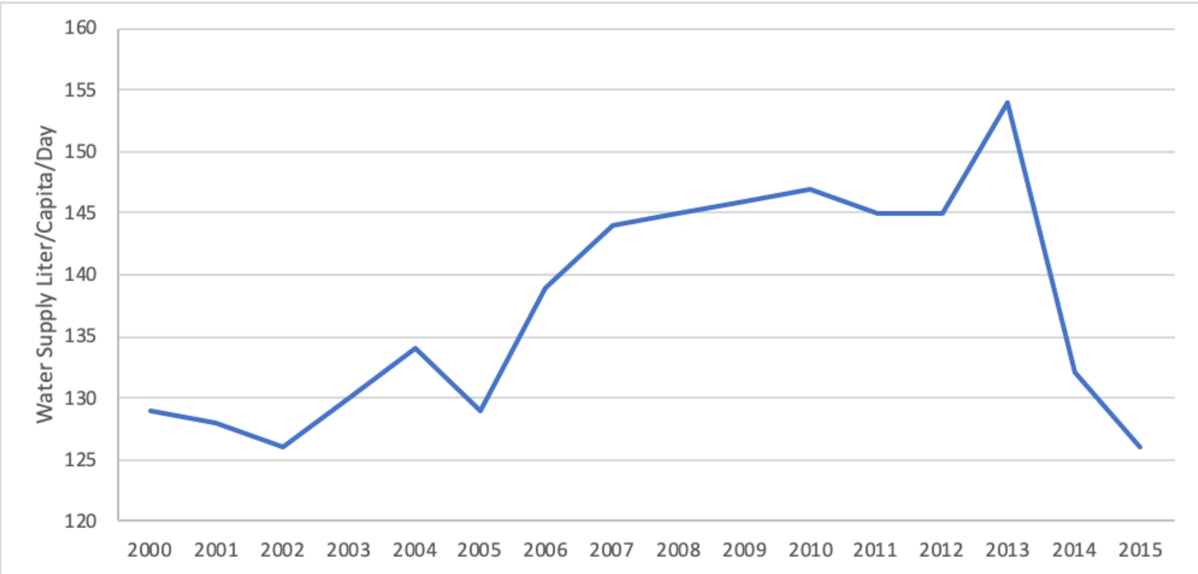
*Note: Rainfall – Evaporation – Runoff = Recharge

Table 1 above shows Jordan's surface water budget, up until 2013. A water budget is a method of calculating the inflows and outflows of water, in an ecosystem. Specifically, there should be a balance between rainfall, and the other components of the water budget (a combination of evaporation, runoff and recharge). Table 1 does raise the issue of whether Jordan can make better use of its rain resources, to alleviate some of the water pressures facing the country.

As of 2013, water supplies within Jordan amounted to 900 million cubic meters, whereas water demanded amounted to 1,200 million cubic meters. As of 2021, Jordan required 1.3 billion cubic meters, but could only supply 850-900 million cubic meters (Al-Jazeera, 2021). The 400-450 million cubic meter deficit was made up through a variety of methods, including importing water intensive goods such as crops and the usage of non-renewable groundwater.

Water prices are kept artificially low in Jordan, through a variety of methods, such as governmental subsidies and foreign grants. Proponents of the neoliberal paradigm maintain that due to the combination of water scarcity and over-pumping, offering water at subsidised prices is not feasible in the long term, putting ever greater strains on the environment. By raising the price of water to market levels, investors will have an incentive to invest in the repair of Jordan's crumbling water provision infrastructure.

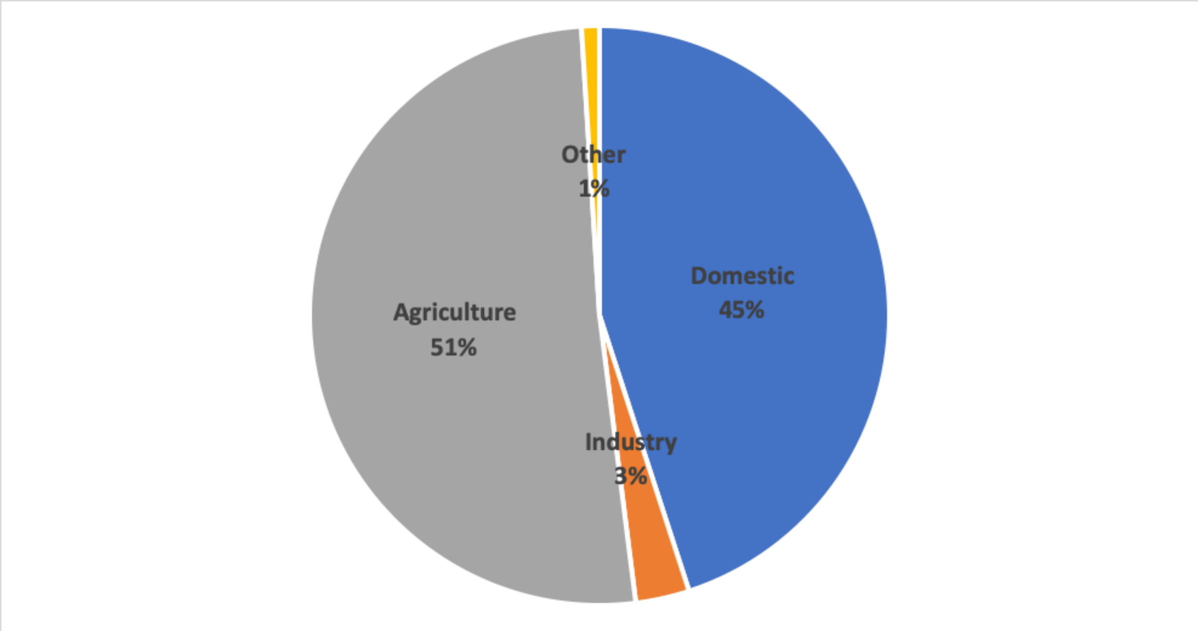
Figure 4 Water Supply Litre/Capita/Day



Source: MWI (2015)

As Figure 4 above shows, the average person in Jordan received 126 litres of water on an average day in 2015. This is equivalent to 0.126 cubic meters per day, or 46 cubic meters per year. It should be noted that the internationally recognised benchmark for 'absolute scarcity' in water usage, is anything less than 500 cubic meters per year (Brown & Matlock, 2011). This implies that Jordanians consume one tenth of the amount needed to reach 'absolute scarcity,' placing Jordan in the bottom ten countries in water scarcity. The distribution of water resources across sectors, as of 2013, can be shown in the following chart:

Figure 5 Water Usage per Sector



Source: MWI (2013)

As Figure 5 above shows, over half of the nation's water resources are geared towards irrigated agriculture, thus making it clear that food production and sovereignty is a high priority for Jordanians, despite the significant opportunity cost. Harrigan (2014) expands on this theme, explaining that drops in rainfall and water supply in general, along with weaker returns to cereal production, have left the country only able to generate 7% of its needed grains, thus necessitating excessive grain imports. The author also shows that, with a rapidly growing population and diminishing water reserves, Jordan should strongly consider a shift to less water intensive crops (like fruits and vegetables), and meet its grain needs through trade.

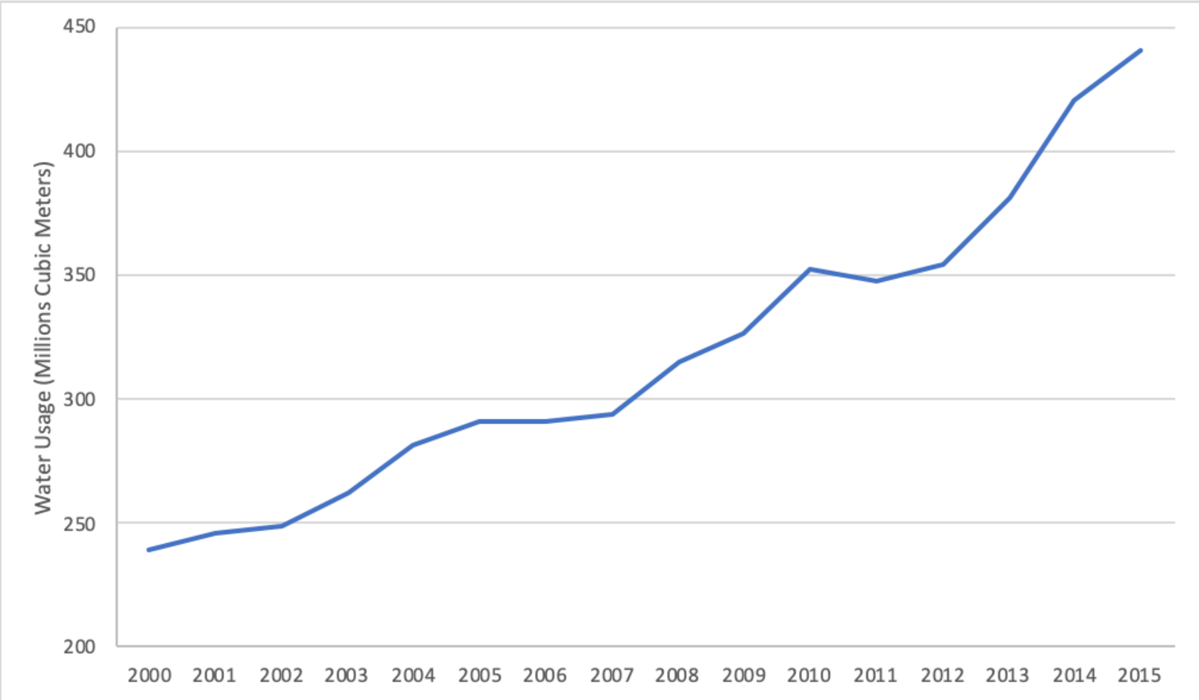
In fact, Solomon (2010) maintains that Jordan, in addition to most Arab countries, ran out of renewable water in the 1950s-60s, thus making food self-sufficiency an unattainable dream. Specifically, the residents of the Jordan River Basin (Jordan, Palestinian Territories and Israel) possess approximately one third of the water required for food self-sufficiency. Also, it should be noted that desalination techniques, up until recently, cost almost 100 times more than conventional water extraction techniques.

However, modern technologies have brought the price of desalination down significantly (Solomon, 2010), although it is still doubtful whether developing countries will deem it cost effective to invest in desalination.

6.3 Water Usage in Jordan

As the previous section offered a background into the various issues plaguing the water sector in Jordan, this section will go into more depth, showing how water consumption and supplies have fluctuated in Jordan in recent years.

Figure 6 Water Usage for Household and Municipal Purposes (MCM)



Source: MWI (2015)

As Figure 6 above shows, water usage for household and municipal purposes increased from 239 million cubic meters to 440 million cubic meters between 2000 and 2015, an 84.1% increase or an annual average increase of 5.6%. It should be noted that during this time period, Jordan's population increased 29.2%, or an annual average increase of 2.7%. This shows that Jordan's rapid population growth alone cannot account for the surge in water usage during this period, with other factors such as urbanisation, evolving lifestyles, and a growing middle class, all contributing to the water crisis in Jordan.

Table 2 Water Supply for Household and Municipal Purposes (MCM)

	2006	2007	2008	2009	2010	2011	2012	2013	Change (%)
Central	189.8	198	202.3	202.3	215.5	215.1	219.8	244.9	29
North	59.6	62.2	66.1	66.2	67	70.2	72.3	73.1	22.7
South	36.9	40.7	42	42	45.2	44.5	74.3	49.1	33
Total	**286.3**	**300.9**	**310.4**	**310.5**	**327.7**	**329.9**	**339.4**	**367.2**	**28.3**

Source: Department of Statistics (DOS) of Jordan, (2014)

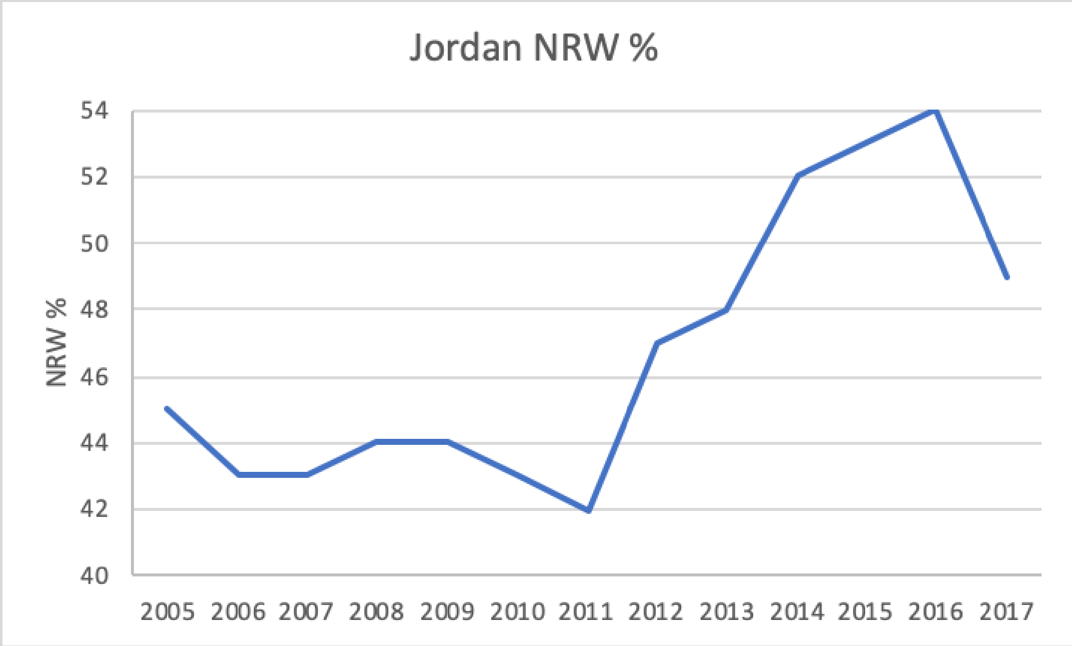
As Table 2 above shows, there is wide variation both in terms of water usage and the growth in water usage, amongst the different regions in Jordan, with the Central region showing the most usage of water for household and municipal purposes, at 244.9 million cubic meters in 2013, due to Amman being located there. However, the Southern region, which has shown the least usage of water in 2013, has shown the most growth, at a 33% increase over 2006 (perhaps due to the fact that this is the least developed region in the country, and therefore had the most potential for growth).

Approximately 97% of the population is served by water pipes. While this may seem impressive, there are various underlying weaknesses. In addition to receiving water only 8-18 hours per week, NRW, that is, water which does not reach its intended destination, remains excessive, as the section below shows.

Non-Revenue Water

While this chapter focuses on issues pertaining to water supply and demand, it is pertinent to note that not all the water which is calculated as 'supply' will actually reach its intended target, being lost on the way, due to infrastructure weaknesses or theft, resulting in NRW.

Figure 7 Non-Revenue Water (%)



Source: Ministry of the Environment, Jordan (2020)

As Figure 7 above shows, Jordan has shown a steady increase in the amount of water lost in delivery to its destination, from 45% of water lost along the way in 2005, to 49% lost in 2017 (with the highest NRW levels in 2016, at 54%). Indeed, these levels are still significantly above world averages. For example, the country with the best track record in dealing with NRW is Singapore, at 8%, whereas the average for the developing world is approximately 30% (Haddadin, 2006). However, it should be noted that even the figure of 49% NRW may be an underestimate, as the government lacks the necessary tools and resources to measure NRW with real precision. Specifically, the government cannot determine where the leaks take place, what are the source of the leaks (that is, is it dilapidated infrastructure or theft), or how much each leak costs in terms of water loss. Due to these technological limitations, the figure of 49% may very well be an underestimate.

Having discussed the amount of water Jordanians are supplied with (and how much actually reaches them, due to NRW), it will be instructive to understand how much Jordanians pay for their water.

The price charged by the Water Authority in Jordan, for water, is 1.06 Jordanian dinar (JD) per cubic metre. However, it costs the Water Authority 1.88 JD/m^3, in order to extract, process and deliver water, leading to a net loss of 0.82 JD/m^3 (MWI, 2014). The Authority sets the price artificially low for political reasons, but this has led the Authority to experience a loss of 169 million JD in 2014 (in conjunction with rising capital and operational costs, as well as external factors such as rapidly increasing numbers of refugees).

Inflation, with respect to water and sanitation, increased by 1.96%, between 2010 and 2015 (CBJ, 2015). While this is a miniscule change (representing less than 0.4% increase per annum between 2010 and 2015), this may largely be a reflection of governmental subsidies and price ceilings. Indeed, in a nation with extreme water deficits and rapidly growing water demand, economic theory tells us that the price of water should be increasing drastically.

Another component essential to an understanding of the nature of water usage in Jordan is the actual source of water for Jordanian households.

Table 3 Households by Main Source of Water

	Public Network (%)	**Tanker (%)**	**Rain Water (%)**	**Other (%)**
Amman	98.3	1.3	0	0.3
Balqa	96.8	2.8	0.2	0.2
Zarqa	98.9	0.9	0	0.2
Madaba	97.2	2.4	0.3	0.2
Irbid	94.9	4.4	0.5	0.2
Mafraq	90.6	9.2	0	0.2
Jarash	97.9	1.8	0.1	0.3
Ajlun	94	3.5	2.1	0.4
Karak	99.1	0.7	0	0.2

Tafiela	99.7	0.2	0	0.1
Ma'an	98.9	0.6	0.1	0.4
Aqaba	99.6	0.1	0	0.3
Urban	98.3	1.5	0.1	0.2
Rural	92.9	6	0.4	0.6
Jordan	**97.4**	**2.2**	**0.2**	**0.2**

Source: DOS, (2013)

As Table 3 above shows, the overwhelming majority of Jordanians get their water through the pipes within the public network, with only 2.6% of the population getting their water from outside the public network.

Table 4 Households by Main Source of Drinking Water

	Public Network (%)	**Mineral Water (%)**	**Tanker (%)**	**Rain Water (%)**	**Other (%)**
Amman	42.6	55.7	0.8	0.5	0.5
Balqa	59.1	31.2	2.6	6.5	0.6
Zarqa	60.4	38.8	0.4	0.2	0.2
Madaba	40.1	56.4	0.9	1.7	0.9
Irbid	34.3	35.1	2.6	26.1	1.8
Mafraq	77.3	13.7	8.4	0.1	0.5
Jarash	35	58.1	0.5	4.7	1.7
Ajlun	38.4	35.3	1.6	21.6	3.2
Karak	56.3	41.2	0.5	0.5	1.6
Tafiela	96	3.5	0.1	0.3	0.1
Ma'an	57.6	37.7	0.6	0	4.1
Aqaba	96.9	2.7	0.3	0	0.2
Urban	47.6	46.4	0.9	4.6	0.5
Rural	53.2	28.2	4.1	11.6	2.9
Jordan	**48.6**	**43.3**	**1.4**	**5.8**	**0.9**

Source: DOS (2013)

As Table 4 above shows, the main sources of drinking water for Jordanians are the public network, at 48.6% of the population, and mineral bottles, at 43.3% of the population.

As of 2013, the average Jordanian consumed, as an annual average, 198.3 litres of bottled mineral water. This amounts to 540 millilitres (or a little over half a litre) of water per person per day. However, these figures vary widely across governorates. Specifically, in 2013, urban Jordanians consumed 213.1 litres of bottled mineral water as an annual average, as opposed to 131.5 litres for rural Jordanians (DOS, 2013). This shows the extent to which Jordanians are dependent on a private source of water, as bottled water may be considered expensive, especially for individuals from rural and disadvantaged households.

6.4 Jordan's Water Challenges

In 2015, Jordan consumed 1.4 billion m^3 of water, but had a sustainable water replenishment rate of 1 billion m^3, thus implying a 400 million m^3 renewable water deficit. This deficit is expected to grow to almost 700 million m^3 by 2040 (with a 1.5 billion m^3 supply and almost 2.2 billion m^3 demand) (MWI, 2016).

Before delving into the available statistics on water in Jordan, it is necessary to offer some disclaimers. Any chapter on the statistics of a developing country should discuss the difficulties of obtaining accurate data in such countries. In many developing countries, issues relating to scarce resources are highly politicised, and therefore sensitive. In Jordan, the MWI is the sole source of information on water in the country. This leaves such data at the mercies of the government, who are acutely aware how important is the perceptions of the population, that they are seen as providing sufficiently for the needs of the people.

Water Investment

Any attempt to reduce Jordan's challenging water deficit will require significant investment and upgrading of the nation's water infrastructure. The MWI devised the "Water Sector Capital Investment Plan, 2016-2025," (MWI, 2018) to meet this challenge. This includes the following targets: ensuring stable water supplies and accessing new water resources in order to increase water supply/capita. By 2025, the plan aims to increase metered water to 105 litres/capita/day, limit NRW to 30%, increasing energy efficiency to 3.66 kwh/m^3 of water, and increase wastewater coverage to 80% of the population. The report predicts that Jordan will require 557 MCM by 2025 (based on the 429 MCM required in 2014, and an estimated 30% increase in demand). Overall, the plan will require approximately 3.5 billion JD for water projects, and 1.9 billion JD for wastewater projects, for a combined total of 5.4 billion JD. With the investments in energy needed for a project of this scale, the projected cost ultimately comes to 6 billion JD. As the plan is expected to encompass the decade 2016-2025, this means that the plan envisions roughly 600 million USD/annum. However, the report is not entirely clear on where these funds will come from.

Table 5 Investment in Water and Sanitation with Private Participation

Year	Value (Hundreds of Millions USD)
2003	169
2009	951
2012	192

Source: World Bank (2016)

Table 5 above shows that private participation in water investment in Jordan has been not only sporadic, but relatively minor. If the government is to complete its lofty ambitions of providing water for the populace, then it will need a much larger amount of foreign direct investment (the Red-Dead Sea Conveyance Project, for example, will require 10 billion USD, and the private investments obtained between 2003 to 2012 are nowhere near sufficient).

Beyond the lack of investment, the nation struggles with the costs of the water sector. It should be noted that water itself is virtually free, it is the cost of infrastructure and directing water towards consumers that requires significant investment. The extraction, pumping and distribution of water requires substantial amounts of energy (one of the biggest contributors to Jordan's national deficit). This is compounded by the rapidly growing number of homes connected to the water network. For example, the number of water subscribers in Jordan increased from 838,000 in 2005 to 1.3 million in 2015. The number of waste-water subscribers in the country increased from 528,000 in 2005 to 834,000 in 2015 (MWI, 2013); (MWI, 2015).

This has led to a situation whereby the WAJ (along with its affiliate companies), incurred approximately 245 million JD in operational and maintenance costs (without interest), which was a 44.5% jump over the 2010 figure. Capital costs amounted to 336 million JD, of which the vast bulk, 206 million JD, was self-financed, 55 million was covered by international loans and 75 million was covered by external grants (MWI, 2016).

This is compounded by the fact that cost recovery in the Jordanian water sector has been declining in recent years, as the extensive investments in water provision and wastewater did not result in concomitant water price increases. Indeed, cash subsidies have to be provided by the central government to compensate for the shortfall in revenue collection. Cash subsidies for water in Jordan amounted to 220.3 million JD in 2010, up from 66.3 million JD in 2008. The World Bank calculates that removing water subsidies will increase water prices by 257% (as opposed to 69% for food products). The World Bank calculated subsidy levels as the gap between the revenues and the costs of the WAJ, and the gap between the budget and costs for the MWI and JVA. However, the World Bank makes clear that this methodology of estimating subsidies is almost certainly an underestimate, as water project investment is channelled outside the MWI (World Bank, 2011).

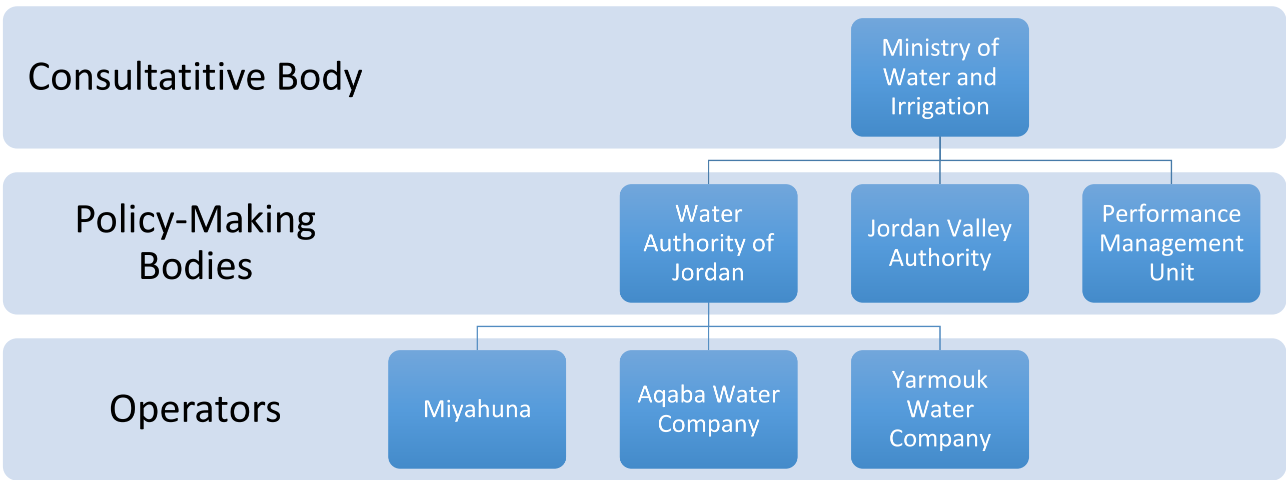
All the aforementioned costs have been exacerbated by the various crises affecting Jordan's neighbours. There were approximately 655,000 Syrian refugees in Jordan, at the end of 2015. The MWI has calculated the total costs of supplying the refugees with water at 439.1 million JD (or 440 JD/year for each Syrian refugee). This can be broken down into economic costs, at 368.8 million JD, and environmental costs at 70.2 million JD (the costs of over-pumping groundwater). The economic costs include an opportunity cost of 187.3 million JD (it is unclear how the ministry came to that number), and a financial cost of 181.5 million JD. This financial cost can further be broken down into future costs of 121.7 million JD and current costs of 59.8 million JD (MWI, 2015).

7 Overview Jordanian Water Sector

7.1 An Overview of the Major Actors in the Jordanian Water Sector

This section provides a brief overview of the key actors in the Jordanian water sector. Three corporatised water utility firms service Jordan's citizenry: The Jordan Water Company (frequently shortened to Miyahuna); AWC; and YWC. These three utilities provide water for eight out of twelve governorates in the country, with the remaining governorates (particularly those in poorer and more remote locations) served by the WAJ (RCEPR, 2016). These three main water suppliers function as subsidiaries of WAJ, which in turn is a branch of the MWI. Figure 8 below is a representation of the various institutions involved in the supply, management and regulation of water in Jordan:

Figure 8 Main Institutions in the Jordanian Water Sector



Source: Adapted from RCEPR (2016)

7.1.1 Ministry of Water and Irrigation

The MWI is the governmental entity tasked with managing and regulating the water sector, formulating local water strategies, monitoring of water supply, and management of the country's wastage system.

Established in 1988 by the government's executive branch, it currently consists of at least six major departments (better known as 'directorates' locally), including the Department of Internal Monitoring and Department of Technical Affairs (MWI, 2010). The former department focuses heavily on the financial dimensions of water management and requires financial audit plans and procedures to be submitted to the Minister for his approval, in order to protect MWI's financial resources from being misused. The latter department on the other hand monitors the usage of water resources, in particular groundwater, and monitors usage via geographic information systems and mathematical models. Its subsidiaries are JVA, WAJ, and the corporatised water companies.

MWI is tasked with directing Jordan's overall water strategy, as well as water planning and sanitation (Diep, Hayward, Walnycki, Husseiki, & Karlsson, 2017). It is a regulatory body, implying that it is charged with the monitoring of Jordan's water system, water supply and wastewater systems. This is in addition to planning and the running of water-related projects. Also, the Ministry takes part in water strategy and the development of policy, information systems, research and development, and the provision of water related data and statistics (GTZ, N.D.).

7.1.2 Jordan Valley Authority

The JVA, created in 1977, is the legal body tasked with the economic and social development of the Jordan Valley. It does this through the protection and conservation of water, as well as promoting sound irrigation practices. The JVA manages irrigation between the south of the Yarmouk River and north of the Dead Sea.

As JVA is primarily responsible for irrigation in the Jordan Valley, it falls out of the scope of this research, which focuses more on the efficiency of water suppliers to households.

7.1.3 Water Authority of Jordan

The second entity existing under MWI's umbrella, established in 1983, the WAJ treats wastewater and creates sewage systems to sanitize it. They are also responsible in particular for the supply of potable water. WAJ is composed of roughly eighteen departments, including the Irrigation, Water Studies, and Drilling departments. Its organizational structure is highly centralised and all departments report to the Secretary General.

WAJ owns and regulates the three main corporatised entities: Miyahuna, the AWC and YWC. WAJ holds a 100% ownership of the three firms. Thus, WAJ exerts control over many aspects in the three corporatised firms, including their general assemblies and how managers and board members are appointed and dismissed. However, the corporatised companies have full responsibility over all operations in their jurisdiction, as well as for small to medium sized investments. Large-scale investments however, require the authorisation of WAJ, and the bulk of the nation's water infrastructure is in WAJ's control (Mahayni, 2015). However, all four of these organisations are ultimately owned, managed and regulated by the MWI.

WAJ used to oversee the entirety of Jordanian water production, but, the creation of the AWC in 2004 gave management of AWC's water distribution to that company. The creation of Miyhauna in 2007 saw Amman, Zarqa and Madaba taken away from WAJ's direct management. The creation of YWC in 2010 saw the management of Irbid, Mafraq, Jarash and Ajloun transferred away from WAJ.

After the creation of Miyahuna, AWC and YWC, WAJ is left to manage the governorates of: Balqa, Karak, Tafileh and Ma'an.

7.2 The History of Water Sector Reforms in Jordan

The main institutional and policy change in Jordan started in 1997 with intervention of World Bank's neoliberal policies. As a result of agreements with the IMF and the World Bank, the Government of Jordan increased water tariffs in 1997 (for the bottom consumption range) from

0.28 USD/m^3 to 0.49 USD/m^3. By almost doubling the price of water, the average household was spending approximately 1.34% of its annual income on water (Haddadin, 2006).

The government continued the neoliberalisation process in 1999, with the establishment of a PPP to manage Amman's water provision system, with the assistance of 'Suez Environment,' a French company, and 'MWH Consulting,' a British Company. There is also a Build-Operate-Transfer for the largest Wastewater Treatment Facility in Jordan, which will expire in 2025, led by an international consortium. One of the purported advantages of the PPPs included the potential reduction of NRW by half (from 48% to 24%, baseline year of the agreement). However, by the end of the contract period in 2007, NRW still amounted to 43% of the national total. Another rationale was the improved quantity and quality of water reaching the populace, although nine World Bank-funded projects failed to achieve reduction of NRW (World Bank 2008).

Odeh (2009) finds that the water PPPs in Jordan offer mixed results, in terms of effectiveness and efficiency. The author finds that efficiency and effectiveness primarily depend on the structure and legal organisation of the PPP. The author recommends the usage of clear targets embedded in contracts, including all stakeholders in decision-making, increased accountability (codified legally) for consumers, and increased regulatory oversight.

Other justifications offered for the corporatisation process included (WAJ, 2010):

- Increasing local and foreign direct investment, through developing a lucrative investment environment
- Re-directing private capital to long-term investment, in order to support and develop internal capital markets
- Reduce national debt levels, by eliminating projects the government deems to be unsuccessful and costly, but that require consistent debt financing and grants

- Make use of international best practices, techniques and technology, in order to run national projects efficiently

The results of the water corporatisation process in Jordan, have been mixed. The number of homes supplied with piped water in Amman have increased, from 90% before corporatisation to 100% afterwards. However, the quality of the water remained poor, and the number of hours on the only day in the week in which water is available increased from 4 hours to 9 hours. The government also boasts that sewage coverage has increased from over two thirds to over 90% in the same timeframe. Also, water consumption/capita has increased from 70 cubic litres/day to over 90 cubic litres/day. Finally, homes with functioning water meters increased from just over half of homes in 2000, to almost 100% by 2005 (World Bank, 2008).

The era of water PPPs mostly ended in Jordan in 2007. Afterwards, the nation engaged in a different strategy, that of corporatisation. Specifically, the public sector attempted to employ a private sector model, whereby the practices, policies and operating procedures of private firms were emulated in the public sector. However, Build-Operate-Transfer Projects are still used, the main one being the Disi Water Conveyance Project. This project was a Build-Operate-Transfer concession for 25 years and transports 100 million cubic meters of water from aquifers to Amman (MEED, 2017).

The most prominent example of corporatised water in Jordan is 'Miyahuna' or 'Our Water.' Formed in 2007, it was designed to take over from the Consortium running Amman's water supply from 1999 to 2007, that is, after the end of the PPP and after the government took back full control of the water sector. The company is still an independent, autonomous entity, with corporatised business practices, making use of PPPs, private contracts, leases and concessions. However, prices it sets are politically determined, by the Jordanian Parliament. Also, it (as well as the other two corporatised entities) are heavily subsidised by the government.

However, Daher (2016) argues that neoliberalism in the Jordanian water sector did not end in 2007, it just took a different form. That is, the corporatisation that came to characterise the post-2007 era in itself amounted to a form of deregulation. Indeed, the author continues to show that many developing countries went through a similar pattern to Jordan, whereby the water sector was initially privatised (either outright or through PPPs), after which the water sector was corporatised, internalising private sector logic in the water sector. Also, with the corporatisation of the water sector, focus has shifted to cost recovery, ignoring the need for water recovery and investment in sustainable water extraction.

7.3 Introduction to Corporatised Jordanian Water Suppliers

7.3.1 Miyahuna

Miyahuna or Jordan Water Company is a private limited liability company. It is run by a CEO appointed by a board of directors, with the help of 1,500 staff members, and provides water to at least 2.5 million residents in Amman (OECD, 2014). The firm is a state-run utility tasked with managing the water distribution and wastewater in Amman, Madaba and Zarqa, as well as managing relations with consumers (Diep, Hayward, Walnycki, Husseiki, & Karlsson, 2017). This is done by promoting the utility’s goals and programs to consumers, tackling their concerns and educating the general public in the three governorates about water conservation.

The company is owned and regulated by WAJ, and ultimately, by the MWI. This means that WAJ exerts jurisdiction over Miyahuna's general assembly as well as influencing nominations to, and dismissals from, the board. Additionally, Miyahuna is responsible over all operations (including distributing water to Amman’s citizenry) and minor to medium investments in Amman’s water and waste water services. WAJ retains veto power over major investments, as well as the supply and regulation of bulk water. WAJ also owns Amman's municipal water infrastructure (Mahayni, 2015). However, as was previously mentioned, WAJ, Miyahuna and the other corporatised companies are ultimately all owned and regulated by the MWI.

Telfah, Halalsheh, Ribbe and Roth (2017) find that corporatisation improved the performance of Miyahuna, especially in the case of NRW, which went from 47% in 2000, to 33% in 2011. The authors then compare the performance of Miyahuna to international standards, specifically the median performance levels of international utilities. They find that Miyahuna's billed water operational unit cost was 160% of the international average for 2007-2013. When comparing against other MENA utilities, Miyahuna showed 190% greater costs for 2007-2010. However, Miyahuna billed 140% higher revenues than the international average, between 2007-2013. Median international NRW was 28% from 2009-2011, while Miyahuna's was 33%. The authors conclude that the implementation of corporatisation was successful in Amman. However, this is only correct when examining Miyahuna's progression across the years. The authors' own data shows that, when compared to other countries' utilities, Miyahuna still has significant progress to make in efficiency. Specifically, between 2007-2013, its revenues were 140% higher than the international average, but its costs were 160% higher. The authors also deem Miyahuna's financial position as 'satisfactory', which is questionable as Miyahuna could not cover its costs from 2008-2016; rather, it was only able to do so in 2017-2018 (GBD, 2008a); (GBD, 2009a); (GBD, 2010a); (GBD, 2011a); (GBD, 2012a); (GBD, 2013a); (GBD, 2014a); (GBD, 2015a); (GBD, 2016a); (GBD, 2017a); (GBD, 2018a).

7.3.2 Aqaba Water Company

Aqaba Water Company (AWC) was established in 2004 autonomously as a limited liability company, in order to handle the Aqaba Government's functions of operating water and wastewater systems in Aqaba. AWC is required to issue annual reports to its shareholders at the end of each fiscal year, in addition to submitting quarterly financial documents to WAJ (OECD, 2014) .

The Aqaba Special Economic Zone Authority (ASEZA) has the legal mandate for the development and management of water utilities in Aqaba.

ASEZA used its political clout to persuade the government of Jordan that a corporatized model would be more efficient than a purely state-run system. ASEZA maintained that upgraded water and wastewater systems were needed to promote development in Aqaba. Also, this was around the time that the Jordanian public sector started to come around to the idea of corporatised utilities (partially due to agreements with the World Bank). Thus, Jordan's Council of Ministers legislated the formation of the AWC (Mahayni, 2015).

WAJ is the predominant shareholder in AWC, with 85% ownership of the utility, with ASEZA owning the remaining 15%. As WAJ is the main shareholder, it controls the utility's general assembly, which contains the AWC's key decision-makers. Also, WAJ dominates the board of directors, with 5 of the 7 seats on the board, while ASEZA has the remaining two. The utility receives a designated bulk supply of water from MWI, which it in-turn uses to meet Aqaba's water needs. The utility, as earlier discussed, is financially autonomous regarding its short-term finances; WAJ has jurisdiction over long-term financial strategies.

7.3.3 Yarmouk Water Company

The YWC was registered as a limited liability company in 2010, previously existing as the Northern Governorates Water Administration. YWC provides water and wastewater services to Irbid, Mafraq, Ajloun and Jarash.

YWC supplies water to more than 300,000 households, dispersed over a wide, rural environment, and to roughly 100,000 people for wastewater services. YWC optimizes the use of groundwater sources, primarily the wells of Al-Aqeb, Wadi Arab, Hakama, and Al-Ramtha.

More recently, YWC is working in conjunction with USAID to create milestone initiatives in improving water and wastewater services in the north of Jordan. Part of the plan included reducing NRW, increasing debt collection (debts amounted to JD 3 million), increasing the workforce and developing a control centre for customer services (USAIDa, 2017).

Veolia Water managed YWC's more than 1,600 employees. The contract between the YWC and Veolia was based on meeting key performance indicators, meaning that compensation to Veolia would depend on various indicators, including water sales, lowering energy costs, managing cash flows and ensuring that water supply remained consistent (Aqua Treat, 2017). However, the contract between Veolia and YWC, which was meant to last between 2011-2018, was cancelled in 2013, as there were multiple financial and personnel challenges. Currently, it is wholly owned by WAJ (USAID, 2020).

7.4 Comparing the Efficiency of Jordanian Providers

This chapter will now discuss the efficiency of Jordanian water suppliers, by examining a variety of indicators. First, a brief financial background of each supplier is given.

7.4.1 Miyahuna

Miyahuna's revenues increased from 90.2 million JD in 2011, to almost 157 million JD in 2018, an increase of 74.1%, or an annual average increase of 10.6%. Operational expenses increased from 71.4 million JD in 2011, to 141 million JD in 2018, an increase of 98.3%, or annual average increase of 14%. The company's capital costs were 11.9 million JD in 2011, decreasing to 6.3 million JD in 2018, a drop of 47%; (GBD, 2008a); (GBD, 2009a); (GBD, 2010a); (GBD, 2011a); (GBD, 2012a); (GBD, 2013a); (GBD, 2014a); (GBD, 2015a); (GBD, 2016a); (GBD, 2017a); (GBD, 2018a). In 2011, revenues from bill payments covered only 49.6% of operational expenses increasing to 74.1% in 2017 (Miyahuna, 2017). Also, the company served 461,654 households in 2009, jumping to 650,000 households in 2018, an increase of 40.8% (Miyahuna, 2018).

7.4.2 Aqaba Water Company

The AWC served 9,800 households with water in 2010, increasing to 12,000 buildings in 2016, an increase of 22.4%, or an annual average increase of 3.7%. The company earned 12.6 million JD in 2010, increasing to 19.2 million JD in 2018, an increase of 52.4%, or an annual average increase of 6.5%. The company's current costs amounted to 8.7 million JD in 2010, increasing to 13 million JD in 2018, an increase of 49.4%, or an annual average increase of 6.2%. The company's capital costs amounted to 3.3 million JD in 2010, rising to 4.1 million JD in 2018, a rise of 24.2%, or an annual average rise of 3% (GBD, 2008b); (GBD, 2009b); (GBD, 2010b); (GBD, 2011b); (GBD, 2012b); (GBD, 2013b); (GBD, 2014b); (GBD, 2015b); (GBD, 2016b); (GBD, 2017b); (GBD, 2018b).

7.4.3 Yarmouk Water Company

The YWC made revenues of 17.8 million JD in 2010, climbing to 38.9 million JD in 2018, an increase of 118.9%, or annual average increase of 14.8%. Total costs increased from 29.5 million JD in 2010, to 49.7 million JD in 2018, an increase of 68.5%, or annual average increase of 8.6%. The company made a loss of 11.7 million JD in 2010, and 10.8 million JD in 2018, an improvement of 7.7%, or annual average of 1% (GBD, 2008c); (GBD, 2009c); (GBD, 2010c); (GBD, 2011c); (GBD, 2012c); (GBD, 2013c); (GBD, 2014c); (GBD, 2015c); (GBD, 2016c); (GBD, 2017c); (GBD, 2018c).

7.4.4 Water Authority of Jordan

The WAJ made revenues of 165.8 million JD in 2009, dropping to 132.8 million JD in 2018, a drop of 20%, or annual average drop of 2.2%. Total costs increased from 255 million JD in 2009, to 438.9 million JD in 2018, an increase of 72.1%, or annual average increase of 8%. The company made a loss of 89.2 million JD in 2009, and 306.1 million JD in 2018, a negative increase of 243%, or annual average increase of 27% (GBD, 2008d); (GBD, 2009d); (GBD, 2010d); (GBD, 2011d); (GBD, 2012d); (GBD, 2013d); (GBD, 2014d); (GBD, 2015d); (GBD, 2016d); (GBD, 2017d); (GBD, 2018d).

7.4.5 Comparison of Water Providers

Having offered a brief financial background of each supplier, this section compares the financial situation of the providers.

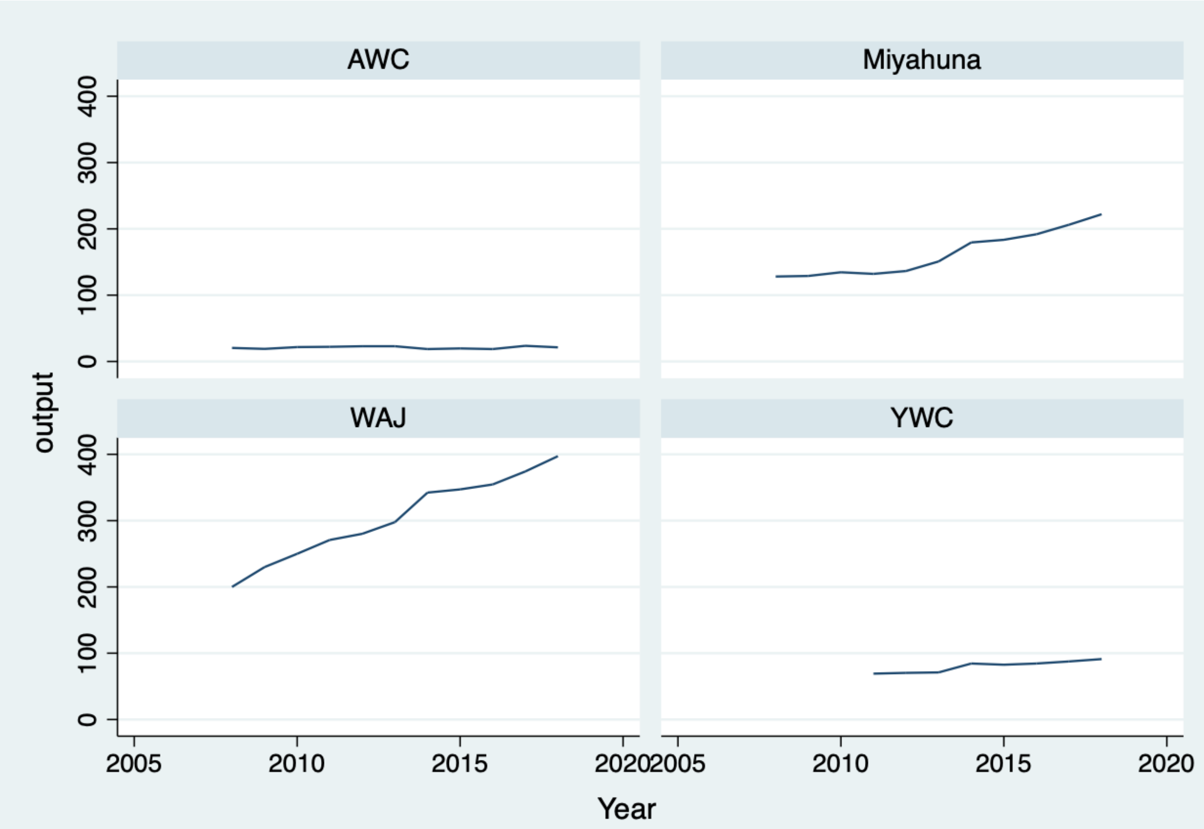
Table 6 Comparison of the Finances of Jordanian Water Suppliers, JD, 2018

	Miyahuna (JD)	AWC (JD)	YWC (JD)	WAJ (JD)
Revenue Water	156,956,000	19,192,000	38,940,000	132,793,000
Cost Capital	6,275,000	4,125,000	7,000,000	307,793,000
Total Operating Costs	141,152,000	12,977,000	42,730,000	131,087,000
Total Costs	147,427,000	17,102,000	49,730,000	438,880,000
Profit/Loss	9,529,000	2,090,000	(10,790,000)	(306,087,000)
Population Served (Households)	690,000	197,104	2,951,700	1,090,600
Water Volume, millions cubic meters	224	18	91	397.2

Sources: General Budget Department (GBD), Data Centre, "General Budget Law" Jordan, 2018 and Personal Correspondence, Ministry Water and Irrigation, Jordan, 2018

Table 6 above offers a comparison of the financial performance of each of the water providers, in Jordan, for the year 2018. Miyahuna and AWC made modest profits, while YWC and WAJ both suffered losses. However, both YWC and WAJ supplied far more households, even if Miyahuna supplied more water overall. This is because Miyahuna services the capital and other large cities, thus the amount of water used per household, in the capital, is substantially higher than in more rural areas. Figure 9 offers a graphic comparison of the production levels of each supplier, in millions of cubic meters of water:

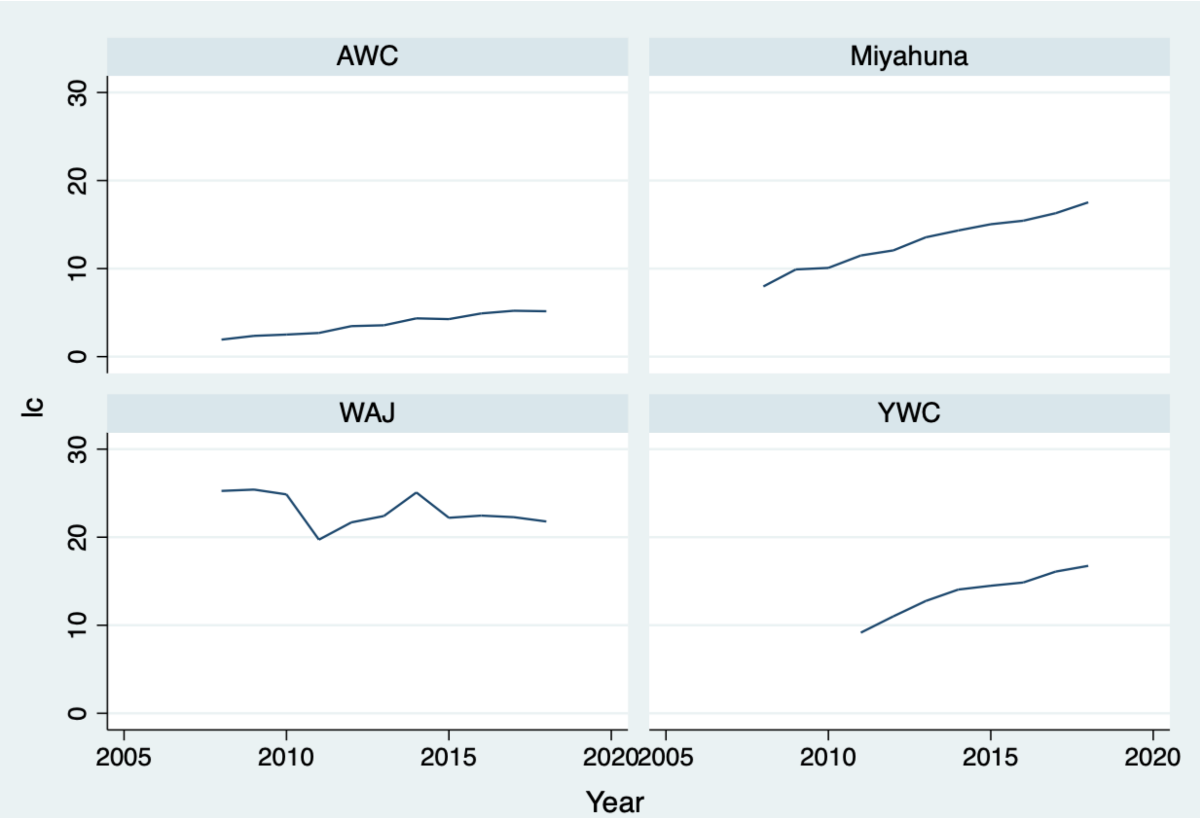
Figure 9 Production, MCM, for Water Suppliers, 2008-2018



Source: Personal Correspondence, MWI, Jordan

Figure 9 above shows the Output, in millions of cubic meters, of each of the four companies, from 2008 until 2018. As the Figure shows, both Miyahuna and WAJ had rapidly growing output over the decade. YWC achieved modest growth, and AWC remained steady over the decade.

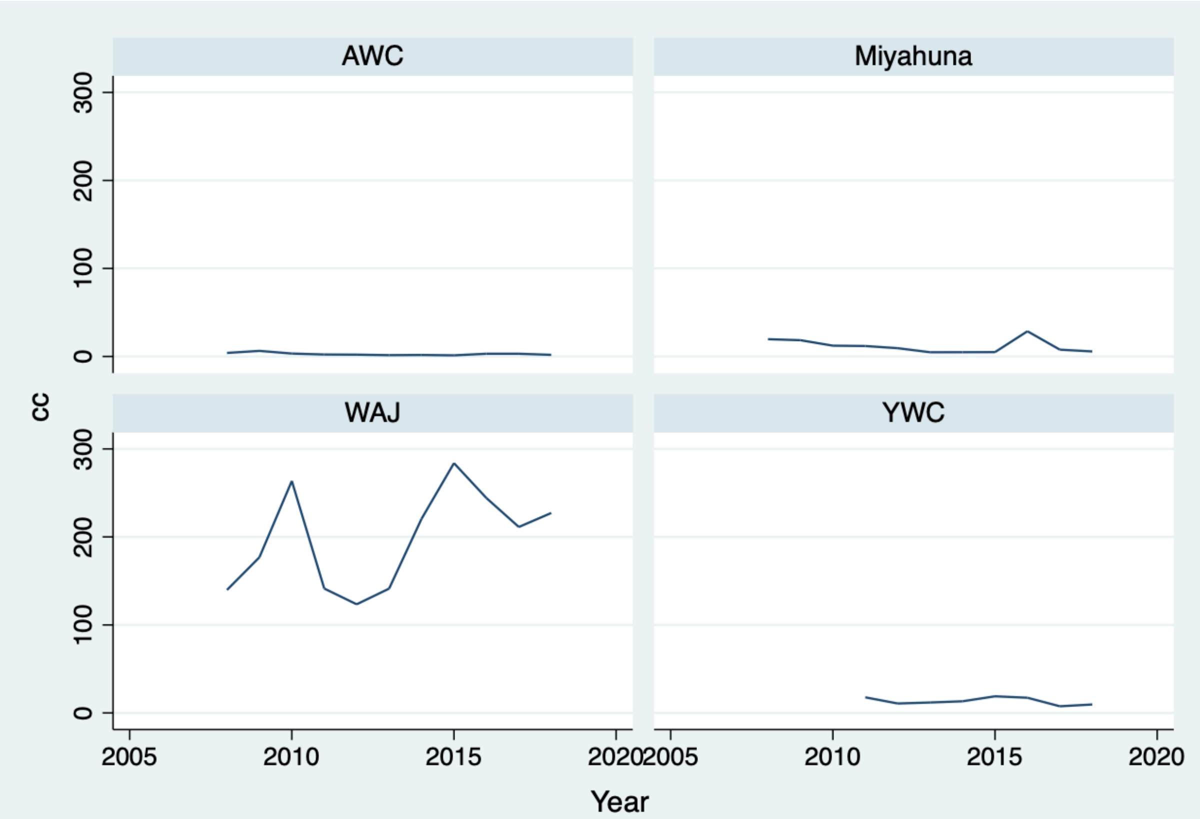
Figure 10 Labour Costs for Each Water Supplier, Millions JD, 2008-2018



Source: GBD, Jordan, 2008-2018: Chapter 8161 Jordan Water Company, Miyahuna; Chapter 8162 Aqaba Water Company; Chapter 8172 Yarmouk Water Company; Chapter 8102 WAJ

Figure 10 above shows the labour costs of each of the 4 companies, from 2008 until 2018. As Figure 10 shows, Miyahuna had the most rapidly growing labour costs over the decade, with YWC also showing rapidly growing labour costs, and AWC showed more modest growth. However, WAJ has shown relatively stable labour costs.

Figure 11 Capital Costs for Each Water Supplier, Millions JD, 2008-2018



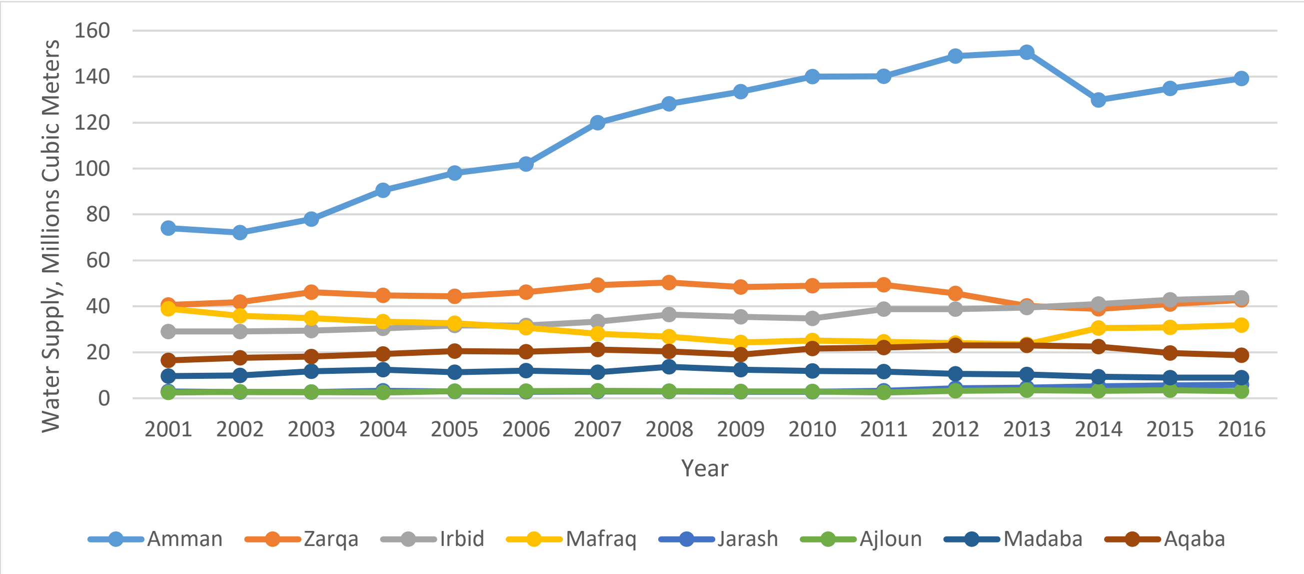
Source: GBD, Jordan, 2008-2018: Chapter 8161 Jordan Water Company, Miyahuna; Chapter 8162 Aqaba Water Company; Chapter 8172 Yarmouk Water Company; Chapter 8102 WAJ

Figure 11 above shows the capital costs of each of the 4 companies, from 2008 until 2018. As Figure 11 shows, WAJ had not only the highest capital costs, but also the most widely fluctuating capital costs. Miyahuna and YWC showed gradually reducing capital costs, and AWC shows steady capital costs across the decade.

7.5 Efficiency Ratios

Having provided an overview of the supply levels and basic financial information of each supplier, this section analyses each supplier's efficiency. It is likely that water supplies, per unit of input, is a more relevant measure of efficiency than revenue per unit of input. This is because increased revenues could simply arise from price fluctuations, and do not say anything about how much water is being produced. Therefore, this chapter will make use of both water supply and revenues, each as a ratio of costs. This section will start by measuring each of the components of the ratio separately, starting with water supply within the corporatised governorates.

Figure 12 Water Supply, MCM, Across Corporatised Governorates, 2001-2016



Source: Personal Correspondence with the MWI, Jordan

Table 7 Water Supply Across Corporatised Governorates, 2001-2016

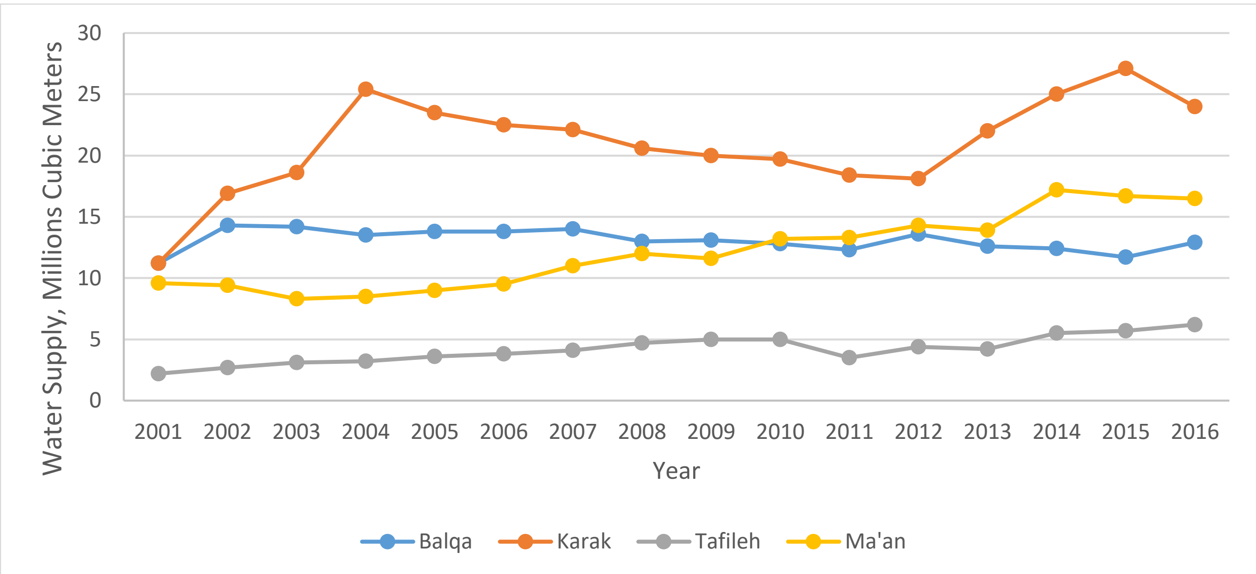
	MCM of Water, 2001	**MCM of Water, 2016**	**Change (%)**	**Annual Average Change (%)**
Amman	74	139.2	88.1	5.9
Zarqa	40.6	42.8	5.4	0.4
Irbid	29.1	43.7	50.2	3.3
Mafraq	39	31.8	-18.5	-1.2
Jarash	2.9	5.9	103.4	6.9
Ajloun	2.5	3.1	24.0	1.6

	MCM of Water, 2001	MCM of Water, 2016	Change (%)	Annual Average Change (%)
Madaba	9.7	9	-7.2	-0.5
Aqaba	16.5	18.7	13.3	0.9

Source: Personal Correspondence with the MWI, Jordan

As Figure 12 and Table 7 above show, most governorates experienced an increase in the supply of water, between 2001 and 2016. For example, Amman, experienced an 88.1% growth, or an annual average growth rate of 5.9%, while Jarash experienced a 103.4% jump, or an average annual increase of 6.9%. Only Mafraq and Madaba experienced drops in supply, at 18.5% and 7.2% respectively (or an annual average drop of 1.2% and 0.5% respectively).

Figure 13 Water Supply Across State-Run Governorates, 2001-2016



Source: Personal Correspondence with the MWI, Jordan

Table 8 Water Supply Across State-Run Governorates, 2001-2016

	MCM of Water, 2001	MCM of Water, 2016	Change (%)	Annual Average Change (%)
Balqa	11.2	12.9	15.2	1.0
Karak	11.2	24	114.3	7.6
Tafileh	2.2	6.2	181.8	12.1
Ma'an	9.6	16.5	71.9	4.8

Source: Personal Correspondence with the MWI, Jordan

As Figure 13 and Table 8 above show, all the state-run governorates have shown significant growth in terms of water supply, with Karak more than doubling its water supply, and Tafileh almost tripling supply, between 2001 and 2016. This is partially explained by population growth, with both states increasing their populations by roughly three-quarters, between 2004[1] and 2019 (Department of Statistics, 2020). The changes in growth rates among these governorates (and others) will be explored in the chapter on Difference-in-Difference Analysis.

Having established water supply levels across the governorates, this chapter will turn now to efficiency. For this thesis, efficiency is the ratio of outputs to inputs, where output is the generation of a desired good/service, and inputs are the components used to create that good/service. This definition can be applied to a wide range of fields of study beyond the water sector (Farrell, 1957); (Palmer & Torgerson, 1999); (Kao, 2017). For a more in-depth discussion of efficiency, this can be found in the 'Literature Review' Chapter 2.

[1] 2004 is the earliest year for which population data on these governorates is available.

Thus, in order to understand the efficiency of the water sector in Jordan, one must understand the ratio of water generated to the costs of generating that water.

Table 9 Expenditures of Miyahuna and Aqaba Water Company, JD Thousands

	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Miyahuna	11,888	12,800	13,785	10,935	9,965	31,932	28,618
AWC	3,302	5,050	6,250	1,468	2,714	5,040	5,640

Source: GBD, Data Centre, "General Budget Law" Jordan, 2010-2018

As Table 9 above shows, Miyahuna's expenditures more than doubled between 2010 and 2016, at 140.7%, or an annual average of 23.5%. The AWC's expenditures increased by 70.8% during the same time period, or an annual average growth of 11.8%.

The following section provides a more detailed overview of the efficiency of each provider. To begin with, the ratios of revenues to expenditures and water supply to expenditures were calculated for Miyahuna. This is based on data gathered from the MWI and the General Budget Department of Jordan.

7.5.1 Miyahuna Efficiency Ratios

Table 10 Efficiency Ratios for Miyahuna, 2007 to 2016

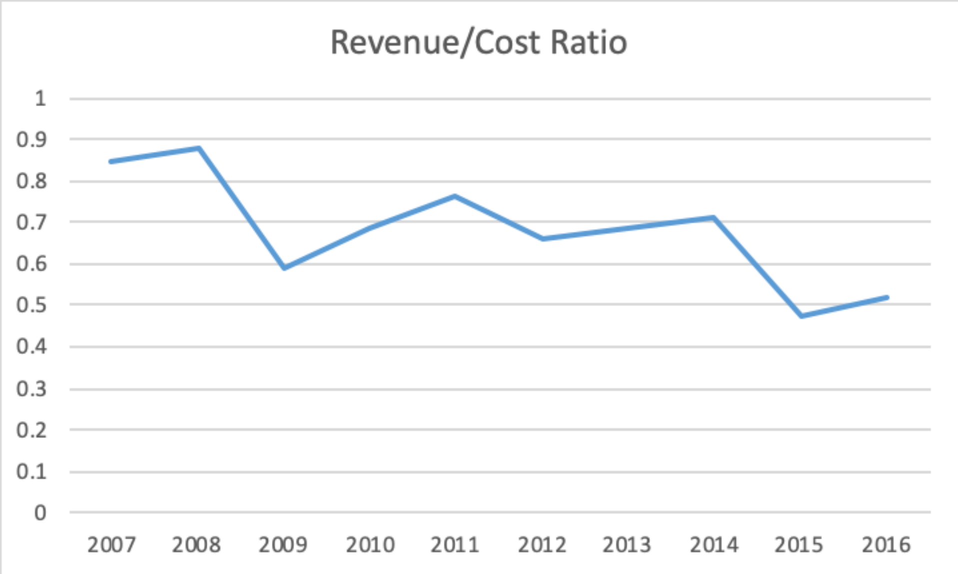
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Revenue to Expenditures Ratio	0.85	0.88	0.59	0.69	0.77	0.66	0.69	0.71	0.47	0.52
Water Supply to Expenditures Ratio	1.45	1.47	1.47	1.69	1.59	1.45	1.52	1.63	1.05	1.08

Source: Personal Correspondence with MWI, 2018; GBD, Data Centre, "General Budget Law" Jordan, 2007-2016

Table 10 above shows that the ratio of revenue to expenditures in Miyahuna has been decreasing steadily between 2007 and 2016, dropping by 38.8%. The ratio of water supplies to expenditures has also steadily deteriorated, from 1.45 cubic meters of water for each JD of expenditure in 2007, to 1.08 cubic meters for each JD of expenditure in 2016. That is, using two different measures of efficiency, it appears that Miyahuna's efficiency decreased between 2007 and 2016. The primary reason for this drop in efficiency is the rapid hikes in expenditures over this time period.

Figure 14 below shows Miyahuna's Revenue to Cost Ratio.

Figure 14 Revenue to Cost Ratio, Miyahuna, 2007-2016

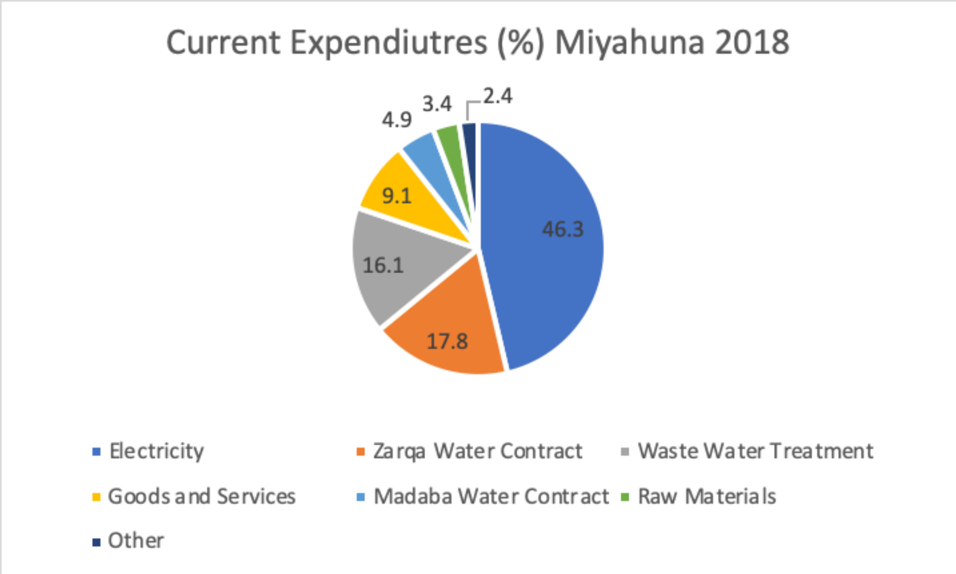


Source: GBD, Data Centre, "General Budget Law" Jordan, 2007-2016

As Figure 14 shows, Miyahuna's Revenue to Cost Ratio gradually decreased, from 0.85 in 2007 to 0.52 in 2016. That is, in 2016, for every JD in costs, only 0.52 JD was earned. During this period, revenues increased by 27.3%, but costs soared by 107.6%.

Turning to the most recently available expenditure data, Miyahuna's current expenses for 2018 are shown below:

Figure 15 Current Expenditures (%), Miyahuna, 2018

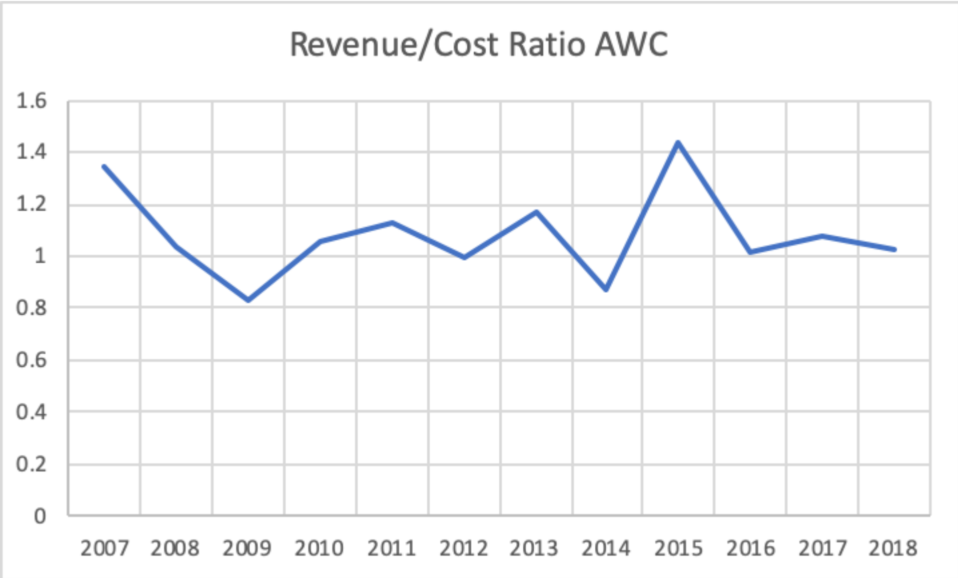


Source: GBD (2018a)

As Figure 15 above shows, the biggest expenditures of Miyahuna are: electricity (for powering water distribution), the Zarqa Water Management Contract and wastewater treatment. Together, these three expenditures amount to 95.7 million JD, or roughly 80% of current expenditures. In fact, electricity for water distribution consumes almost half of current expenditures, at 55.3 million JD, or 46.3% of current expenditures.

7.5.2 AWC

Figure 16 Revenue to Cost Ratio, AWC, 2007-2018

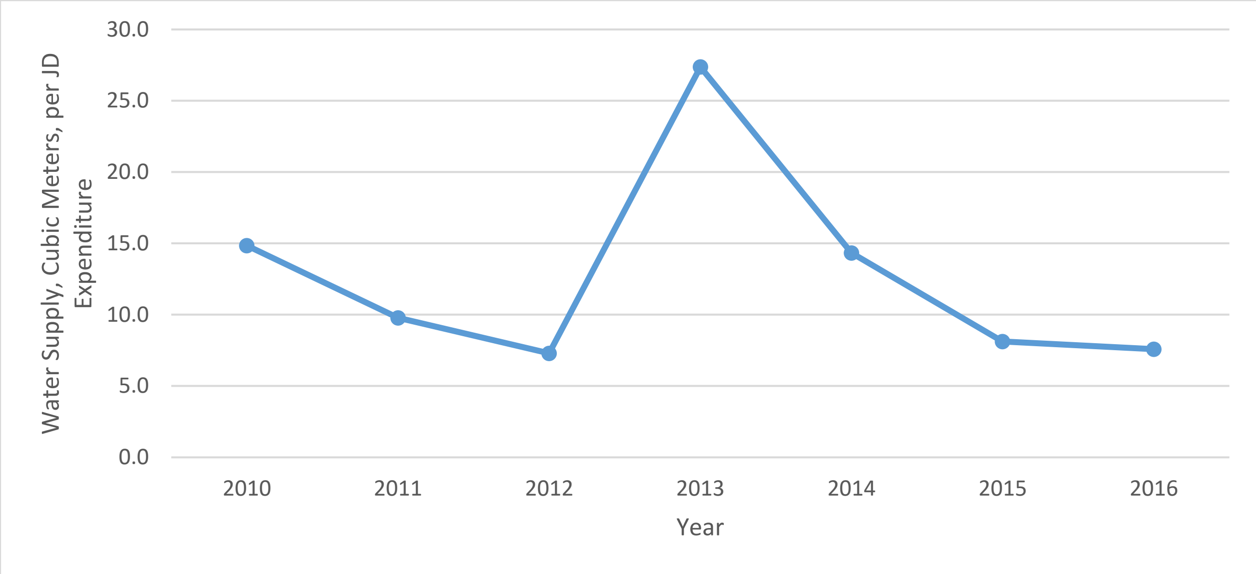


Source: General Budget Department, Data Centre, "General Budget Law" Jordan, 2007-2018

As Figure 16 above shows, AWC's Revenue to Cost Ratio gradually decreased, from 1.3 JD in revenue per unit of cost in 2007, to 1 JD in revenue per unit of cost in 2018. That is, in 2018, the company just broke even. During this period, revenues increased by 32.3%, but costs increased by 73.4%.

Turning to supply, a more volatile picture is created, as is shown in Figure 17 below.

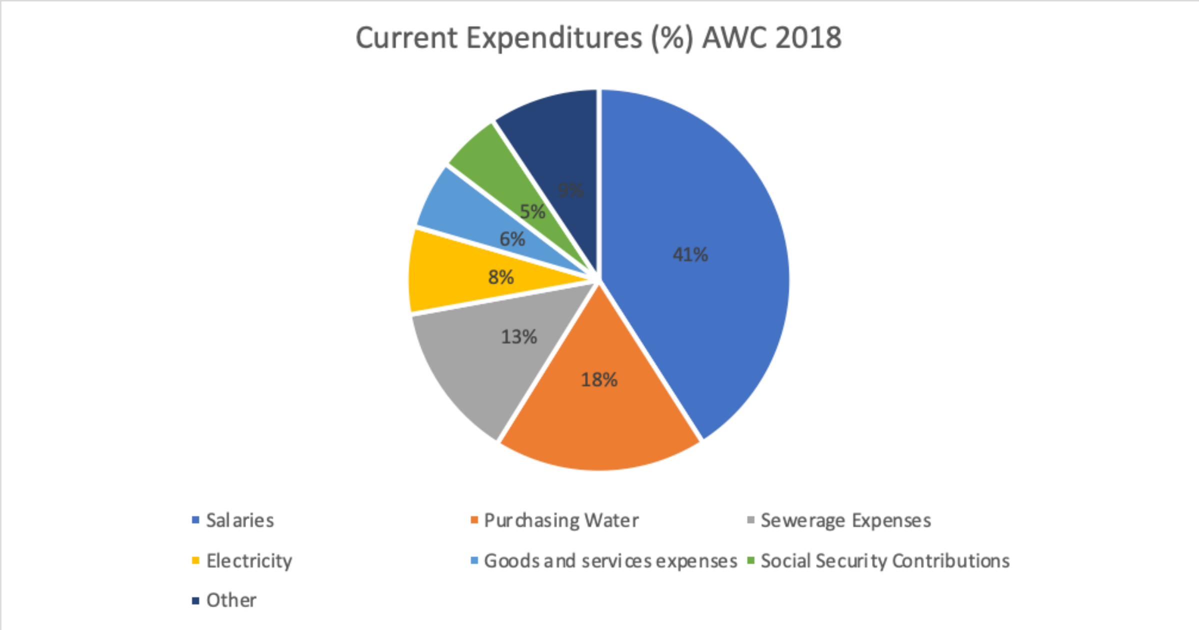
Figure 17 Water Supply to Expenditures Ratios in Aqaba, 2010-2016



Source: Personal Correspondence with MWI, 2018; General Budget Department, Data Centre, "General Budget Law" Jordan, 2007-2016

Figure 17 above shows that the AWC's efficiency (as measured by water supply per JD of expenditure) shows a steadily declining trend (with the exception of a sudden jump between 2012 and 2013). That is, while the AWC produced 15 cubic meters of water for each JD of expenditure in 2010, this dropped to 7.6 cubic meters per JD of expenditure in 2016. In other words, efficiency effectively dropped by half, over a six-year period. As with Miyahuna, this is due to rapidly increasing expenditures. In 2018, current expenditures were arranged as follows:

Figure 18 Current Expenditures, AWC, (%) 2018

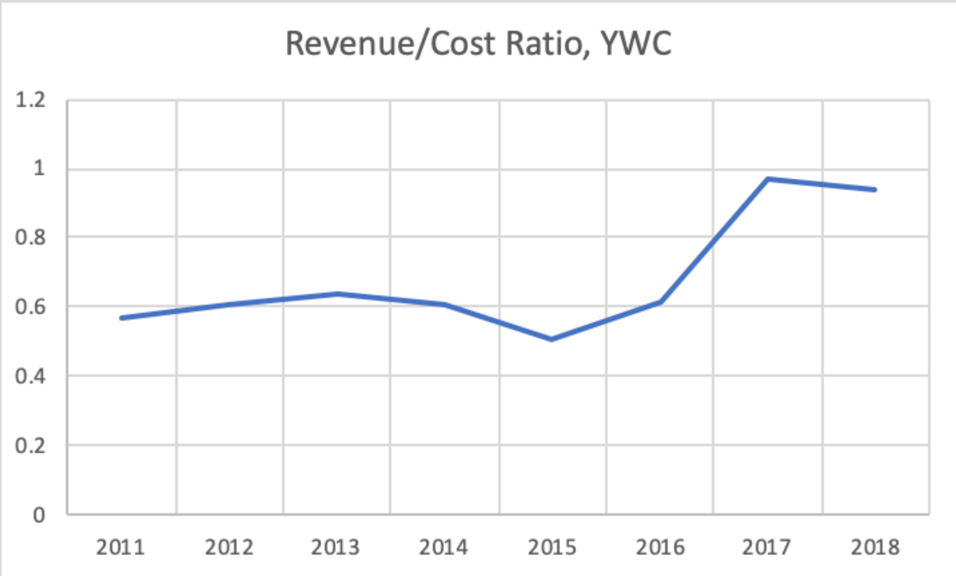


Source: GBD (2018b)

As Figure 18 above shows, the biggest expenditures of AWC are: salaries, purchasing water and operational expenses for sewerage. Together, these three expenditures amount to 9.1 million JD, or 72.1% of total expenditures.

7.5.3 YWC

Figure 19 YWC Revenue to Cost Ratio 2011-2018

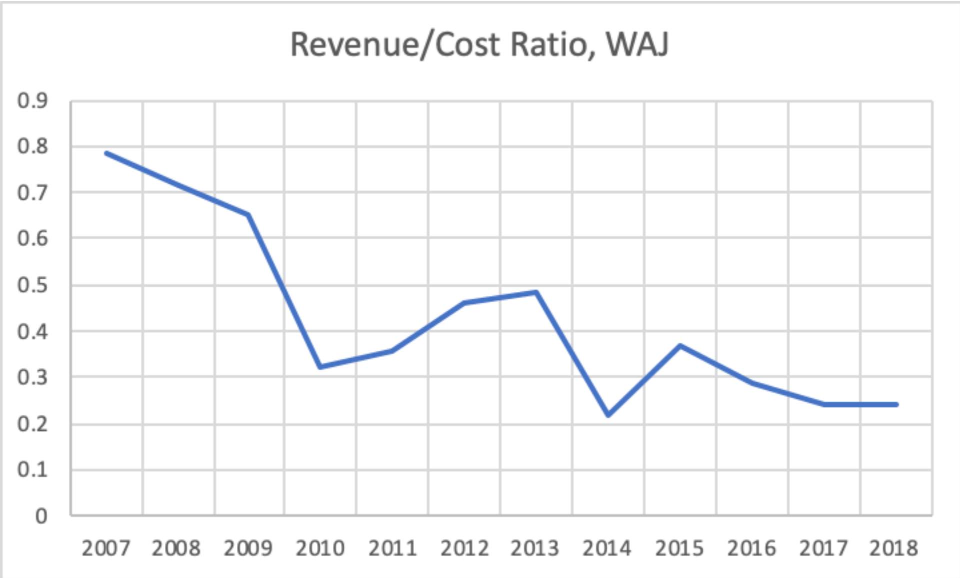


Source: General Budget Department, Data Centre, "General Budget Law" Jordan, 2011-2018

As Figure 19 above shows, YWC's Revenue to Cost Ratio gradually increased, from 0.57 in 2007 to 0.94 in 2018. That is, in 2018, for every JD in costs, only 0.94 JD was earned. During this period, revenues increased by 51%, and costs dropped by 8.6%.

7.5.4 WAJ

Figure 20 WAJ Revenue to Cost Ratio, 2007-2018



Source: General Budget Department, Data Centre, "General Budget Law" Jordan, 2007-2018

As Figure 20 above shows, WAJ's Revenue to Cost Ratio gradually decreased, from 0.78 in 2007 to 0.24 in 2018. Revenues dropped by 35.6%, but costs soared by 106.8% during this time period. WAJ showed by far the biggest drop in its revenue/cost ratio, losing 0.54 JD per JD of cost.

In summary, it was YWC that actually showed an improvement, from 0.57 JD in revenue per JD of cost in 2007, to 0.94 JD per JD of cost in 2018, almost breaking even. However, in terms of performance, only AWC actually managed to break even, and between 2016-2018, just barely. Miyahuna also dropped in terms of revenue/cost ratio, from almost breaking even in 2008, to barely making half its costs back in 2016.

It should be noted that Amman and Zarqa are both managed by Miyahuna and that the poorest of the corporatised governorates are managed by YWC. In other words, the one corporate water supplier to show improvements in overall efficiency is the one that saw the most improved water supply from corporatisation.

Most of the Jordanian water providers made consistent losses over the previous decade. This is primarily because, under Jordanian law, water providers are not allowed to increase prices without Parliamentary approval. This makes cost recovery especially difficult. Thus, it is clear that these corporatised companies are allowed to run massive deficits, as long as they supply cheap water to the populace.

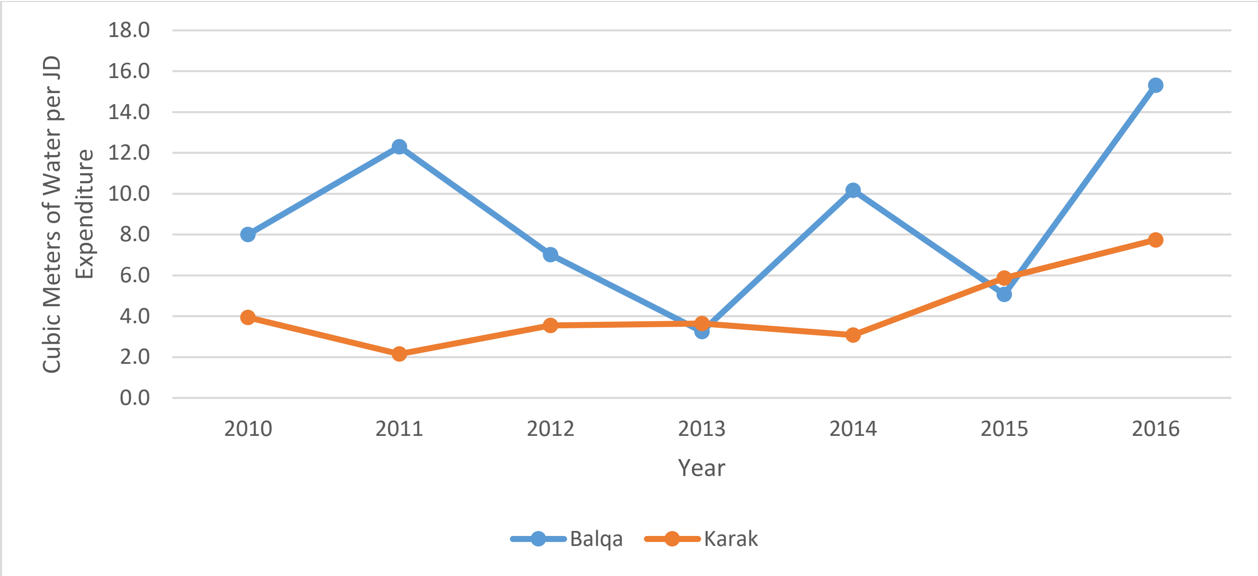
Finally, this section will examine the efficiency of Balqa and Karak, two governorates whose water systems are completely managed by WAJ. The other two governorates whose systems are managed by WAJ, Tafileh and Ma'an, are not included, due to a lack of data pertaining to their expenditures.

Table 11 Water Supply to Expenditures Ratios in Two State-Run Governorates, 2010-2016

	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Balqa	8.0	12.3	7.0	3.2	10.2	5.1	15.3
Karak	3.9	2.2	3.5	3.6	3.1	5.9	7.7

Source: Personal Correspondence with MWI, 2018; General Budget Department, Data Centre, "General Budget Law" Jordan, 2010-2016

Figure 21 Water Supply to Expenditures Ratios in Two State-Run Governorates, 2010-2016



Source: Personal Correspondence with MWI, 2018; General Budget Department, Data Centre, "General Budget Law" Jordan, 2010-2016

As Table 11 and Figure 21 above show, the amount of water supplied, measured in cubic meters, per unit of expenditure (measured in JD), actually increased for both Balqa and Karak, between 2010 and 2016. This may be due to the high influx of refugees arriving in both governorates, which increased the demand (and therefore supply) of water in these governorates, without a corresponding increase in water expenditures.

8 Data Envelopment Analysis

8.1 DEA Studies of Water Efficiency

This section will review the literature on water efficiency, specifically using DEA, as DEA will form the primary methodology of this chapter. As this literature review will show, the literature on water efficiency has only occasionally touched upon water sectors in the MENA region. These studies will be discussed below in the literature review. Indeed, there were only two studies using DEA to study the water sector of Jordan [(Al-Assa'd & Sauer, 2010); (Theeb, Smadi, & Obaidat, 2019)]. This thesis makes significant differences to the methodologies used by those studies. These include, but are not limited to, the fact that they study Jordan at the governorate level, whereas this thesis analyses at both the company and governorate level.

The Jordanian water provision system has rarely been studied from an economic efficiency perspective. Instead, the focus has been on solving water shortages through demand-management, hydrological, geological and technological perspectives [see for example (Hadadin, Qaqish, Akawwi, & Bdour, 2010) and (Al-Ansari, Alibraheim, Alsaman, & Knutsson, 2014)]. Also, it is only within the last decade that the water provision system in Jordan was studied through a political-economic lens (Mahayni, 2015); (Hussein, 2018); (Yorke, 2016); (Mustafa, 2016); (Zeitoun, Allan, Al-Aulaqi, Jabarin, & Laamrani, 2012). However, the discourse has only occasionally addressed the impacts of different methods of running Jordanian water supply, especially using frontier techniques (Al-Assa'd & Sauer, 2010); (Al-Theeb, Smadi, & Obaidat, 2019).

Also more generally, DEA water studies have rarely been applied to arid, developing countries. Worthington (2014) who offers an overview of frontier studies between 1991-2010 finds 17 DEA studies, none of which studied the MENA region. As so few DEA studies about the MENA countries' water exist, this study will contribute by using DEA to gauge the efficiency of water supply in a MENA country. Furthermore, there are no studies in the literature examining Jordanian water supply using SFA and DID. Consequently, there are no studies offering a comparison of DEA, SFA and DID methodologies and results. Thus, this thesis will add to the literature by discussing water efficiency in an arid developing country, specifically in Jordan, using two methodologies that have not been applied to Jordanian water before. The methodology that has been applied to Jordanian water before (DEA), has been applied differently, focusing on water utilities, as opposed to governorates. Before exploring the rest of the literature, this review will examine the two previous studies of Jordanian water efficiency, using DEA.

8.1.1 DEA in the Jordanian Water Sector

This section will review the literature on Jordanian water efficiency. As this literature review will show, the literature on water efficiency has only occasionally touched upon water sector in Jordan. This is because most studies on Jordanian water focus on increasing supply, demand management, political economy or tariffs; few focus on actual efficiency. Additionally, few focus specifically on how much water is obtained from a set of resources, and whether such supply can be enhanced simply by improving efficiency. Indeed, there were only two studies using DEA to study the water sector of Jordan (Al-Assa'd & Sauer, 2010); (Al-Theeb, Smadi, & Obaidat, 2019). This thesis modifies the methodologies used by those studies. These include, but are not limited to, the fact that they study Jordan at the governorate level, whereas this thesis analyses at both the company and governorate level.

Al-Assa’d and Sauer (2010) study the water efficiency of Jordanian governorates. First, a DEA is used to estimate the efficiency of utilities and scale effect of the utilities. Then, a Tobit regression was used to assess how exogenous factors affected inefficiency. The authors find that inputs can be reduced, without impacting output; 15-20% for water supply’s operational expenses (OPEX) and 23-27% for wastewater’s OPEX. The governorates of Aqaba and Jarash showed the most efficient water supply, whereas Amman showed the most efficient wastewater. The study also maintains that the size of the utility has only a modest impact on efficiency. That being said, it was found that medium sized firms for water supply and large firms for waste-water were most suitable. The Tobit regression showed that corporatisation had a statistically significant, positive effect for both water and wastewater.

Their results showed that Aqaba was the most efficient governorate, in terms of water supply. This is understandable, as in 2006, Aqaba was the only corporatised governorate in Jordan, (Amman's water sector was run by a Public-Private Partnership from 1999-2006). Every other governorate was still run by WAJ. Also, Aqaba was the first governorate run on corporatised lines (not PPP), in 2004. Thus, it is quite understandable that Aqaba or Amman would be the most efficient in terms of water supply, in 2006. However, with the creation of the YWC in 2011, and Miyahuna managing more governorates (Zarqa and Madaba, and in 2018 parts of Balqa), these results may not remain accurate today. Also, the authors study efficiency at the governorate level, not at the company level. This may be because when the study was conducted, only Amman and Aqaba had corporatised water companies (Miyhauna and AWC respectively). Today however, most governorates are managed by corporatised water utilities, with each supplier running multiple governorates (except for AWC). Thus, studying at the company level offers unique insights into water sector efficiency, as opposed to just studying the governorates they serve.

The other study to use DEA to analyse water in Jordan was performed by Theeb, Smadi and Obaidat (2019), who study the Jordanian water sector from a different angle than Al-Assa'd and Sauer (2010). The most important difference is that the output in this study is not water, but net collected billings for water. This is a very under-studied aspect of water utilities, especially when considering that this is an important component of utilities' revenue streams. This prevents utilities from covering their operation and maintenance costs, and makes expansion, repair, upgrading and other necessary tasks more difficult. The inputs the authors use are:

collectors/1,000 consumers; vehicles/1,000 consumers; population density (consumers/km of pipe length); difficulty of collecting bills; and cost of bill (JD/bill). Thus, while it is useful to study this output (bill collection), it is not clear whether the best inputs were used in this study (although population density and bill costs are clearly useful). Using inputs such as the number of water meters/km, or the number of fines issued for late payment, may have offered more insight into how the utilities are keeping track of water bills, and how they would attempt to extract payment from non-payers. However, while their subject of study is notable, they only study the years 2013-2014, and the DMUs are not matched to any specific governorate. That is, it is not at all clear what each DMU actually refers to, which prevents an understanding of the results.

Examining 10 geographic regions in Jordan, the authors find that most DMUs could not reach full efficiency. The authors demonstrate that even the suppliers showing proficiency in bill collecting have much room for improvement. Few companies reached 100% collection rates, resulting in high levels of uncollected revenues. Even the most efficient water supplier had room for improvement, in this regard. Also, the authors use sensitivity analysis to show that the deficit in collected receipts towards Jordanian water utilities is 36 million JD. It is not immediately clear to what extent an extra 36 million JD can improve the running of the water sector. At most, it may contribute to reducing operations and maintenance costs, but will do little in the way of mitigating capital costs (the bulk of expenditure in most water sectors).

8.1.2 DEA in Water Sectors of Developed Countries

Having examined the two previous studies using DEAs to examine Jordanian water, this literature review will now examine other studies using DEA. This section will show if a general consensus has been reached, relating to water and corporatisation, in the developed countries.

As Da Cruz, Marques, Romano and Guerrini (2012) point out, the literature has gauged the efficiency of water utilities primarily through various key performance indicators. These can either be amalgamated into a single index, with the one score giving an overall sense of the efficiency of the utility, or a detailed checklist of indicators. These can also be broken down into simple reporting of indicators (such as accounting ratios), or they can be examined through the lens of regression analysis, or DEA. This methodology can be applied to state-owned or corporatised utilities, as this chapter will show in in the 'Methodology' Section 8.2. This Literature Review will show how these techniques have been applied in the discourse.

Da Cruz, Marques, Romano, & Guerrini (2012), using a DEA analysis, examine the impacts of reforms on the water sector in Portugal and Italy. The authors conduct two DEA analyses, on 88 water suppliers in 2007, in order to analyse the impacts of privatisation on water suppliers. The first DEA uses staff costs, operational expenditures and capital costs as inputs, and water supplied and population served as outputs. The second DEA uses the number of employees, pipe length and operations expenditures as inputs, and water supplied and population served as outputs. The authors find significant levels of inefficiency, with both countries being able to reduce inputs while maintaining output (36% for Portugal and 38% for Italy). Also, in both countries, public utilities outperformed the private ones, in terms of efficiency.

Storto (2013), however, comes to a diametrically opposing conclusion. The author analyses the performance of 21 private or partially private, and 32 government owned water suppliers in Italy. First, the author uses a DEA model incorporating both physical and financial variables, as well as analysing economies of scale. Secondly, a bootstrapped DEA and Tobit regression is used to study the impacts of external factors on water efficiency. The author finds that the private sector (either alone or in conjunction with the government) can improve water supply efficiency. This shows a major point of contention in the debate, with extensive disagreements as to the impacts of corporatisation on water efficiency. Even using the same methodology (DEA) and analysing the same country's water sector (Italy), in similar time periods, can lead to drastically different results. However, it should be noted that this is not a perfect comparison. Da Cruz, Marques, Romano and Guerrini (2012) analyse both Italy and Portugal (only 33 out of 88 firms analysed were Italian), whereas Storto (2013) exclusively analyses Italy. Also, Storto (2013) supports his study with a bootstrapped DEA and Tobit regressions, whereas Da Cruz, Marques, Romano and Guerrini (2012) did two different DEAs. These differences partially explain why the two studies come to diametrically opposing results.

Norton and Webber (2009) come to similar conclusions as Da Cruz, Marques, Romano and Guerrini (2012) in their study of the U.S. The authors use DEA to report on the relative efficiencies of water utilities (private, non-profit private and government-owned) in the U.S. The authors find that government-owned utilities show the most efficiency, private non-profits less efficiency and private utilities being the least efficient.

Suárez-Varela, García-Valiñas, González-Gómez and Picazo-Tadeo (2016) comes to similar findings as Storto (2013). The author measures the efficiency of water providers in 70 Spanish municipalities, across a variety of production factors, managerial efficiency and technological capability. The authors find that privately run firms use labour more efficiently, as public water providers face technological, legal and institutional challenges. However, private firms are less efficient in terms of operational expenditure.

Pazzi, Tortosa-Ausina, Duygun and Zambelli (2016) come to different conclusions than any of the previously mentioned authors. Like the previous authors, they use DEA (though combined it with cluster analysis), in order to study the efficiency of water providers (in this case, Italian), including the structure of ownership. The authors find that the mode of ownership does not impact efficiency in itself, but combined with other factors such as firm size and geography, then ownership structure can impact efficiency. Specifically, mixed-ownership firms, with either direct or indirect state ownership, proves to be the most efficient.

Thus, from the selected sample of the literature, we see a mix in the question of corporatisation and water efficiency, with no clear answer one way or the other. However, there has been an evolution in the literature, regarding water in developed countries (using DEA studies). The literature appears to be moving away from a direct 'public versus private' discussion, and more towards a nuanced discussion of the factors which promote/inhibit efficiency. The next section will focus on the literature regarding developing countries.

8.1.3 DEA in Water Sectors of Developing Countries

Having given an overview of the literature of the water sectors of developed countries, this section will examine the literature relating to developing countries, more relevant given the context of Jordan.

Kirkpatrick, Parker and Zhang (2004) study the privatisation of water services in Africa, using both DEA and SFA. The DEA showed that private-owned water firms performed more efficiently, but the SFA showed no meaningful difference in the mode of ownership's impact on efficiency.

Munisamy (2009) reaches a similar conclusion to Kirkpatrick, Parker and Zhang (2004). The author uses DEA to study the impacts of privatisation on Malaysian water suppliers, including technical and scale efficiencies. The study argued that private suppliers were more efficient than public ones, in technical efficiency (86% to 70%, respectively). The private sector's inefficiencies are primarily due to issues of size and scale, whereas the public sector suffers from both scale and technical issues. However, the author is reluctant to draw a definite conclusion, as the study found technically efficient government run water providers.

Thus, the literature on water supply efficiency, using DEA specifically, seems to support state-managed firms in developed countries, and privatised utilities in developing countries. Other DEA studies have focused on water efficiency in developing countries, but not on the issue of ownership structure; rather, many of these studies examine the technical aspects of water efficiency. For example, Pan, Wang, Zhou and Wang (2020) use a super-efficiency DEA model, to not only determine which firms are efficient or inefficient, but to find the main impediments to efficiency. Studying water suppliers in Shandong between 2006 and 2015, the authors determine that technological factors are the main bottlenecks in improving efficiency in Shandong. One of the unique aspects of this article is the theory of 'super-efficiency.' In a typical DEA, a DMU is considered to be efficient if it cannot be improved relative to another DMU in that specific sample. Thus, the theory of super-efficiency came about, which allows efficiency scores beyond the theoretical Maximum of '1.' For example, whereas in a normal DEA, the most efficient score for a DMU could be '1', in a super-efficient DEA, it could be '1.4' or '1.9'. This allows for an efficiency score that more accurately reflects the efficiency of the DMU, without an artificial ceiling of '1'.

8.1.4 DEA in Arid Countries (Excluding Jordan)

Having examined DEA in developing countries, this section will examine studies of DEA in arid countries, where the effects of water inefficiency are most acutely felt. The following studies of water efficiency are of countries that are among the top 25 in terms of water stress, according to Wright (2019).

In trying to find specific technical issues, Ablanedo-Rosas, Guerrero Campanur, Olivares-Benitez, Sánchez-García and Nuñez-Ríos, (2020) study the efficiency of Mexican water providers, as well as the causes for their relative efficiencies. Specifically, the authors examine the contexts which give rise to gaps in water efficiency, including metering, wastewater treatment, sewer coverage and connections. Using a bootstrap DEA and bootstrap regression analysis, the authors find that only the amount of water lost per connection had a significant impact on operational efficiency. Indeed, water loss is one of the most important factors limiting efficiency in water. This is especially a problem in developing countries, where water loss reaches on average 34% (Patience, 2014). This issue will be studied further in later chapters, particularly in the DID and SFA chapters.

Nourali, Davoodabadi and Pashazadeh (2014) analyse 34 Iranian water providers with DEA. Under conditions of Constant Returns to Scale, Iranian firms are 77% efficient (technical efficiency) and under Variable Returns to Scale, 88% efficient (scale efficiency). This implies that Iranian firms could improve their performance by 23% and 12%, depending on how efficiency is measured, without increasing inputs. While the article is about water in a developing, arid country, it is still in an oil-rich country. Thus, the article only possesses some relevance to those wanting to study water efficiency in arid, developing countries.

Hence, we turn to the following study on India. India is a developing country, and one of the most water stressed in the world, but without extensive fossil fuel resources. Thus, the following article may provide more relevance. Kulshrestha and Vishwakarma (2013) use DEA to study the efficiency of water providers in 20 cities in Madhya Pradesh, India. The authors show that business practices can impact water efficiency remarkably. Most municipalities showed inefficiencies, necessitating downsizing and restructuring. Implementing best practices would result in reduced operational costs (staff and otherwise) and lower NRW. Such practices include, but are not limited to, flexible hiring, cost efficiency, and minimising NRW. These are all sound measures, but more needs to be said about how these measures can be implemented, especially in the context of arid, developing countries.

The literature on water efficiency using DEAs shows that most DEAs use five to six variables in their regressions (usually three to four inputs and one to two outputs). Also, it should be noted that water can be considered as, depending on the study, an input or an output. Usually, if water is an output, then billed water is the corresponding output. Also, the variables used in DEA water studies usually include a combination of financial and physical variables, such as costs, length of pipes, customer density, water loss, etc. The factors studied in the discourse included the impacts of mode of ownership on supply/efficiency, constant versus variable returns to scale, technical efficiency and the extent/causes of inefficiency. Most of these factors will be examined later in this chapter.

Having briefly summarised what is in the literature, it may be beneficial to show what is lacking in the discourse. As the literature review above showed, the literature rarely analyses the efficiency of water supplies in arid, developing countries. The focus is usually on developed countries, or the larger developing countries (this extends to studies using DEA). Excluding Jordan, there were studies on Mexico, Iran and India. These were the only countries to have their water sectors studied using DEA, in the top 25 most water-stressed countries list in Wright (2019) (mentioned above).

Worthington (2014) offers a detailed summary of the studies on water in the literature, using frontier methodologies, and the countries/regions focused on. The only country that was in the top 25 water stressed countries in Wright (2019) was Mexico. This also shows that the literature has barely focused on arid, developing countries.

In addition to leaving out arid countries, most of the studies sampled above show that authors generally avoid stating which mode of ownership is more efficient. However, among those that do make a recommendation for the developing countries, it seems that more studies recommend privatised water than state-run. Thus, this chapter will use a DEA to show which mode of ownership is more efficient, in a developing, highly water-stressed country.

8.2 Methodology for Data Envelopment Analysis

A DEA examines the efficiency of various decision making units within an organisation. Created by Charnes, Cooper and Rhodes (1978), this performance measurement tool gauges the efficiency of DMUs in a company, relative to other DMUs in that company. Beasley (N.D.) defines a DMU as "A distinct unit within an organisation that has flexibility with respect to some of the decisions it makes, but not necessarily complete freedom with respect to those decisions". This definition fits the case of the four Jordanian water suppliers well, as all of them have only partial freedom to achieve their goals, within a specific framework.

In a DEA, the inputs and measures of output efficiency are chosen, and then applied to each decision-making unit. The most efficient decision-making unit is considered to be the utmost bound of the efficiency frontier, and other branches can aspire to that efficiency level.

This section provides the methodology for the DEA, based on Da Cruz, Marques, Romano and Guerrini (2012). The authors studied the efficiency of 88 Italian and Portuguese water suppliers in 2007, so as to determine which mode of ownership was more efficient. The authors ran two DEAs, with the following inputs and outputs:

Table 12 Inputs and Outputs used in DEA performed in Da Cruz, Marques, Romano and Guerrini (2012)

	DEA 1	**DEA 2**
Inputs	Staff Costs; Other Variable Costs; Capital Costs	Other Variable Costs; Pipe Length; Number of Employees
Outputs	Water Volume; Population Served	Water Volume; Population Served

However, due to data limitations, this chapter shall use the inputs and outputs of the first DEA model. Also, this DEA will combine staff costs and other variable costs into operational costs. Thus, this DEA will use two inputs and two outputs. This chapter's DEA will use the following inputs and outputs:

Table 13 Inputs and Outputs to be used in DEA of Jordanian Water Supply

	DEA
Inputs	Operational Costs, Capital Costs

Outputs	Water Volume, Population Served

The DMUs to be studied are the four main water providers in Jordan: Miyahuna, AWC, YWC and WAJ. This DEA will measure the performance of the four DMUs from 2011 to 2018.

In Constant Returns to Scale models, it is assumed that any change in inputs should result in a concurrent change in outputs. That is, if inputs are halved, then outputs are halved. However, in VRS models, it is assumed that factors in production technology may result in rising, constant or dropping returns to scale. That is, a doubling of inputs will may result in less than, or more than, a doubling of outputs. Indeed, as Thanassoulis (2001) points out, CRS assumptions do not always hold in reality. Thanassoulis uses the example of two students, with inputs being the hours studied, and outputs being grades. If both students double the number of hours studied, it will not mean that both students double their output (grades) equally.

If the CRS and VRS scores match, then the DMU shows a constant return to scale, with a scale efficiency equal to '1'. However, if the CRS and VRS efficiency results of a DMU do not match, then the DMU is functioning at a scale below optimal levels. If a producer has a scale efficiency of less than '1', then the firm shows either increasing or decreasing returns to scale technology. If a firm showed signs of increasing returns to scale, then scale efficiency would increase with more output. If a firm showed signs of decreasing returns to scale, then scale efficiency would decrease with more output (Da Cruz, Marques, Romano, & Guerrini, 2012).

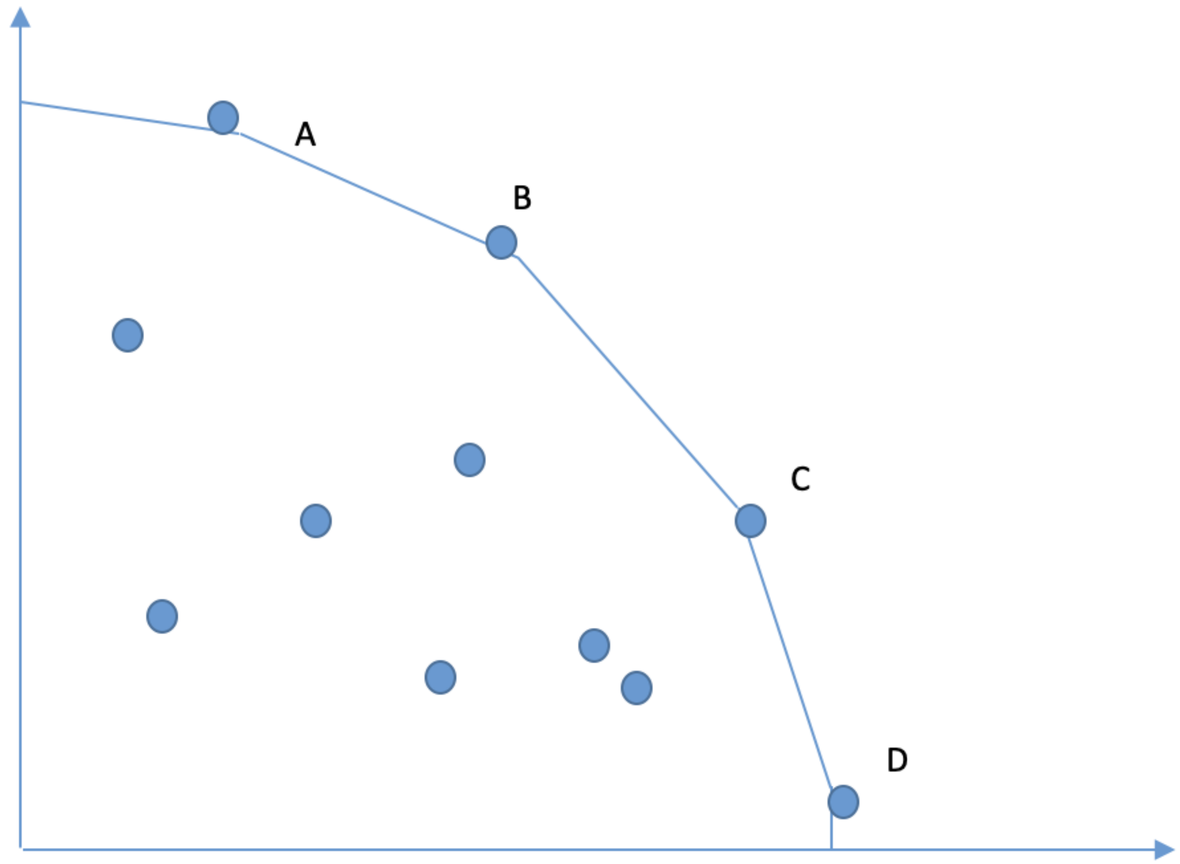
However, in a DEA, the number of DMUs should always be at least three times the number of combined inputs and outputs (Raa & Greene, 2019), so in my DEA, it would have to be at least 12 DMUs. By using a time series, and making each year of each company a separate DMU, this DEA will then have 32 DMUs.

Data for the DMUs was taken from the companies' annual financial reports, and the Jordanian General Budget Department. This model will examine the difference in the corporatly run branches, and the government managed branch (WAJ).

This model is input oriented (as opposed to output), as the purpose of water utilities (especially government-owned) is to provide water, not make a profit. In other words, with an input-oriented DEA, the analysis reduces inputs for a given output, to the absolute minimum they can be reduced. It should be noted that whether the orientation is input or output, the efficiency frontier of the DEA is not changed. This methodology assumes disposable inputs, but does not establish assumptions about production conditions, thus demanding less from the data than parametric methods (Huguenin, 2013).

However, this methodology does have its setbacks. Vaninsky (2013) details three weaknesses of DEAs. First, it is an assessment of relative efficiency, against other branches within an organisation. That is, while useful in comparing efficiencies across branches of an umbrella organisation, it is not particularly helpful in comparisons with other organisations. Second, it is possible for just one very strong output, or very weak input, to skew a result and classify that DMU as 'efficient.' Finally, the Linear Programming Algorithm, which DEA applies, is a 'black box,' with respect to weight coefficients. In theory, DEA takes into account all the indicators. This is because it "Maximises the ratio of the weighted sum of all outputs to the weighted sum of all inputs," (Vaninsky, 2013). However, the DEA optimal solution gives non-zero weights to some inputs and outputs, not all of them. Thus, it is possible to raise or lower outputs and inputs with zero weights, without any impact on the efficiency score. Therefore, important components about the efficiency score are effectively hidden in a 'black box' (Vaninsky, 2013).

Figure 22 Example of DEA



Source: Adapted from Rogge, Van Reeth and Van Puyenbroeck (2012)

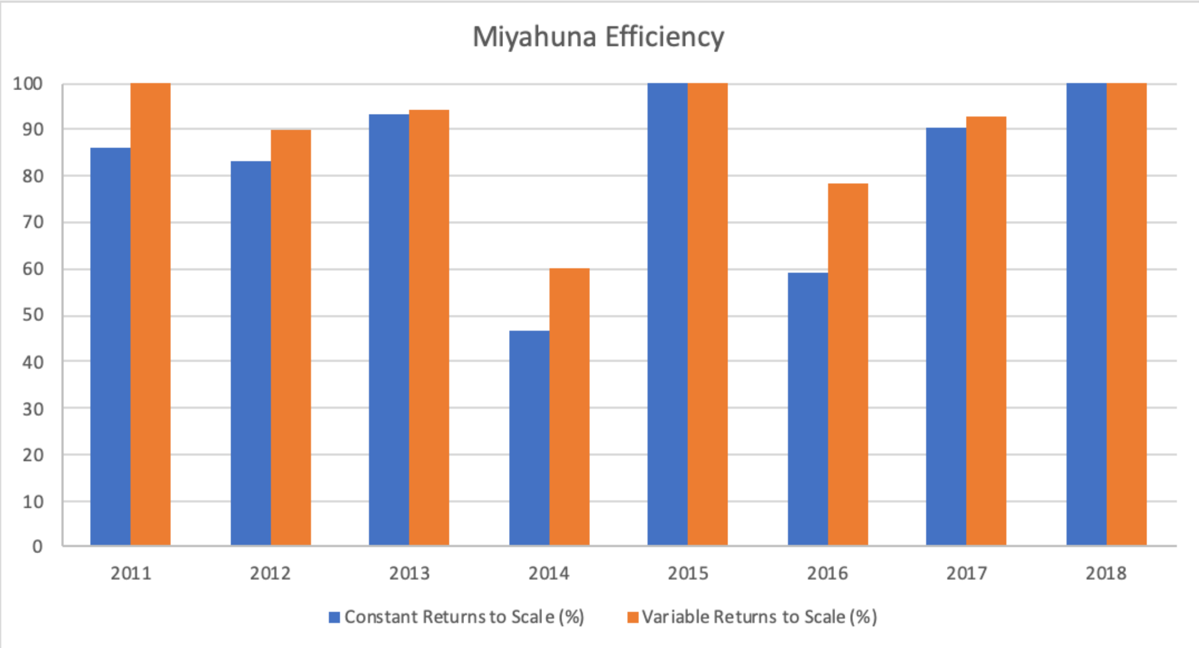
The Figure above is a representation of a DEA. Efficient DMUs lie on the frontier of the graph (on the curve ABCD), and inefficient DMUs lie inside the curve. The closer a DMU is to the curve, the more efficient it is.

For this DEA, online software from a company called "Data Envelopment Analysis Online Software," or DEAOS, was utilised. DMUs, inputs and outputs can be uploaded directly into the software, and results pertaining to the efficiency of each DMU are then produced (DEAOS, 2020).

8.3 Results

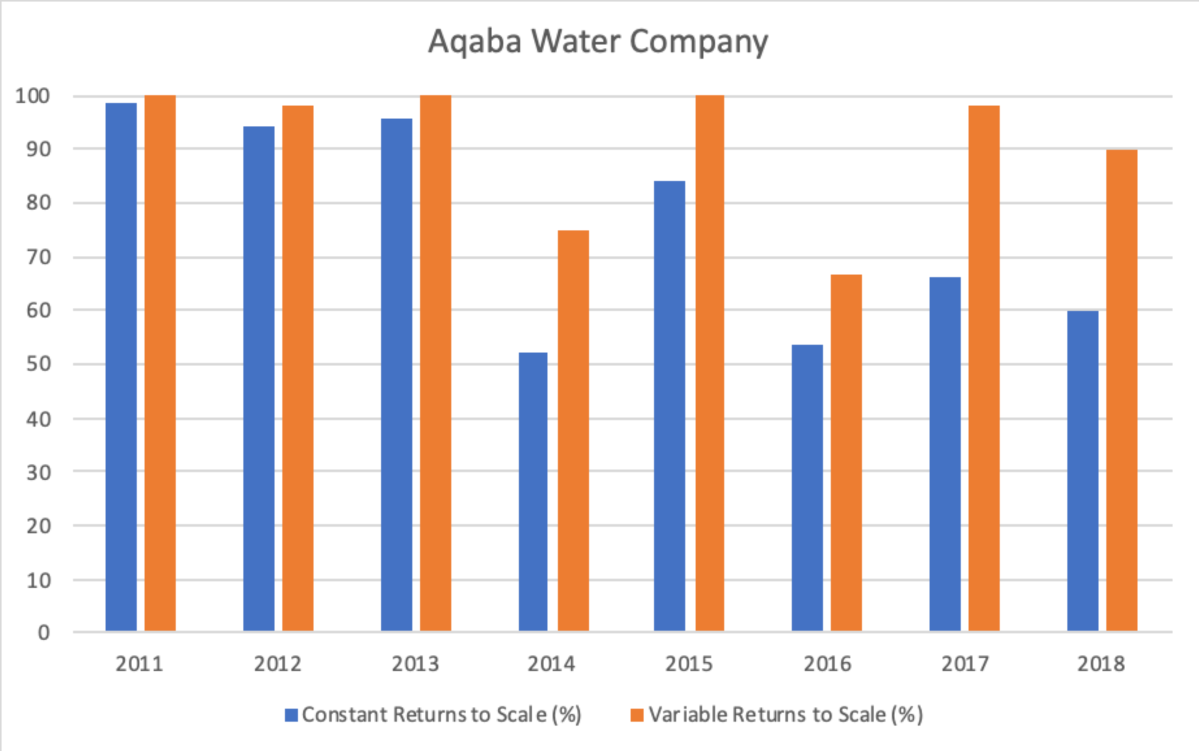
The DEA used the following inputs and outputs, for each of the Jordanian water providers:

Figure 23 Efficiency of Miyahuna using DEA Analysis, 2011-2018



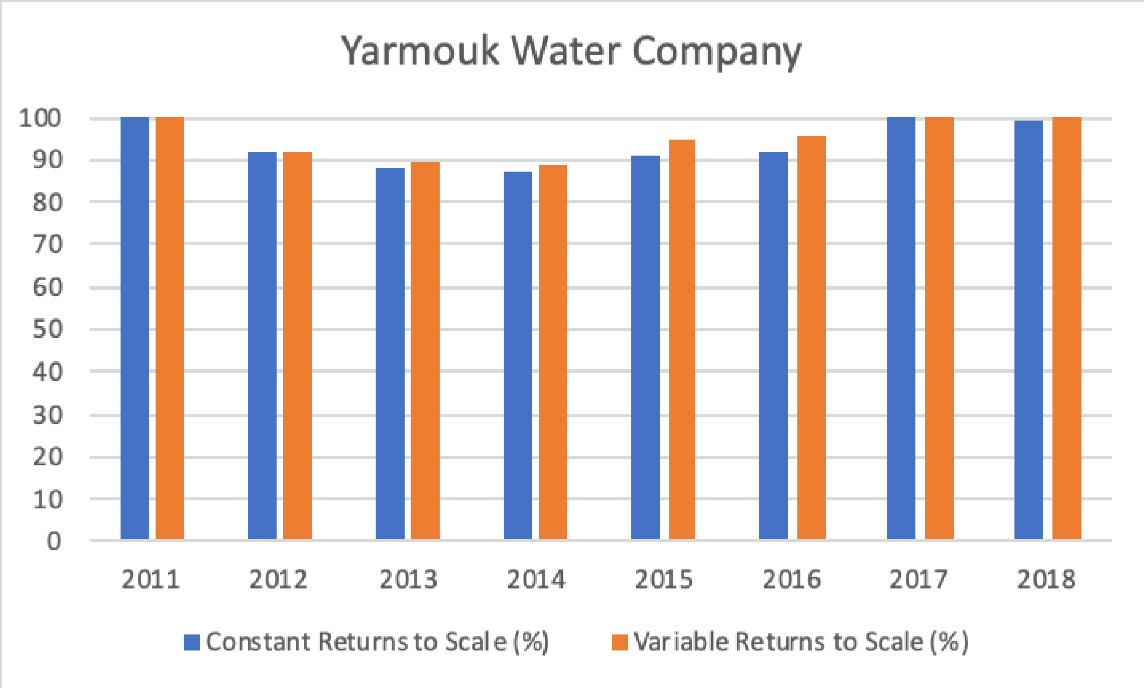
The figure above shows the efficiency scores for the water company Miyahuna, for the years 2011 to 2018, for both Constant and Variable Returns to Scale. The figure shows that Miyahuna showed strong signs of efficiency, compared with other Jordanian water suppliers, from 2011 to 2018, with the exceptions of 2014 and 2016. By 2018, the firm had reached 100% efficiency. Also, in most years there is little difference between models run under conditions of CRS and VRS.

Figure 24 Efficiency of AWC, 2011-2018



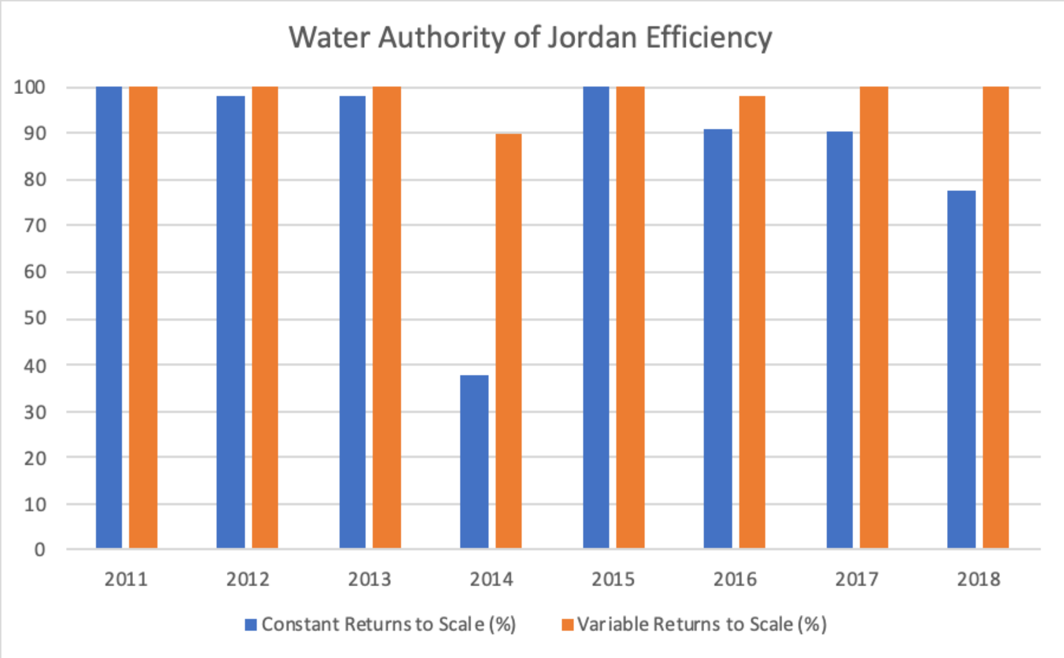
The AWC also shows signs of high efficiency, for the years 2011 to 2013. However, there is a noticeable drop in efficiency, from 2014 to 2018. There is also a noticeable difference, in 2014 to 2018, in the results for CRS and VRS. Under conditions of VRS, the company's efficiency never drops below 66.5% in 2016, whereas in CRS, it drops to 52.3% in 2014. This gap implies that changes in inputs will not result in an equal change in outputs, and therefore there is room for improved efficiency.

Figure 25 Yarmouk Water Company Efficiency, 2011 to 2018



As Figure 25 above shows, the YWC was very efficient towards the beginning and end of the 2011 to 2018 period (at 100% efficiency), and was quite efficient from 2012 to 2016. It should be noted that efficiency never dropped below 87.4% in 2014 (CRS conditions). However, unlike the two previous DMUs, this one has CRS and VRS at almost parity, implying that it is the only one that could achieve constant returns, should inputs change.

Figure 26 Efficiency of WAJ, 2011 to 2018



As Figure 26 above shows, WAJ showed relatively strong efficiency. Under CRS conditions, it only dipped below 90% efficiency in 2014 and 2018, and under VRS conditions, it never dipped below 90%. The weakest year was 2014, where efficiency was 38% under CRS, but 90% under VRS.

Having analyzed the four DMUs, it is time to analyze the performance of the corporatized versus state-managed firms. This is shown below:

Table 14 Efficiency of Corporatized vs State Owned Companies, Under Conditions of Constant Returns to Scale

	Corporatised Water Utilities (%)			**State-Managed Water Utility (%)**
	Miyahuna	**AWC**	**YWC**	**WAJ**
2011	86.3	98.6	100	100
2012	83.4	94.1	91.7	97.8
2013	93.2	95.6	87.8	98
2014	46.8	52.3	87.4	38
2015	100	83.9	91.1	100

2016	59.2	53.7	91.8	90.9
2017	90.6	66.3	100	90.5
2018	100	59.9	99	77.5

Table 14 above shows the efficiency of each of the four Jordanian water utilities, including the three corporatized companies against the state-run WAJ, under condition of CRS. In most years, the state-run WAJ was on par or more efficient than the corporatized companies, with the exception of 2014 when it dropped to 38% and 2018 when it dropped to 77.5%. The most efficient provider appears to be YWC, with an efficiency that does not drop below 87.4%. Twice Miyahuna had dramatic efficiency drops: 46.8% in 2014 and 59.2% in 2016. AWC showed the least efficiency overall, with efficiency dropping dramatically in 2014, to 52.3%, 2016, to 53.7% and 2018, to 59.9%.

Table 15 Efficiency of Corporatized vs State Owned Companies, Under Conditions of Variable Returns to Scale

	Corporatised Water Utilities (%)			**State-Managed Water Utility (%)**
	Miyahuna	**AWC**	**YWC**	**WAJ**
2011	96.9	100	100	100
2012	89.8	98.2	92	100
2013	94.2	100	89.9	100
2014	56	75.1	89	90
2015	100	100	94.8	100
2016	71	66.5	95.2	98
2017	93	98.1	100	100
2018	100	90	100	100

Table 15 above shows the efficiency of the three corporatized companies, against the state owned company (WAJ), under conditions of

VRS. This time, it was the purely state-run company (WAJ) which showed the most efficiency. Again, of the corporatized firms, YWC showed the most efficiency, not dipping below 89% during the 2011-2018 period. AWC only twice showed significant drops in efficiency: 2014 at 75.1% and 2016 at 66.5%. Miyahuna also only showed drops in efficiency twice: 2014 at 56% and 2016 at 71%.

Ultimately, using CRS, water suppliers were considered to be 100% efficient six times between 2011 to 2018, as opposed to fifteen times using VRS. This raises some questions as to whether the corporatised firms had some success in exploiting economies of scale. Should economies of scale exist, then conditions of CRS are biased towards larger DMUs; that is, smaller DMUs will seem more inefficient. However, under conditions of VRS (and economies of scale), smaller DMUs appear to be more efficient (Harton, 2010). In the results shown above, under conditions of CRS, the smallest DMU, the AWC, was inefficient, whereas the WAJ and Miyahuna both showed high levels of efficiency. Under conditions of VRS, the largest organisation, WAJ, was the most consistently efficient. Thus, it appears that the DMUs do exploit economies of scale under conditions of CRS, but not under conditions of VRS.

As was previously mentioned, studying both CRS and VRS yields additional information. By dividing CRS over VRS, one obtains the 'scale efficiency.' The larger the scale efficiency, the more scope there is for reducing inputs, while maintaining outputs. Table 16 below shows the scale efficiencies for this DEA.

Table 16 Scale Efficiencies of the Main Water Providers in Jordan, 2011-2018

	Miyahuna	**AWC**	**YWC**	**WAJ**
2011	0.89	0.99	1.00	1.00
2012	0.94	0.96	1.00	0.98
2013	0.99	0.96	0.98	0.98
2014	0.84	0.70	0.99	0.42

2015	1.00	0.84	0.96	1.00
2016	0.83	0.81	0.97	0.93
2017	0.97	0.68	1.00	0.91
2018	1.00	0.67	1.00	0.78
Average Scale Efficiency, 2011 to 2018	0.93	0.82	0.99	0.87

As Table 16 above shows, it is AWC which shows the biggest gap between its CRS and VRS results, implying it can reduce its inputs by 18% on average, and still supply the same amount of water to the same amount of people. Miyahuna can also reduce inputs by 7%, and produce the same output. YWC can only reduce inputs by 1%, to maintain current outputs. WAJ can reduce its inputs by 13%, while maintaining the same level of output.

Thus, while WAJ appears to be one of the more efficient of the producers in this dataset, it still has room to further improve efficiency. Miyahuna and AWC can also reduce costs while keeping output constant. On the other hand, YWC, one of the more efficient corporate suppliers, has little scope to improve efficiency through a reduction in inputs.

8.4 Analysis

The results have shown that YWC is one of the more efficient of the four water suppliers in Jordan. YWC is also a corporatized water utility. Conversely, it was AWC which showed relatively low efficiency compared to the others. Both Miyahuna and WAJ were efficient overall, with the exception of a couple of years (2014 and 2016 for Miyauna, 2014 and 2018 for WAJ). Furthermore, under conditions of VRS, it is WAJ which is the most efficient supplier. Of the corporatized entities, it is Miyahuna and YWC which have shown above average efficiency. Thus, the impacts corporatization has had on Jordanian water efficiency are ambiguous. One can conclude that corporatization amongst Jordanian water suppliers has improved overall efficiency, but efficiency has not yet surpassed that of the state-run WAJ. At first glance, this implies that other providers in Jordan should try to emulate the managerial and corporate actions of the successful utilities. However, in terms of reducing costs (while maintaining output), AWC and WAJ especially show great scope for improvement, at 18% and 13% respectively.

However, using CRS, efficiency as a whole has dropped considerably, within the Jordanian water sector, with 2011, being the most efficient year. Indeed, 2011 sets the uppermost bounds of efficiency, as 2012 to 2016 show somewhat lower efficiency, before picking up again in 2017 and 2018. The main reason for the low efficiency rating in the middle years is the fact that costs (operational and capital) soared during these years (partially due to the Syrian refugee crisis within this period).

It should be noted that these results only show efficiency relative to other firms in the data sample. DEA computations are useful for comparing the efficiency of branches within one over-arching organization, but they are less reliable for comparing efficiency with other organizations. This is because the DEA implicitly assumes that the efficiency frontier is set by the most efficient department within the data sample.

However, it is worth exploring whether other analyses in the literature have reached similar conclusions. As shown in Chapter 3, the literature is divided on this issue, with some studies maintaining that corporatisation of utilities can improve efficiency, while others argue SOEs are the most efficient. However, most of the studies of developed countries supported SOEs as the most efficient mode of ownership, while studies of developing countries showed that corporatisation or corporatization could offer efficiency gains. The results of the DEA for Jordanian water suppliers concur, with Miyahuna especially having been shown to be efficient, although the state-owned and managed WAJ was also one of the more efficient DMUs.

8.5 Improvements

Having shown the gaps between the efficiency scores and the efficiency frontier, this section will translate that data into actual inputs and outputs. That is, this section will show how much more output, or how much less input, a truly efficient DMU will generate or require.

For each of the following Tables 17-20, the 'Value' is the amount of input actually put into the DMU, or output generated. The 'Target' is what the input or output would be, should it be operating at perfect efficiency. The 'Difference' is simply the 'Target' subtracted from the 'Value'.

For each DMU, the value, target and difference was calculated, for each input and output, from 2011 to 2018, and then averaged, as shown in Table 17 below:

Table 17 Difference Between Efficiency Score and Efficiency Frontier, Miyahuna, 2011-2018

	Value	**Target**	**Difference**
CAPEX, USD	12,908,138	8,959,180	(3,948,958)
OPEX, USD	122,865,803	97,884,855	(24,980,949)
Water Volume, M^3	176	176	-
Population Served, Households	596,827	2,908,098	2,311,271

In Table 17 above, the column 'Value' shows the average values of the efficiency scores for Miyahuna, from 2011 to 2018, assuming CRS. The column 'Target,' shows the possible value which could be achieved, should efficiency be maximized. For example, if Miyahuna operated under perfect efficiency, it would have 3.9 million JD less in capital expenditures, 24.98 million JD less in operating expenditures, and would be able to serve an additional 2.3 million households. However, maximum efficiency will not increase the potential amount of water supplied.

Table 18 Difference Between Efficiency Score and Frontier, AWC, 2011-2018

	Value	Target	Difference
CAPEX, USD	2,376,635	1,705,669	(670,966)
OPEX, USD	13,360,662	9,674,773	(3,685,890)
Water Volume, M^3	20	20	-
Population Served, Households	58,197	570,075	511,877

As Table 18 above shows, if AWC operated under conditions of perfect efficiency, it would save capital costs of 671,000 JD and operating costs of 3.7 million JD. It would also be able to serve 512,000 households more. However, like Miyahuna, maximum efficiency would not improve water production.

Table 19 Difference Between Efficiency Score and Frontier, YWC, 2011-2018

	Value	Target	Difference
CAPEX, USD	12,868,951	11,974,046	(894,906)
OPEX, USD	37,852,353	41,639,804	3,787,451
Water Volume, M^3	80	83	3

Population Served, Households	2,219,641	2,534,530	314,889

If YWC were to function at perfect efficiency, it would save capital expenses of 895,000 JD, and be able to serve 315,000 more households. However, unlike Miyahuna and AWC, maximum efficiency would also generate a small amount of water, at 3 million cubic meters extra.

Table 20 Difference Between Efficiency Score and Frontier, WAJ, 2011-2018

	Value	**Target**	**Difference**
CAPEX, USD	213,663,958	181,613,568	(32,050,391)
OPEX, USD	123,414,536	91,530,246	(31,884,290)
Water Volume, M^3	333	333	-
Population Served, Households	963,832	2,496,025	1,532,193

If WAJ were to function at perfect efficiency, it would save capital expenses of 32.1 million JD, operating expenses of 31.9 million JD, and be able to serve 1.5 million more households. Like Miyahuna and AWC, maximum efficiency would not generate additional water.

8.6 Conclusion

As this chapter has shown, the three corporatized companies all showed strong signs of efficiency, from the DEA. WAJ also showed high levels of efficiency. Under conditions of CRS, Miyahuna, YWC and WAJ each had two years when efficiency reached 100%; AWC had none. Under conditions of VRS, again Miyahuna had two years reaching 100% efficiency, but AWC and YWC had three years each, and WAJ was mostly 100% efficient.

Overall, the process of corporatization amongst Jordanian water suppliers has improved their efficiency. Specifically, the corporatized entities show more output, per unit of input. Of the corporatized entities, it is Miyahuna and YWC which have shown above average efficiency. WAJ also showed consistent efficiency. At first glance, this implies that other providers in Jordan should try to emulate the managerial and corporate actions of these companies. AWC especially shows great scope for improvement, with the least efficient results.

However, efficiency in Jordanian water supply as a whole has dropped considerably, within the Jordanian water sector, with 2011-2012, being the most efficient years. Indeed, 2013 to 2016 show consistently lower levels of efficiency, before picking up again in 2017 and 2018.

If Miyahuna operated under perfect efficiency, it would have had 3.9 million JD less in capital expenditures, 24.98 million JD less in operating expenditures, and would be able to serve an additional 2.3 million households. However, maximum efficiency will not increase the potential amount of water supplied. If AWC operated under conditions of perfect efficiency, it would save capital costs of 671,000 JD and operating costs of 3.7 million JD. It would also be able to serve 512,000 households more. However, like Miyahuna, maximum efficiency would not improve water production. If YWC were to function at perfect efficiency, it would save capital expenses of 895,000 JD and be able to serve 315,000 more households. However, unlike Miyahuna and AWC, maximum efficiency would also generate a small amount of water, at 3 million cubic meters extra. If WAJ were to function at perfect efficiency, it would save capital expenses of 32 million JD, operating expenses of 31.9 million JD, and be able to serve 1.5 million more households. Like Miyahuna and AWC, maximum efficiency would not generate any more water.

9. Difference-in-Difference

9.1 Introduction

This chapter will use a DID analysis, in order to analyse whether water suppliers are more efficient due to corporatisation. Specifically, this chapter will analyse whether the changes in efficiency are a result of corporatisation itself, or the result of natural trends these companies would have followed anyway.

9.2 Literature Review

The literature on the impacts of corporatisation on water supply has rarely made use of DID. In fact, there are few studies using DID to examine water supply at all, or to study Jordan at all. This chapter will fill in a gap in the literature, using DID to examine the impacts of mode of ownership on water supply, in this case in Jordan. In order to do so, first an overview will be provided of the existing literature using DID to examine water supply. This will give an overview of the existing literature, as well as where the gaps are. The next section discusses the methodology of the chapter, outlining how the regressions will be implemented. Afterwards, a wide range of regressions are conducted, examining the differences in water supplies between states that corporatised, and those that did not. These results are then analysed, offering possible explanations as to why corporatisation had the impacts it did. Finally, the limitations of the chapter are discussed.

9.2.1 DID and Water Supply

As was shown in Chapter 8, there is no clear consensus in the literature, regarding the impacts of corporatisation on water supply. However, general themes which arise include cutting off water supplies to poorer customers and price hikes, as well as eventual reverting to state-run water systems. For example, Borraz, Pampillón and Olarreaga (2013) use DID to analyse the impacts of various modes of water supplier ownership, in Uruguay. The authors found that the privatisation of water provision did not improve access to water, but the later nationalisation did improve both water access and quality (especially for those in poverty).

Barrera-Osorio, Ospino and Olivera (2009) used DID to study how privatisation affected water quality and access in Colombia. The authors showed that privatisation did increase access to water (and quality of water) in urban areas, but significantly reduced access in rural areas. Both urban and rural areas saw improvements to health, but the drops in water access in rural areas cancelled out the increases to health in rural areas.

These results contradict Borraz, Pampillón and Olarreaga (2013), which found that nationalisation improved water access for those in the lowest income groups, not privatisation. However, both Borraz, Pampillón and Olarreaga (2013) and Barrera-Osorio, Ospino and Olivera (2009) found that privatisation negatively impacted less privileged communities, whether those in poverty or in rural areas.

Sekhri (2011) analyses central governmental versus local control over the supply of resources, and its impacts on sustainability. Specifically, the author analyses the compromise between immediate gains in growth versus long-term incentives to protect groundwater reserves by elected officials. Regional officials have greater motivations to encourage growth, negatively impacting resources. However, regional officials also have motivation to preserve groundwater reserves, in order to compete in elections. These simultaneous motivations have a balancing effect. The author uses DID methodology to show that due to the high cost of groundwater, legislators internalise the long-term costs of excessive water use, and promote conservation.

Barde (2017) analyses the relationship between small-scale water supply systems managed by local water associations and access to piped water in rural Brazil. The study finds that access to rural piped water increased from 15-16% in 2000, to 33.4% in 2010. In locations with local government supply networks, access increased to 24.9%. The study finds that project choice and accountability largely account for these differences. A DID methodology is used to analyse the impact of project type on water access rates, as well as to address issues of endogeneity. Ultimately, projects led by water user associations improved access to water by at least 6%, and government led projects only achieved similar results if there was accountability.

Both Barde (2017) and Sekhri (2011) touch upon the importance of accountability and public perception in water supply. These dimensions, although less tangible than water supplier ownership and efficiency ratios, can still impact water supplies extensively, and can be measured, using DID methodology.

9.2.2 DID and Water and Health

While the literature on DID in water supply is relatively sparse, there is a greater literature, studying the effects of different types of water ownership on health factors.

Lambert (2019) uses DID methodology to analyse the impacts of privatising the water and sanitation sectors, on child mortality in Guayaquil, Ecuador. By studying mortality rates in Guayaquil from 1990-2010, the author constructs a DID. He examines the privatisation of water in the city (independent variable) and mortality for under-three, under-five and under-ten year olds (the dependent variable). It is found that privatisation had negligible impacts on water-associated child mortality in the city.

Galiani, Gertler and Schargrodsky (2005) study the impacts of water privatisation on infant mortality in Argentina, using DID. They find that child mortality dropped 8% in the privatised areas, and the impacts were highest (at 26%) in the most poverty stricken areas. Thus, Galliani et. al. (2005) are in stark contrast to Lambert (2019), who maintains that water utility ownership does not significantly impact child mortality. It should be noted that Lambert’s (2019) study is a period of 20 years, whereas Galiani, Gertler and Schargrodsky (2005) is nine years. Also, Lambert (2019) is only studying one city, Galiani, Gertler and Schargrodsky (2005) are studying an entire country, Argentina. Thus, Lambert’s (2019) study allows for a much more ‘micro’ analysis, whereas Galiani, Gertler and Schargrodsky (2005) offers a broader scope.

Wallsten and Kosec (2005) use panel data for American community water systems, for 1997 to 2003, analysing how ownership and competition impact violations of the ‘Safe Drinking Water Act’. Public systems allowed more contaminants in the water, and private systems ignored reporting and monitoring standards (the results are inverted for systems with more than 100,000 people). Overall, the authors found that mode of ownership had little impact on safety violations. Finding that mode of ownership does not significantly impact water quality concurs with Lambert (2019), who finds that ownership does not, in itself, significantly impact child mortality.

9.2.3 DID and Irrigation

Having discussed the literature relating to water supply for domestic consumption, the literature review will now turn to irrigation. This is warranted, as irrigation takes up the bulk of Jordan’s water consumption, though domestic water use is fast catching up, as discussed in previous chapters. Irrigation is still an important component of Jordan’s water budget, thus this brief overview of how DID methodology is used to analyse irrigation.

Debaere and Li (2017) analyse the impacts of the Rio Grande water markets on irrigation supply, from 1954 to 2012, using DID. As the market was formed in 1971, that is the cut-off point between the ‘pre’ and ‘post’ periods. The authors find that water markets create a shift in the pattern of crops produced, from more water intensive to more water conserving crops (especially in droughts). The authors recommend water markets as a tool to promote water conservation in arid areas.

Drysdale (2020) uses DID to analyse the impacts of a collective action management plan on irrigation in Kansas, USA. The author compares changes in irrigation amongst farmers within the policy zone, against farmers within a five-mile zone outside the policy change. Using DID methodology, the author analysed the effects of the management plan on affected locales' irrigated area size, intensity and crop type, against unaffected locales. The author also examines differences in affected areas' in crop yields and input usage. The author finds that the plan reduced irrigation by 25%: 4% in irrigated areas, 19% in water intensity and 3% in crop allocations.

Drysdale & Hendricks (2018) use DID to measure how farmers respond to constraints levied on them by local governments. Specifically, local governments set quotas on water consumption, which were tradable amongst the farmers. The authors compare the impacts of these quotas to unaffected farmland nearby. They find that water consumption in affected areas dropped by 26%, primarily because farmers were using less water on the same crops, as opposed to reducing irrigated areas.

Thus, Drysdale (2020) and Drysdale and Hendricks (2018), using DID methodology, show that irrigation can be limited by government policy. This implies that irrigation might be more price elastic than is typically thought, and this might be especially important for arid countries such as Jordan.

9.2.4 DID and Water Consumption or Demand

DID has also been used to study water consumption and demand. Hailu, Osorio and Tsukada (2009) use DID to measure the impacts of water privatisation on Bolivian household water consumption, comparing cities that privatised water, and those that did not. In 1996 in La Paz and El Alto, the privatised cities, the richest 20% of the city received 30% more water than the poorest 20%. In 2005, after the privatisation, the consumption gap between the richest and poorest quintiles reduced to 5%. In the cities that did not privatise, the gap remained consistent during the same time period. However, even with this impressive achievement, the concession contract was cancelled, as the concession did not meet a number of targets and price hikes were unpopular.

However, even shifts in perception can impact water conservation. Lurbe, Burkhardt, Goemans and Manning (2018) examine how societal perceptions impact water usage, that is, whether social comparisons may result in residential water conservation. The authors use a randomised control trial in an American city, to analyse the impacts of the Home Water Report, over two years. The authors find that social comparison reduces home water consumption by 2.4%, across most quintiles (except at the top and bottom). Concurrently, Otaki, Honda and Ueda (2020) examine how water demand is affected by visualisations of water data and social comparisons with others. Using DID, the authors studied how visualisations of water as a public good impacted household water usage. The authors found that drops in water usage was (barely) significant, for middle and low income households.

9.2.5 Summary of Literature Review

As the literature review above has shown, a DID Analysis can provide insight into the impacts of corporatisation on Jordanian water supply efficiency. While a straightforward timeline of a state's progress in increasing water supply is informative, it is not clear what percentage of that progress is attributable to corporatisation. That is the power of a DID methodology; not only is the change in water supply measured, but how much of that change is directly attributable to corporatisation. Also, the literature review has shown that a DID can shed light not only on how a specific policy impacts water supply, but other factors such as NRW. This chapter will make use of this methodology, in order to assess Jordan's corporatisation of its water sector.

9.3 Methodology

A DID method is used to measure the causal impact of a policy change on an outcome variable by comparing two differences: the first difference is the difference in outcome between the treated and control group; and the second difference is the difference in outcome between 'before' and 'after' the policy intervention periods. In panel data, this is a version of fixed effect estimation which allows for the presence of unobserved heterogeneity.

$$Y_{it} = \alpha + \gamma Post_t + \delta Treat_i + \beta(Post_t * Treat_i) + \rho X_{it} + \varepsilon_i$$

β is the coefficient of the interaction term, and measures the treatment effect using the DID method. It measures the effect of a specific policy on a specific variable (the difference is in the treatment and control groups, before and after the treatment occurs). Essentially, DID compares the change in a specific variable after the policy is implemented, simultaneously across time (before and after the policy is implemented), and between the treatment and control groups. After the time difference is found, and the difference between the treatment and control groups are found, these two differences are then subtracted, giving the difference between the differences. Given the two time periods (T=0 corresponds to before the policy change and T=1 corresponds to after policy change) with Y^T and Y^C as outcomes for treated and control groups, the DID method provides the estimate of the policy's effects (Khandker, Koolwal, & Samad, 2010):

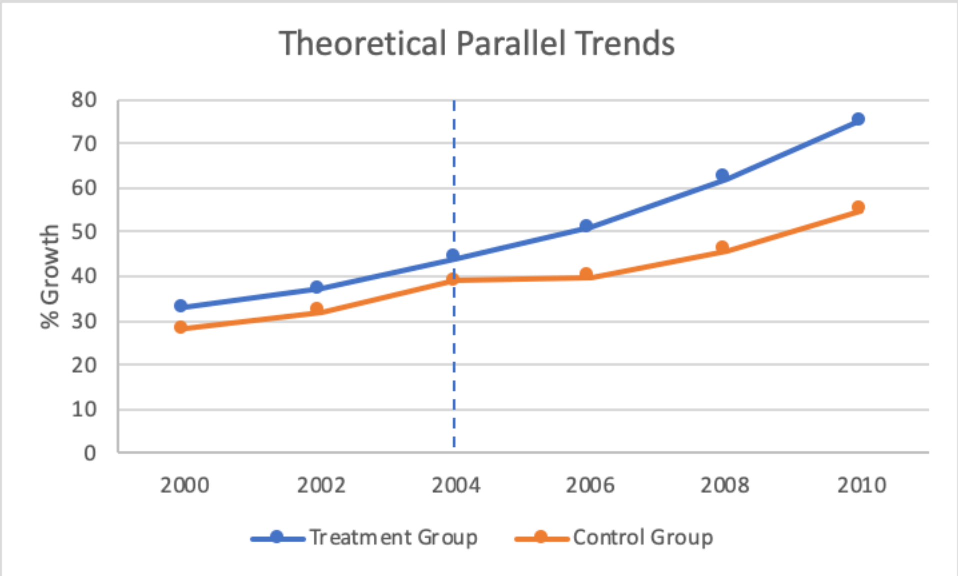
$$DID = E(Y_1^T - Y_0^T \mid T=1) - E(Y_1^C - Y_0^C \mid T=0)$$

The Program STATA will be used to model the DID (STATA, 2017).

9.3.1 Assumptions of DID

For a DID analysis to be robust and rigorous, a set of assumptions and conditions must be true. Under the parallel-trend assumption, unobserved heterogeneity that affects corporatization do not vary over time. The parallel trend assumption requires this specific condition: should the policy implementation be absent from the treatment group, the difference (or gap) between the treatment group and control group is constant over time. In other words, there should be no unobserved time-variant differences between the treatment and control groups, except for the implementation of a specific policy. This assumption is one of the foundations of DID methodology; that the parallel trends between the two groups would have continued, had the policy intervention not taken place.

Figure 27 Theoretical Parallel Trends Prior to Intervention



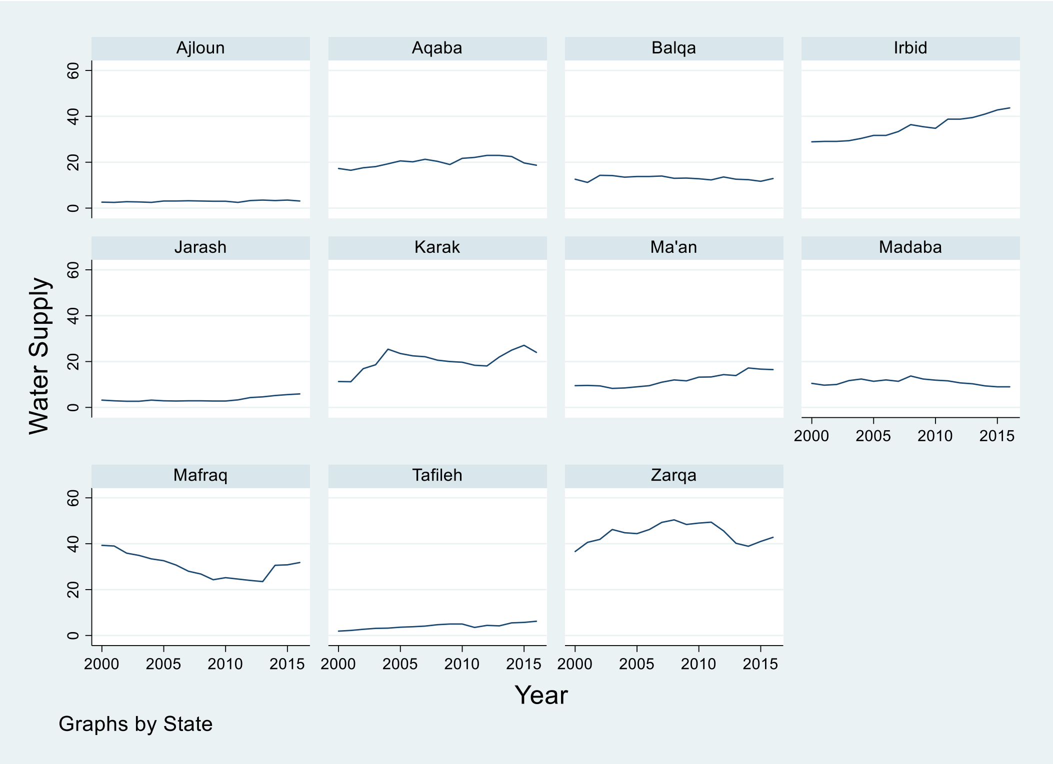
Source: Adapted from (Colombia Public Health, N.D.)

Figure 27 above is an example of the parallel trends assumption in DID. As the Figure shows, the two groups, 'control' and 'treatment,' both showed parallel growth trends prior to the treatment, after which divergence is seen.

This section will examine whether water supplies in Jordanian governorates have progressed in a similar direction before the corporatisation of water suppliers. If the water supply of Jordanian governorates did indeed progress in parallel before corporatisation, then changes observed *after* the implemented policy are at least partially attributable to that policy.

I excluded Amman from these states, because Amman was not state-run during 2000-2006, it was run by a Public-Private Partnership, hence neither state-run nor corporatised. Thus, the graphs of the 11 remaining states are shown below in Figure 28, for the years between 2000 and 2016.

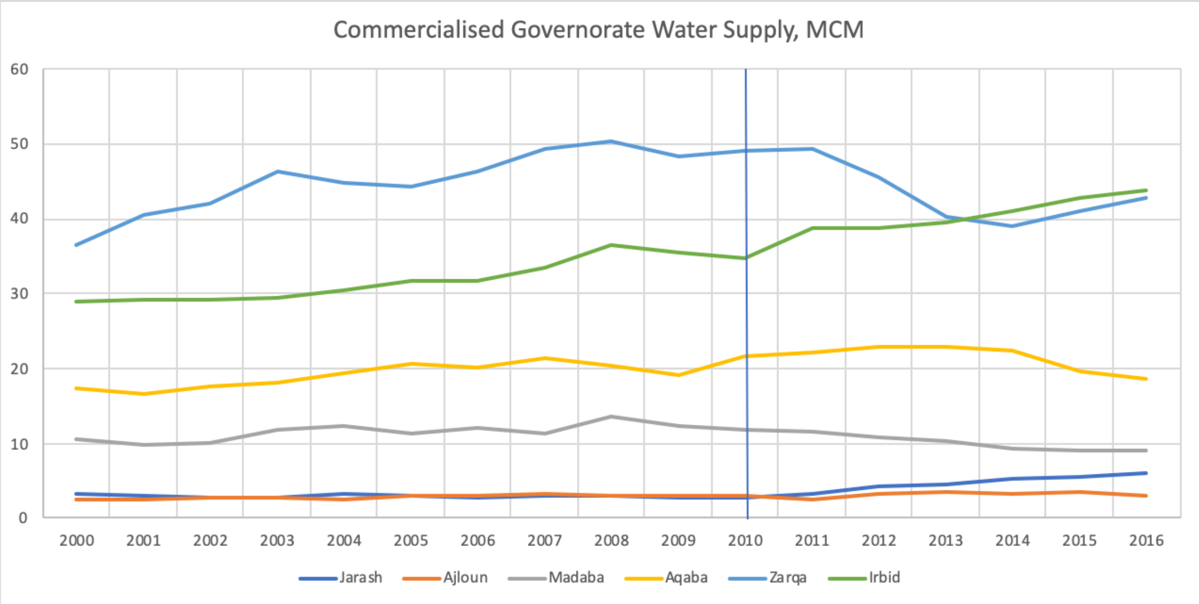
Figure 28 Water Supply of Each Governorate, Jordan, MCM, 2000-2016



Source: Personal Correspondence with MWI, Jordan

Figure 28 above is a compilation of the growth trends, in water supply, for each of the Jordanian governorates (excluding Amman). When compared separately, it is difficult to find parallel trends. Therefore, Figure 29 will put the ‘treatment’ or corporatised governorates into one chart.

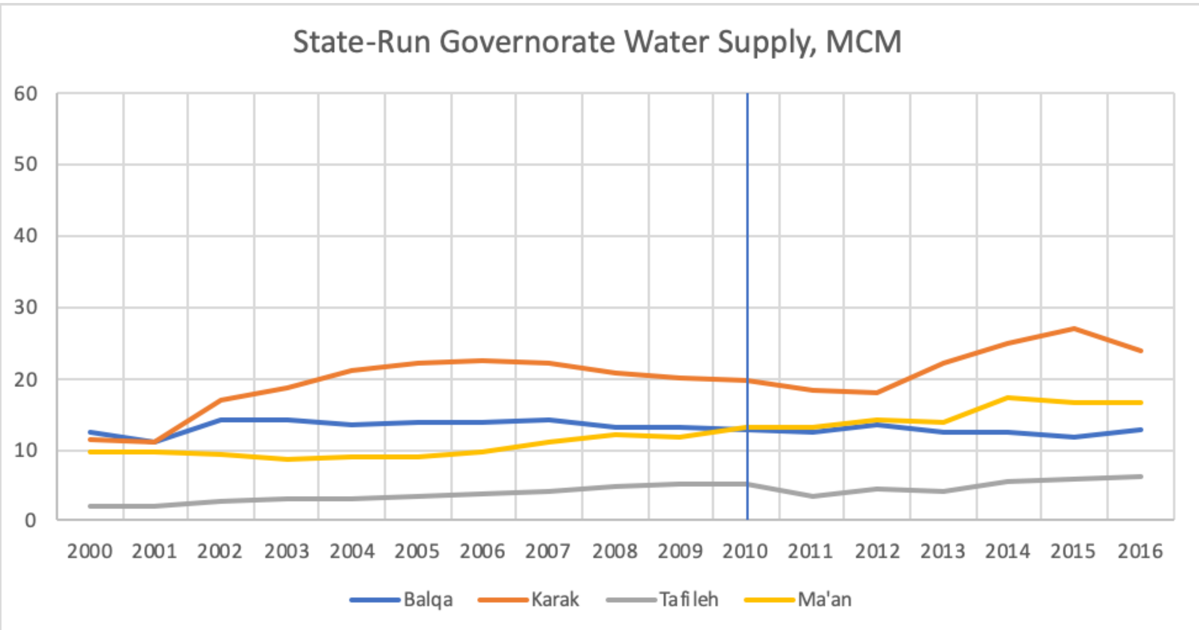
Figure 29 Corporatised Governorate Water Supply, (MCM)



Source: Personal Correspondence with MWI, Jordan

Figure 29 above shows most of the governorates which experienced corporatisation, showing similar trends in water supply, up until 2010.

Figure 30 State-Run Governorate Water Supply, MCM



Source: Personal Correspondence with MWI, Jordan

Figure 30 above shows the governorates which remained state-run, showing similar trends in water supply, up until 2010. Please note that

Figure 31 is kept to the same scale as Figure 30, going from '0' to '60' million cubic meters of water on the Y-Axis, to allow for comparison with Figure 30.

9.3.2 Simple Linear Regression Analysis

The first regression analysis is a simple panel data regression, examining the water supply across the 12 governorates of Jordan, between 2000 and 2016. For each governorate, a dummy variable was given for whether that governorate was corporatised or not. In order to clarify, corporatisation in this context means when a Jordanian governorate's water has come under the management of a newly corporatised entity. Thus, Aqaba's water was corporatised in 2004 with the formation of the Aqaba Water Company, Amman in 2007 with the formation of Miyahuna, and so on. A value of '0' was assigned to governorates that were not corporatised, and '1' to governorates that were. For each year, a dummy variable was assigned to whether corporatisation had taken place, with '0' showing no corporatisation, and '1' showing corporatisation had been implemented.

9.4 Results

9.4.1 Simple Relationship between Corporatisation and Water Supply

The following table shows the results of the simple panel data regression analysis. This regression only examined whether a governorate was corporatised, and its impacts on water supply. Dummy variables were used to indicate whether the governorate was corporatised or not. The 'post' variable indicates the year of corporatisation, and the 'treat' variable indicates whether the governorate is corporatised. The results are shown in the table below:

Table 21 Water Supply Regressed against Corporatisation

```
. reg WaterSupply treat post, robust

Linear regression                               Number of obs     =        204
                                                F(2, 201)         =      20.40
                                                Prob > F          =     0.0000
                                                R-squared         =     0.1179
                                                Root MSE          =     29.135
```

WaterSupply	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
treat	11.9578	2.450772	4.88	0.000	7.125283	16.79032
post	17.36898	6.924238	2.51	0.013	3.715517	31.02245
_cons	12.4902	1.012428	12.34	0.000	10.49385	14.48654

This regression showed an 'R-Squared' value of 11.8%, implying that corporatisation explains 11.8% of the changes in water supply in Jordan. The results are statistically significant, as all P-values are less than 0.05. The regression also shows a positive relationship between corporatisation and water supply in Jordan. That is, corporatisation was likely to result in an extra 12 million cubic meters of water supply over non-corporatised governorates.

In order to run a regression with an improved R-Squared (over 11.8%), another variable was added. This variable is the interaction between time and treatment.

Table 22 Water Supply Regressed against Corporatisation, with Interaction between Variables

```
. reg WaterSupply treat time int_treat_time, robust

Linear regression                               Number of obs     =         85
                                                F(3, 81)          =      16.22
                                                Prob > F          =     0.0000
                                                R-squared         =     0.2977
                                                Root MSE          =     14.657

--------------------------------------------------------------------------------
               |               Robust
   WaterSupply |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
         treat |   18.22424   3.371256     5.41   0.000      11.5165    24.93198
          time |   .3136364    1.58426     0.20   0.844    -2.838543    3.465816
int_treat_time |   2.009091   5.696632     0.35   0.725    -9.325421     13.3436
         _cons |   8.436364   1.082046     7.80   0.000     6.283432    10.58929
--------------------------------------------------------------------------------
```

The above regression includes the interaction between treatment*time variable, shown as 'int_treat_time'. As Table 22 above shows, the R-Squared increased to 29.8%, but the 'time' and 'int_treat_time' variables have P-values above 0.05. The 'treat' variable however, is statistically significant. It shows that corporatised states produce an additional 18 million cubic meters of water, over non-corporatised states.

Having experimented with linear regressions, a random effects generalised least squares (GLS) regression was run. In a 'random effects model' the model parameters are random variables. A GLS regression is a generalisation of the Ordinary Least Squares (OLS) regression, the primary difference being in the assumptions about the error term. That is, the assumptions that the errors are homoscedastic and uncorrelated are discarded (Kaufman, 2013).

Table 23 Water Supply Regressed Against Corporatisation

```
Random-effects GLS regression                   Number of obs     =        204
Group variable: st                              Number of groups  =         12

R-sq:                                           Obs per group:
     within  = 0.1438                                         min =         17
     between = 0.1047                                         avg =       17.0
     overall = 0.1073                                         max =         17

                                                Wald chi2(2)      =      33.24
corr(u_i, X)   = 0 (assumed)                    Prob > chi2       =     0.0000
```

WaterSupply	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
treat	14.89955	20.73281	0.72	0.472	-25.73601	55.53511
post	8.876774	1.557482	5.70	0.000	5.824164	11.92938
_cons	12.4902	17.94906	0.70	0.487	-22.68931	47.66971
sigma_u	31.044952					
sigma_e	8.1813256					
rho	.93506104	(fraction of variance due to u_i)				

In Table 23 above, the random effects GLS examining water supply and corporatisation showed an R-Squared of 10.7%. Also, the only P-value to be statistically significant is that of the 'post' variable, implying that governorates 'post' (or after) corporatisation saw an increase of 8.9 million cubic meters of water.

9.4.2 DID Regression

Section 9.3.1 established that various governorates had comparable growth trends in water supply, before the implementation of corporatisation (in the period 2000-2010). Specifically, it examined changes in water supply in the 'pre-implementation' and 'post-implementation' periods. First, it has shown which states experienced increases in water supply, and which did not. Second, by comparing the changes in the states which did corporatise with those that did not, it has shown to what extent corporatisation was responsible for changes in water supply. The eight governorates, showing parallel trends, to be examined are: Ajloun, Balqa, Irbid, Jarash, Karak, Ma'an, Mafraq and Tafileh, and are numbered respectively in the regression below.

In order to improve these results, a pseudo state fixed effect model is introduced. A 'Fixed Effect' model controls for the average difference between variables. That is, random variables (in this case, governorates) are treated as if they were not random. In this pseudo fixed effects model, each governorate is treated like its own individual variable.

Table 24 Water Supply Regressed Against Corporatisation, Specific Governorates

Source	SS	df	MS			
				Number of obs	=	136
				F(9, 126)	=	209.69
Model	18334.5309	9	2037.1701	Prob > F	=	0.0000
Residual	1224.11965	126	9.71523532	R-squared	=	0.9374
				Adj R-squared	=	0.9329
Total	19558.6506	135	144.878893	Root MSE	=	3.1169

WaterSupplyM~t	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
1.Treatment	.8744652	1.139661	0.77	0.444	-1.380891	3.129822
1.Time	1.72197	.7909502	2.18	0.031	.1567024	3.287237
Treatment#Time						
1 1	.5223485	1.118573	0.47	0.641	-1.691274	2.735971
State						
2	9	1.069097	8.42	0.000	6.884288	11.11571
3	32.01176	1.069097	29.94	0.000	29.89605	34.12748
4	.5823529	1.069097	0.54	0.587	-1.533359	2.698065
5	16.32941	1.069097	15.27	0.000	14.2137	18.44512
6	7.923529	1.069097	7.41	0.000	5.807817	10.03924
7	27.32941	1.069097	25.56	0.000	25.2137	29.44512
8	0	(omitted)				
_cons	2.380481	.8058623	2.95	0.004	.7857034	3.975259

As Table 24 above shows, the results improve significantly. The R-Squared jumps to 93.7%, and most of the P-Values are below 0.05, hence statistically significant. The variables with a P-Value above 0.05 are 'Treatment,' 'Treatment*Time,' and 'State 4.' This implies that most governorates, except for 4 and 8 (Jarash and Tafileh respectively) show statistically significant results. Also, there is a positive relationship between corporatisation and water supply, with corporatisation adding between 7.9 million to 32 million cubic meters of water supply.

9.4.3 Model with Independent Variables

The above models only measured corporatisation and water supply; in order to make the findings more robust, two control variables were added: population and NRW. This regression will be for all governorates, not a select few like in Table 29. If we add independent variables to this regression, then the results change considerably, as indicated below:

Table 25 Water Supply Regressed Against Multiple Variables

```
. reg WaterSupply treat post Population NRW, robust

Linear regression                              Number of obs     =        156
                                               F(4, 151)         =     133.46
                                               Prob > F          =     0.0000
                                               R-squared         =     0.8946
                                               Root MSE          =     10.103

------------------------------------------------------------------------------
             |               Robust
 WaterSupply |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       treat |   1.412833   1.512142     0.93   0.352    -1.574856    4.400522
        post |   1.654196    2.10727     0.78   0.434    -2.509346    5.817738
  Population |   .0000365   1.77e-06    20.59   0.000      .000033      .00004
         NRW |   .1039364   .0642768     1.62   0.108    -.0230616    .2309345
       _cons |  -.6683349   3.124019    -0.21   0.831    -6.840768    5.504098
------------------------------------------------------------------------------
```

As Table 25 above shows, the R-Squared has jumped dramatically, from 10.7% in Table 28 to 89.5% in this regression. However, only one variable, 'Population,' has a P-Value lower than 0.05. This implies that the other variables are not statistically significant.

These results show that, as soon as two new independent variables are added, the variables relating to corporatisation become statistically insignificant. In order to deal with this challenge, the time indicator is changed. Instead of the 'post' indicator being the year of corporatisation (for ex. 2007, 2011, 2015, etc.) of each governorate, the 'post' indicator now uses 2011 as the cut-off point, and is now 'time'.

Table 26 Water Supply Regressed Against Multiple Variables, Altered Time-Frame

```
. reg WaterSupply treat time int_treat_time Population NRW, robust

Linear regression                               Number of obs     =         64
                                                F(5, 58)          =      80.25
                                                Prob > F          =     0.0000
                                                R-squared         =     0.8651
                                                Root MSE          =      6.526

--------------------------------------------------------------------------------
               |               Robust
   WaterSupply |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
         treat |   3.645279   1.906812     1.91   0.061    -.1716212    7.462178
          time |   -1.50618   1.973754    -0.76   0.448    -5.457078    2.444718
int_treat_time |  -4.405021   3.229893    -1.36   0.178    -10.87035    2.060312
    Population |   .0000305   1.73e-06    17.61   0.000      .000027    .0000339
           NRW |    .254446   .0884718     2.88   0.006     .0773504    .4315416
         _cons |  -9.376506   4.065781    -2.31   0.025    -17.51505   -1.237961
```

In the regression above, population, NRW and the interaction between treatment and time (int_treat_time) are all measured. The R-

Squared is 86.5%, and the variables with P-values lower than 0.05 are population and NRW. The other variables are statistically insignificant. These results are still unsatisfactory, so now a random effects GLS Regression is used.

The results of the GLS Regression are shown below:

Table 27 Water Supply Regressed Against Multiple Variables, GLS Regression

Random-effects GLS regression		Number of obs	= 64
Group variable: st		Number of groups	= 5
R-sq:		Obs per group:	
within	= 0.0939	min	= 12
between	= 0.9271	avg	= 12.8
overall	= 0.8651	max	= 13
		Wald chi2(5)	= 372.03
corr(u_i, X)	= 0 (assumed)	Prob > chi2	= 0.0000

WaterSupply	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
treat	3.645279	2.378008	1.53	0.125	-1.015531	8.306088
time	-1.50618	2.63335	-0.57	0.567	-6.667452	3.655091
int_treat_time	-4.405021	3.439749	-1.28	0.200	-11.1468	2.336763
Population	.0000305	2.11e-06	14.46	0.000	.0000263	.0000346
NRW	.254446	.0809113	3.14	0.002	.0958627	.4130293
_cons	-9.376506	4.048403	-2.32	0.021	-17.31123	-1.441782
sigma_u	0					
sigma_e	2.4187269					
rho	0	(fraction of variance due to u_i)				

As Table 27 above shows, a random effects GLS taking into account governorate population and NRW yields an R-Squared of 86.5%. However, the only statistically significant P-Values were population and NRW. Ultimately, the random effects GLS model did not improve findings significantly. In order to improve findings, it may be beneficial to examine the impacts of corporatisation not on the overall governorates of Jordan, but between specific ones.

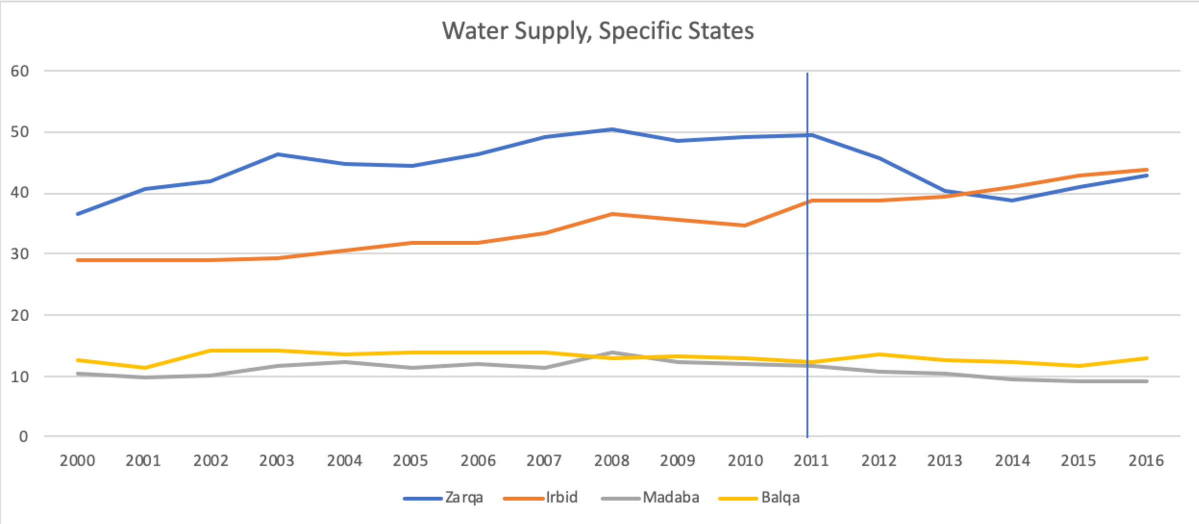
9.4.4 Comparing Individual Governorates

Madaba, Irbid, Zarqa and Balqa

Having examined the relationship between water supply and corporatisation, of the governorates in Jordan, it may now be illuminating to take a more 'micro' approach. That is, by comparing one or two corporatised governorates against one or two non-corporatised governorates, a more nuanced picture might be discerned.

Madaba and Irbid both experienced corporatisation, and both governorates showed similar trends in water supply, up to 2011, when Irbid corporatised (Madaba would follow soon after, in 2013). Balqa did not corporatise its water, and Zarqa only corporatised its water in 2015, but they both showed similar trends in water supply, and are therefore comparable.

Figure 31 Water Supply, Selected Governorates, MCM



Source: Personal Correspondence with MWI, Jordan

Another advantage of examining these four governorates is that they are all smaller governorates, with none of them being the capital. This is advantageous, as the smaller governorates will be much closer to each other in terms of supply and efficiency. Thus, comparisons between them are more warranted (the Capital, Amman, is an outlier in terms of water supply and efficiency). Table 28 below regresses the water supply of each governorate, against the corporatisation (or not) of each governorate.

Table 28 Water Supply Regressed Corporatisation, Madaba and Irbid vs Zarqa and Balqa

```
. reg WaterSupply treatv2 time int_treat_timev2, robust

Linear regression                               Number of obs     =         34
                                                F(3, 30)          =     325.10
                                                Prob > F          =     0.0000
                                                R-squared         =     0.9696
                                                Root MSE          =     2.9657

----------------------------------------------------------------------------------
                 |               Robust
     WaterSupply |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-----------------+----------------------------------------------------------------
         treatv2 |   31.95455   1.317871    24.25   0.000     29.26309      34.646
            time |  -.7166667   .3740455    -1.92   0.065    -1.480569    .0472362
int_treat_timev2 |  -1.554545   2.050875    -0.76   0.454     -5.74299    2.633899
           _cons |       13.3   .2757809    48.23   0.000     12.73678    13.86322
----------------------------------------------------------------------------------
```

As Table 28 above shows, the R-Squared is 96.7%, and the 'treatv2' variable is statistically significant. This implies that the corporatisation of Madaba and Irbid had a statistically significant impact on water supplies. Indeed, corporatisation brought to Madaba and Irbid (compared to Zarqa and Balqa) almost 32 million more cubic meters of water. Although, as Figure 30 shows, Madaba's water supply actually decreased after corporatisation. The increased supply from Irbid offset the drop in Madaba's supply.

Having conducted a simple regression, using only water supply and corporatisation, a linear regression with more variables is shown below. Specifically, in this regression, population and NRW variables included.

Table 29 Water Supply Regressed Against Multiple Variables, Madaba and Irbid vs Zarqa and Balqa

Linear regression

Number of obs	=	25
F(5, 19)	=	208.35
Prob > F	=	0.0000
R-squared	=	0.9812
Root MSE	=	2.504

WaterSupply	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
treatv2	34.9102	5.207133	6.70	0.000	24.01154	45.80886
time	-.2627492	1.137763	-0.23	0.820	-2.644115	2.118617
int_treat_timev2	-.3361583	3.369167	-0.10	0.922	-7.387907	6.71559
Population	-4.89e-06	9.51e-06	-0.51	0.613	-.0000248	.000015
NRW	-.02639	.0275091	-0.96	0.349	-.0839672	.0311873
_cons	16.35606	2.738687	5.97	0.000	10.62392	22.08819

As Table 29 above shows, this model gives an R-Squared of 98.1%. Again, the only statistically significant variable is 'treatv2,' implying that corporatisation brought to Madaba and Irbid 34.9 million cubic meters of water more than Zarqa and Balqa.

In order to make the findings more robust, a fixed effects regression is used, to analyse the relationship between corporatisation and water supply, between specific governorates.

Table 30 Water Supply Regressed Against Multiple Variables, Madaba and Irbid vs Zarqa and Balqa, Fixed Effects

```
. xtreg WaterSupply treatv2 time int_treat_timev2 Population NRW, fe
note: treatv2 omitted because of collinearity

Fixed-effects (within) regression               Number of obs     =         25
Group variable: st                              Number of groups  =          2

R-sq:                                           Obs per group:
     within  = 0.1719                                         min =         12
     between = 1.0000                                         avg =       12.5
     overall = 0.6734                                         max =         13

                                                F(4,19)           =       0.99
corr(u_i, Xb)  = -0.8621                        Prob > F          =     0.4388

------------------------------------------------------------------------------
     WaterSupply |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-----------------+------------------------------------------------------------
         treatv2 |          0  (omitted)
            time |  -.2627492   1.641124    -0.16   0.874    -3.697662    3.172164
int_treat_timev2 |  -.3361583   2.531557    -0.13   0.896    -5.634768    4.962451
      Population |  -4.89e-06   7.56e-06    -0.65   0.526    -.0000207    .0000109
             NRW |    -.02639   .0508759    -0.52   0.610    -.1328745    .0800946
           _cons |   33.11295   3.967255     8.35   0.000     24.80939    41.41651
-----------------+------------------------------------------------------------
         sigma_u |  24.685239
         sigma_e |  2.5040471
             rho |  .98981492   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(1, 19) = 68.95                      Prob > F = 0.0000
```

As Table 30 above shows, there are no statistically significant results. Thus, Table 31 will be a random effects GLS regression.

Table 31 Water Supply Regressed Against Multiple Variables, Madaba and Irbid vs Zarqa and Balqa, GLS Regression

```
. xtreg WaterSupply treatv2 time int_treat_timev2 Population NRW

Random-effects GLS regression                   Number of obs     =         25
Group variable: st                              Number of groups  =          2

R-sq:                                           Obs per group:
     within  = 0.1719                                         min =         12
     between = 1.0000                                         avg =       12.5
     overall = 0.9812                                         max =         13

                                                Wald chi2(5)      =     992.89
corr(u_i, X)   = 0 (assumed)                    Prob > chi2       =     0.0000

------------------------------------------------------------------------------
     WaterSupply |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-----------------+------------------------------------------------------------
         treatv2 |    34.9102   4.204199     8.30   0.000     26.67012    43.15028
            time |  -.2627492   1.641124    -0.16   0.873    -3.479294    2.953796
int_treat_timev2 |  -.3361583   2.531557    -0.13   0.894    -5.297919    4.625602
      Population |  -4.89e-06   7.56e-06    -0.65   0.518    -.0000197    9.93e-06
             NRW |    -.02639   .0508759    -0.52   0.604     -.126105    .0733251
           _cons |   16.35606   2.709826     6.04   0.000     11.04489    21.66722
-----------------+------------------------------------------------------------
         sigma_u |          0
         sigma_e |  2.5040471
             rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

As Table 31 above shows, the R-Squared is 98.1%. Also, the only statistically significant variable is that of ‘treatv2.’ This table shows that corporatisation results in 34.9 million more cubic meters of water, for Madaba and Irbid as opposed to Zarqa and Balqa.

Tafileh, Mafraq, Balqa and Irbid

Having examined the relationship between one set of governorates, this section will examine the relationship between another set: Tafileh, Mafraq, Balqa and Irbid. Tafileh and Balqa were chosen because they are the other two governorates which remain state run.

In this regression, the sample years are 2009-2013. Mafraq and Irbid were corporatised in 2011, thus this regression examines the two years before and after their corporatisation, with Tafileh and Balqa as control.

Table 32 Water Supply Regressed Against Corporatisation, Tafileh and Balqa vs Mafraq and Irbid, 2009-2013

```
. xtreg WaterSupply treat time int_treat_time, fe
note: treat omitted because of collinearity

Fixed-effects (within) regression               Number of obs      =        20
Group variable: st                              Number of groups   =         4

R-sq:                                           Obs per group:
     within  = 0.2941                                         min =         5
     between = 0.8018                                         avg =       5.0
     overall = 0.4779                                         max =         5

                                                F(2,14)            =      2.92
corr(u_i, Xb)  = 0.6544                         Prob > F           =    0.0873

--------------------------------------------------------------------------------
   WaterSupply |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
         treat |          0  (omitted)
          time |  -.5416667   .6928883    -0.78   0.447    -2.027764     .944431
int_treat_time |      2.125   .9798921     2.17   0.048     .0233405    4.226659
         _cons |    19.4625   .3795106    51.28   0.000     18.64853    20.27647
---------------+----------------------------------------------------------------
       sigma_u |  13.690985
       sigma_e |   1.073418
           rho |  .99389048   (fraction of variance due to u_i)
--------------------------------------------------------------------------------
F test that all u_i=0: F(3, 14) = 431.57                     Prob > F = 0.0000
```

As the results above show, the R-Squared is 47.8%. Also, the interaction of 'treat' and 'time' is statistically significant. This shows that corporatisation increased the water supply of the treated group (Mafraq and Irbid) over the control group (Tafileh and Balqa), by over two million cubic meters.

9.5 Analysis

It should be noted that the findings of this chapter concur with those of the previous chapter, which used DEA to measure the effects of corporatisation. That chapter, examining the water supplying companies, instead of the governorates, also found that corporatisation did not increase water supply, overall. However, when looking at certain governorates, specifically those with parallel trends, corporatisation did improve supply. Specifically, Ajloun, Balqa, Irbid, Karak, Ma'an and Mafraq all showed improved water supplies, with corporatisation. In another regression, Madaba and Irbid (treatment group) versus Balqa and Zarqa (control group) also showed a positive relationship between corporatisation and water supply.

Thus, it appears that there is a relationship between corporatisation and water supply in the *poorer* governorates. It appears that corporatisation did not significantly improve water supply in the country's largest and most prosperous governorate, Amman, or the second largest governorate, Zarqa.

The possible reasons for the select corporatised governorates showing improved water supply are varied. As the literature review showed, the literature has mixed conclusions about the relationship between corporatisation and water supply, but overall supports the proposition that corporatisation increases water supply efficiency. Thus, this chapter agrees with the literature on water supply and corporatisation (as analysed through a DID lens).

9.5.1 Comparing Theoretical Advantages of Corporatisation to the Results

The possible reasons for the positive relationship between corporatisation and improved water efficiency include: corporatisation allows companies to cut waste; employ best business practices; avoid political pressures; reduce costs and maximise efficiency. Also, one of the most notable advantages of the corporatised companies over the state-run suppliers, is that of cost recovery, through collecting bills. The corporatised companies have greater incentive to collect water bills than state-run suppliers.

The results of this chapter seem to support this proposition. Indeed, corporatisation has improved water supply, and specifically in the governorates which are frequently cited as the poorest and most inefficient. However, another interpretation is that these governorates were already starting from such a low vantage point, that they were naturally going to show the most progression.

It should be noted that, while corporatisation does improve water supply, another issue is whether these improvements are significant, in light of Jordan's water scarcity. That is, Jordan faces water deficits of 373 million cubic meters in 2018 (Namrouqa, 2018) and improvements of 7.9-32 million cubic meters (as shown in this chapter) are not enough to bridge that gap.

9.5.2 Corporatisation and NRW

Of the regressions in this chapter which contained the 'NRW' variable, there were two categories. In the first category, the 'corporatisation' variable was statistically significant, but NRW was insignificant. This shows that there is no correlation between corporatisation and NRW, either positive or negative. This in turn implies that corporatisation has not made significant inroads in reducing NRW, in the studied governorates. In the second category, NRW was statistically significant, but corporatisation was insignificant. In these regressions, there is a statistically significant, positive relationship between water supply and NRW. That is, as water supply increases, so does NRW.

Thus, the NRW regression performed for this chapter showed that corporatisation does not affect NRW. This is in stark contrast to the literature, which states that corporatisation should result in significant increases in efficiency (as discussed in Section 2.2). This is because, theoretically, corporate companies have a vested interest in minimising cost and waste, and therefore would not tolerate NRW levels of 47%, as is the case in Jordan (Ministry of the Environment, Jordan, 2020). Instead, such companies would identify the leaks, plug them, and fine anyone caught stealing water from the pipes or drilling illegal wells.

The Suez-LEMA consortium managed Amman's water, from 1999-2006. One of the main reasons the Government did not renew the contract in 2006 (opting instead to create Miyahuna) was the consortium's failure to reduce NRW. Indeed, the consortium achieved 12 out of the 15 goals stipulated in the contract, but one of the remaining unfulfilled goals was a reduction in NRW by 25% (World Bank, 2007). Thus, one of the primary incentives for corporatising Amman's water in the first place, is the reduction of NRW.

Miyahuna reduced NRW in Amman from 43% in 2006 to 34% in 2013, whereas the Suez-LEMA consortium reduced NRW in Amman from 52% in 1999 to 43% in 2006 (Telfah, Halalsheh, Ribbe, & Roth, 2017). Using this criteria, it appears that the PPP consortium managing Amman from 1999 to 2006 and the subsequent Miyahuna both had similar results, each dropping NRW by 9% in seven years.

If one takes a political economy approach, then the governorates with rapidly increasing NRW are exercising their political power. That is, the government refuses to clamp down on water theft in these governorates, in return for the tacit support of the citizenry (particularly powerful tribes and farmers) (Yorke, 2016). However, this implies that water theft is a significant component of water loss in Jordan. Al-Ansari, Alibraheim, Alsaman and Knutsson (2014), in discussing Jordanian NRW rates, show that administrative losses account for 27%-32.8% of losses, technical losses 25.6%, water theft 11.8% and faulty meters/readings 8.3%. In other words, water theft or illegal water usage is not the primary cause of NRW water in Jordan; it is technical and administrative issues, in stark contrast to Yorke (2016).

Al-Ansari, Alibraheim, Alsaman, & Knutsson (2014) offer many potential strategies for reducing NRW. First, the authors recommend administrative measures, including increased autonomy for water providers, regulatory reforms, improved training and staff hiring practices and fining water theft. Second, the authors recommend the implementation of new technology, to determine the location of water loss and immediately rectify it, as well as continuous pumping. These are sound propositions, which could reduce Jordanian NRW. However, the authors also make economic recommendations, including demand management and cost-recovery pricing. However, the authors do not mention how to overcome the political deadlock, in increasing prices, as successive governments fear the political backlash of increased water prices. Also, they do not discuss the impacts on poorer consumers, should there be a water price hike. In fact, the authors recommend the outright privatisation of some water services, such as water monitoring and pipe maintenance. However, the authors do not mention that something similar was already tried in Amman, between 1999-2006, and the PPP was not renewed precisely because it failed to significantly reduce NRW.

9.6 Final Recommendations

The corporatised companies made modest improvements to supply, but it should be kept in mind that supply increased even with significant restraints, such as not being able to charge recovery prices for water. However, charging full cost recovery would make water too expensive for many consumers, and would be politically challenging.

As this Chapter, and the previous Chapter, have shown, corporatisation has made notable improvements, in terms of supply efficiency, and other notable indicators such as the number of home connections. Also, many of these benefits manifest in the poorer corporatised governorates, as shown in Table 29.

Therefore, the remaining non-corporatised states should be corporatised. This will contribute towards improving water supplies, especially in poorer governorates.

9.7 Limitations of this Chapter

As with any study, there are a number of limitations to this chapter which should be addressed. The first limitation is that, in this study of corporatisation in Jordan, only two dependent variables were used, water supply and NRW. When water supply was the dependent variable, only two independent variables were used: population and NRW. In each case, dummy variables were used to show whether a governorate was corporatised or not. The use of more variables may have led to more robust findings, with higher R-Squared values and more statistically significant findings.

9.8 Conclusion

This chapter has shown that there is a link between corporatisation and water supply in Jordan, between 2000 and 2016. Running a random effects GLS regression, using only water supply as an independent variable, corporatisation increased water supply by 8.9 million cubic meters.

A fixed effects DID regression was performed for the following states: Ajloun, Balqa, Irbid, Jarash, Karak, Ma'an, Mafraq and Tafileh. With the exception of Jarash and Tafileh, each state showed a statistically significant link with corporatisation. That is, overall, corporatisation improved the water supply in these states from between 7.9 million to 32 million cubic meters.

When population and NRW were added as independent variables, corporatisation suddenly becomes statistically insignificant. However, another regression was run, keeping the new independent variables, and using only four governorates: Madaba and Irbid (treatment group) versus Balqa and Zarqa (control group). This regression showed that corporatisation resulted in 34.9 million more cubic meters of water for Madaba and Irbid, as opposed to Balqa and Zarqa.

This chapter contributes to the literature, as a DID Analysis of Jordanian water supply has not been done before. Thus, this chapter offers a methodology for studying the impacts of a policy decision, such as corporatisation, within a country.

10. Stochastic Frontier Analysis

10.1. Introduction

The previous chapters made use of Data Envelopment Analysis (DEA) and Difference-in-Difference (DID) to measure the efficiency of Jordanian water supply. This chapter provides a third econometric method of gauging efficiency, the Stochastic Frontier Analysis (SFA). The three methodologies will then be compared, so as to gain greater insight into both Jordanian water supply and the methodologies themselves. The SFA was chosen, primarily because it is one of the most widely cited methods for analysing water supply efficiency in the literature. This chapter will use SFA to analyse the costs of Jordanian firms, determining how cost efficient the sector is. SFA was chosen over cost functions, because SFA can separate error terms, distinguishing firm inefficiency from the impacts of external shocks. By separating the two, a more accurate understanding of the source of the inefficiencies in water suppliers is reached, (this separation is not possible in a simple cost function). This chapter will use a wide range of SFA models, thus avoiding the risk of using only one model and the ensuing possibility of skewed results. The chapter details the statistically significant relationship between total costs and output, as well as NRW and the number of water connections (NoC). These relationships are explored across a variety of SFA Models, so that a holistic picture of these relationships is given. This chapter also explores the efficiency of each company, as well as whether the causes of inefficiency are exogenous or internal.

The previous chapters primarily examined efficiency through output, whereas this chapter will examine efficiency in terms of total costs. Using a Stochastic Frontier Analysis (SFA), this chapter will examine the how costs are impacted by various issues, including but not limited to output, corporatization, NRW and NoCs. In order to perform this task, it is first necessary to provide an overview of the literature.

10.2 Literature Review

10.2.1 Different Methods of Increasing Supplier Efficiency and their Impacts

It is clear from the literature that SFA is considered to be one of the premier tools in analysing water-related issues (Estruch-Juan, Cabrera, Molinos-Senante, & Maziotis, 2020); (Worthington, 2014), (Bonifaz & Itakura, 2014). Thus, this section will review the literature, regarding how the different methods of increasing water supplier efficiency impact cost-effectiveness, with a focus on SFAs.

Estache and Rossi (1999) produce one of the first papers to use SFA to examine the efficiency of water suppliers, in this case in Asian and the Pacific Region. Particularly, they examine whether the mode of ownership impacts efficiency. They find that, whether using Maximum Likelihood or Corrected Least Squares methodology, private water suppliers exhibit more efficiency. This is in keeping with reports published by the World Bank, for example: Siregar (2004); Kirkpatrick, Parker and Zhang (2006).

A more recent paper which concurs, and shows that privatized water suppliers can be highly efficient, is Molinos-Senante and Maziotis (2019). They study the cost efficiency of the (privatized) English and Welsh water and sewage sector, from 1998-2009, using a stochastic meta-frontier. The authors find that UK water suppliers are in fact almost completely efficient, with water companies ranging from an average of 0.958 (water only) to 0.965 (water and sanitation) efficiency.

Bonifaz and Itakura (2014) study 12 Latin American water utilities from 1999 to 2010. Using a Stochastic Frontier Analysis, the authors find that the private sector is more cost-efficient than the public sector. Also, the authors found no evidence for economies of scale or density; inefficiency was positively correlated with utility size and pipeline length.

Souza, Faria and Moreira (2008) go against the trend of the previous papers. The authors examine the cost efficiencies of Brazilian water providers, both government owned and privately owned. Using a Cobb-

Douglas SFA, they analyse a panel of Brazilian water providers for 2002-2004. The authors find that state-owned companies show greater efficiency, although the gap between state and privately owned firms diminishes with time, with both improving gradually.

While the previous papers operated under a private/public binary, other papers allow for analyses where suppliers have mixed ownership. Maziotis, Molinos-Senante and Sala-Garrido (2021) examine how the ownership of water suppliers impacts water supply service, including how ownership impacts interruptions to water supply. Using a stochastic frontier methodology, the authors examine cost efficiency, economies of scale and the marginal cost of minimizing unplanned interruptions. They examine 21 Chilean water suppliers between 2007 and 2017, examining private, government-owned and mixed suppliers. They find that mixed suppliers are more efficient at lowering the cost of unplanned water interruptions than either fully private or government-run suppliers.

Abbott and Cohen (2009), in surveying the impacts of mode of ownership on supply efficiency, find varying results. Some studies argue for either the private or public sector, while many find no noticeable difference. The authors cite Bhattacharyya, Harris, Narayanan and Raffiee (1995), who maintain that public suppliers are more efficient at high levels of supply, while private suppliers are more efficient at low supply. The authors conclude that the mode of ownership is not as important as other issues, such as the degree of competition. That is, in many utilities (such as electricity and gas) increased competition results in improved efficiency. In the water sector, however, most private suppliers are monopolies and therefore do not reap the benefits of competition any more than state-run monopolies.

The findings of Hon, Boon and Lee (2016) concur with Abbott and Cohen (2009). The authors examine the technical efficiency of Malaysian water suppliers, using stochastic frontiers and cost functions, from 1999-2008. They find no evidence that either state-owned or privately owned firms were more efficient overall, though the most efficient firm was state-run.

However, the literature has moved away from the idea that one mode of ownership significantly improves cost savings and efficiency in water supply. Now the literature is much more nuanced, eschewing a definitive 'private versus public' judgement. Rather, the literature studies the underlying causes of inefficiency, as this literature review will show.

10.2.2 Different Methodologies and their Impacts on Results

An overview of the methodologies used in the study of water efficiency can be found in Abbott and Cohen (2009). They also provide an overview of the underlying structural factors in water supply, including economies of scale, mode of ownership and impacts of regulation. The authors find that many of the studies in their sample concur that there are extensive economies of scale in the water sector. The main point of contention however, is in the extent of these economies of scale. Generally, smaller water suppliers could benefit from economies of scale as they grew larger. However, at some point, the economies of scale plateau, with some estimates putting that number at 100,000 subscribers, and others reaching one million. This finding contradicts other studies found in the literature.

For example, Guerrini, Romano and Leardini (2018) use stochastic frontiers to examine economies of scale and density in Italian water suppliers. The authors study 43 Italian water suppliers, analysing causes of economies of scale, water quality, ownership and customer density. The authors find that economies of scale are most prevalent in smaller water suppliers, with less than 50,000 customers. Population density has a positive effect on efficiency, with cities showing the lowest delivery cost/m^3 of water.

Another study which shows how using different models, even for the same sample and time period, can produce drastically different results, is Abrate, Erbetta and Fraquelli (2008). The authors discuss the decentralization of Italian water supply and its impacts on the efficiency of water suppliers in disparate socio-economic conditions. The authors used cost frontier models (including stochastic frontiers, random and fixed effects) and contrasted this with 'true' fixed and random effects. In the previous model, variations in cost (caused by time-invariant factors) are thought of as inefficiency. In the latter model, time-varying inefficiency errors are used, encompassing the unobserved heterogeneity (resulting from environmental factors) independently. In the cost frontier models, cost efficiency reaches 0.5-0.6, jumping to 0.98 for the true random and true fixed effects models. In other words, once external factors are removed, the SFA revealed that the firms were almost completely efficient. This shows the great difference a difference in methodology can make, even if it is the same sample and time period.

Worthington (2014) further explores this issue, examining different methods of frontier efficiency and estimating water supply productivity across a range of academic papers. The author examines both estimation methodologies and qualitative structural and regulatory causes of inefficiency. The author finds no consensus in the literature, with widely varying methodologies and conclusions, regarding the superiority of either public or privately managed firms. However, the author did find that in developing countries, the public sector was found to be slightly more efficient than the private sector. This concurs with the findings of Hon et. al. (2016) and Bhattacharyya, Harris, Narayanan and Raffiee (1995).

Another paper which compares different methodologies is Filippini, Hrovatin and Zorić (2008). This paper studies cost inefficiency in Slovenian water suppliers from 1997-2003, using stochastic frontiers. The authors find that inefficiency levels and rankings vary with the econometric model used, but overall, there is a lack of robustness. This is partially due to how well the different models distinguish unobserved heterogeneity from inefficiency. The results were robust when applied to economies of scale and economies of output density. The authors maintain that water suppliers exhibit economies of scale at small size, but diseconomies of scale at large size.

Murwirapachena, Mahabir, Mulwa and Dikgang (2019) also use different methodologies to examine the efficiency of 102 South African water suppliers, for the years 2013-2014. They make use of Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA) and Stochastic Non-Parametric Envelopment of Data (StoNED) Analysis. The authors find that StoNED is the more accurate out of the three methodologies, in most conditions.

Estruch-Juan, Cabrera, Molinos-Senante and Maziotis (2020) study 194 water utilities in Portugal, using both DEA and SFA (although only 108 utilities were studied in the SFA). The authors study the main causes of Portugese water utility costs, finding water supply and home connections being the primary causes. Also, NRW had a statistically significant, positive correlation with total costs. Estruch-Juan, Cabrera, Molinos-Senante and Maziotis (2020), along with Murwirapachena, Mahabir, Mulwa and Dikgang (2019), will be studied in depth later on in the chapter. This is done to compare their results to the results of this thesis.

10.3 Stochastic Frontier Methodology

10.3.1 Introduction to Stochastic Frontier Analysis

This section will outline the methodology for this chapter, using a Stochastic Frontier Analysis (SFA) to gauge the efficiency of the Jordanian water sector. The results of this chapter will be compared to the analyses of Jordanian water supply efficiency form previous chapters, which utilized DEA and DID analyses.

Like the DEA chapter, this chapter will use a cost frontier methodology; producers on the frontier are efficient, and those within the frontier are inefficient.

In a cost function, a quantity of goods (Y) is produced using inputs (X) at specific prices (W), and efficiency (θ) is the ratio of the minimum feasible cost to the real cost of supply. Any deviation from the frontier is a result of management inefficiencies. The further the supplier is from the frontier, the more inefficient it is (Leite, Pessanha, Simoes, Calili, & Souza, 2020). A Cobb-Douglas function is used for this section. This function denotes the relationship between two or more inputs (including, but not limited to, capital and labour). A Cobb-Douglas function has the implicit assumption that the cost function is linear with regards to the logs of the variables. Also, an error term is introduced, which has a mean which is not '0' and is not normally distributed (as opposed to other linear regression models) (Leite, Pessanha, Simoes, Calili, & Souza, 2020).

As Leite, Pessanha, Simoes, Calili and Souza (2020) show, in deterministic frontier models, such as cost functions, the distance from the frontier is because of inefficiency. However, these models do not account for the possibility of random shocks beyond the control of the supplier. This is where a stochastic frontier differs from an ordinary cost function. That is, stochastic frontiers account for inefficiencies arising either from within the supplier or from external shocks beyond the supplier's control. Thus, stochastic frontier analysis (SFA) separates the error term into distinct parts. This is why this chapter uses a stochastic frontier instead of a simple cost function, because the error term incorporates both endogenous and exogenous causes of inefficiency. This allows for a greater understanding of the causes of inefficiency in water suppliers.

Cornwell and Schmidt (2008) point out that deterministic frontiers do not take into account the randomness inherent in economic reality. Also, statistical analysis using deterministic frontiers is not always straightforward, and can be somewhat complex.

10.3.2 Developing the Model

Data on the four main water suppliers in Jordan is used, from 2008-2018 (except for Yarmouk Water Company, which was only created in late 2010, and thus the data is for 2011-2018). This section will make use of both cross-sectional data and panel data. The program STATA will be used to model the SFA (STATA, 2017).

The variables to be used include:

- Total Costs; (Dependent Variable) (JD)
- Labour Costs (JD)
- Capital Costs (JD)
- Water Supply (Millions Cubic Meters)
- Number of Homes with Water Connections (NoC)
- NRW

It should be noted that there is no direct method of gauging the size of each supplier. Thus, a proxy will be used, in the form of the number of homes with water connections. All data is gathered from the various water suppliers' websites, and the General Budget Departments' Annual Reports. The following equation is used:

$$Y_{it} = B_0 + f(X_{it};B) + a_i + v_{it} - u_{it} - h_i$$

In the equation above, Y_{it} is the output (logged) for supplier i at time t; B_0 is the intercept; X_{it} are the logged inputs; B is the vector of technology parameters; $f(X_{it}; B)$ is the production technology; a_i is the unobserved effect; v_{it} is the random noise term (representing external shocks); u_{it} is the one-sided transient inefficiency; and h_i is the one-sided persistent inefficiency (Tenaye, 2020).

The error term is broken up as shown below (Tenaye, 2020):

$$E_{it} = a_i + v_{it} - u_{it} - h_i$$

For the equation above, a_i is the unobserved effect; v_{it} implies a random noise term (signifying external shocks); and u_{it} is the one-sided transient inefficiency; and h_i is the one-sided persistent inefficiency (Tenaye, 2020).

10.4 Stochastic Frontier Results

10.4.1 Cross-Sectional Regression Results

This section will use SFA to explore the efficiency of Jordanian water suppliers. As the literature does not specify one SFA model as the 'best,' a wide variety of SFA models will be used and compared. By running several different SFA models, the results can be compared, thus avoiding outliers and presenting a more rigorous solution.

For each of the regressions conducted below STATA was used. Also, all variables are transformed into natural logs (that is, logarithm base *e*). This allows the results to be directly compared to the dependent variable. For example, if an independent variable has a coefficient of 0.08, then an additional unit of that variable will result in an 8% difference in the dependent variable (Cook, 2015).

For the following stochastic frontier, total cost is the dependent variable, and the independent variables are capital costs, labour costs and output. There are four companies, for the years 2008-2018 (except for YWC, which is only 2011-2018, as the company was created in late 2010). This results in 41 observations. This will be a simple cross-sectional regression, wherein a normal/half-normal model is used. 'Normal/half-normal' distribution is a special instance of folded normal distribution, when the sign of the variable is unspecified. This is used when researchers wish to estimate the size of the variable, instead of the direction or sign (Menezes, Mazucheli, Cardoso, & Chakraborty, 2020).

The results are shown below:

Table 33 Cross-Sectional Regression, Total Costs of Water Sector Jordan

```
Stoc. frontier normal/half-normal model          Number of obs     =         41
                                                 Wald chi2(3)      =    1834.33
Log likelihood =  13.648194                      Prob > chi2       =     0.0000
```

ln_tc	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ln_cc	.132343	.0269908	4.90	0.000	.079442	.185244
ln_labor	.0791038	.1266233	0.62	0.532	-.1690734	.327281
ln_output	.8545276	.0941351	9.08	0.000	.6700263	1.039029
_cons	10.81936	1.607498	6.73	0.000	7.668722	13.97
/lnsig2v	-3.929531	.6450819	-6.09	0.000	-5.193868	-2.665194
/lnsig2u	-3.525966	1.250083	-2.82	0.005	-5.976083	-1.07585
sigma_v	.1401887	.0452166			.0745016	.2637913
sigma_u	.1715324	.1072148			.050386	.5839588
sigma2	.0490762	.0266521			-.0031609	.1013134
lambda	1.223582	.1479552			.933595	1.513569

```
LR test of sigma_u=0: chibar2(01) = 0.29               Prob >= chibar2 = 0.296
```

Thus, using a simple cross-sectional regression, all variables, except for labour costs, are statistically significant. As the results above show, for every 1% increase in capital costs, there is a 0.13% increase in total costs, ceteris paribus. Also, for every 1% increase water supplied, there is 0.85% increase in total costs.

10.4.2 Panel-Data Fixed Effect Regressions

The regression performed above was a simple cross-sectional regression. The following regressions will be panel-data, that is across a time-series. This panel data shows the variations of output, capital and labour costs, over time for four different suppliers (rather than a cross-section of 41 observations). In panel data, observations are clustered or correlated by companies. However, in cross-sectional data, the 41 observations are treated as distinct observations, un-correlated. There are multiple advantages to panel data over cross-sectional data. Some of the challenges associated with distributional assumptions in cross-sectional data are not found in panel data. Also, panel data has a large set of data points, as well as being able to split apart the overall effect into individual and time-specific effects (Rashidghalam, Heshmati, Dashti, & Pishbahar, 2016).

Also, these regressions will be fixed effect, which uses dummy variables to control for average variations within the sample including unobservable factors. Thus, the fixed effects remove the differences between samples, leaving only differences within the sample, and therefore reducing omitted variable bias.

The first fixed-effect model will be a time-invariant model. In each of the following regressions, total costs are the dependent variable, and independent variables are capital costs, labour costs and output. It was run with three distributions: first with an exponential distribution, then a half-normal distribution and a normal distribution. In each case, the results were identical, which are shown below:

Table 34 Time-Invariant Fixed Effect Cross-Sectional Regression, Total Costs of Water Sector, Jordan

```
Time-invariant fixed-effects model (LSDV)          Number of obs =        41
Group variable: FirmID                          Number of groups =         4
Time variable: Year                           Obs per group: min =         8
                                                             avg =      10.2
                                                             max =        11
```

ln_tc	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ln_cc	.2527737	.062917	4.02	0.000	.1294587	.3760887
ln_labor	.6913366	.1236606	5.59	0.000	.4489662	.933707
ln_output	-.126242	.104036	-1.21	0.225	-.3301488	.0776648
_cons	3.215981	2.569144	1.25	0.211	-1.819449	8.25141
sigma_u	.52799975					
sigma_v	.15569344					

This fixed effects panel data model, whether run with an exponential distribution, a half-normal distribution or a normal distribution, produced the same results, shown above. As the results show, total costs are correlated with capital costs and labour costs, but not with output. For every 1% increase in capital costs and labour costs, there are respectively 0.25% and 0.69% increases in total costs, ceteris paribus.

It should be noted that another advantage of panel data is that if the inefficiency is time-invariant then such inefficiencies can be calculated with no distributional assumptions (Rashidghalam, Heshmati, Dashti, & Pishbahar, 2016). Thus, the next regression will be a time-invariant model, based on Battese and Coelli (1988). Again, the dependent variable is total costs, and the independent variables are capital costs, labour costs, output, NoC and NRW. Also, dummy variables will be included for specific time periods: 2011 to 2014 (GPDM2); and 2014 to 2018 (GPDM3). These correlate to different time periods in the corporatisation process, with 2014 to 2018 representing a time when eight out of 12 governorates were corporatised. Specifically, GPDM2 and GPDM3 will be compared against the 2008 to 2011 period, representing a time when only Amman and Aqaba were corporatised. This will show how costs evolved as corporatisation progressed.

Table 35 Time-Invariant Fixed Effect Model, Battese and Coelli **(1988)**, Total Costs Water Sector, Jordan

```
Time-invariant model (truncated-normal)           Number of obs =        41
Group variable: FirmID                        Number of groups =         4
Time variable: Year                          Obs per group: min =         8
                                                            avg =      10.2
                                                            max =        11

                                                Prob > chi2   =    0.0000
Log likelihood =    15.3042                     Wald chi2(7)  =     74.58
```

ln_tc	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Frontier						
ln_cc	.422795	.0762216	5.55	0.000	.2734033	.5721867
ln_labor	-.0820796	.2134168	-0.38	0.701	-.5003689	.3362097
ln_output	.5830659	.1475791	3.95	0.000	.2938161	.8723156
ln_NoC	-.0129353	.0613254	-0.21	0.833	-.1331309	.1072603
ln_NRW	.6473731	.291535	2.22	0.026	.075975	1.218771
year_gpdm2	.4259522	.0947117	4.50	0.000	.2403207	.6115837
year_gpdm3	.5739755	.1162317	4.94	0.000	.3461655	.8017854
_cons	7.627983	3.734227	2.04	0.041	.3090318	14.94693

/lnsigma2	1.304558	.2674016	4.88	0.000	.7804601	1.828655
/ilgtgamma	5.179797	.	.	.	.	.
/mu	-13.22944	.	.	.	.	.
sigma2	3.686058	.9856576			2.182476	6.225507
gamma	.9944024	.			.	.
sigma_u2	3.665424	.			.	.
sigma_v2	.0206332	.			.	.

As Table 35 above shows, all variables, with the exception of NoC and labour costs, are statistically significant. For every 1% increase in capital costs, there is a 0.42% increase in total costs, and for every 1% increase in output, there is a 0.58% increase in total costs, ceteris paribus. For every 1% increase in NRW, there is a 0.65% increase in total costs, ceteris paribus. Also, the GPDM2 result shows that, compared to the years 2008-2011 (around the start of the corporatisation process), the years 2011-2014 had 42.6% higher total costs on average, ceteris paribus. The GPDM3 result shows that, compared to the years 2008-2011, the years 2014-2018 had 57.4% higher total costs on average, ceteris paribus. Thus, the longer the corporatisation process proceeded, the more apparent increases in total costs are.

10.4.3 Panel-Data Fixed Effect Time-Varying Regressions

The section above conducted SFAs that were time-invariant. Time-invariant models assume that inefficiency levels may vary across the firms, but not over time. In other words, the underlying assumption is that these firms do not take steps to improve their efficiency in a given time-period. By changing this assumption to account for time-varying inefficiency, the models now allow for the possibility of technical and managerial improvements to efficiency (Rashidghalam, Heshmati, Dashti, & Pishbahar, 2016). Thus, the following model will be a time-varying fixed effects model, based on the work of (Cornwell, Schmidt, & Sickles, 1990).

Table 36 Time-Varying Fixed Effects Model, Total Costs Water Sector, Jordan

```
Time-varying fixed-effects model (CSS Modified-LSDV) Number of obs =        41
Group variable: FirmID                             Number of groups =        4
Time variable: Year                             Obs per group: min =         8
                                                               avg =      10.2
                                                               max =        11
```

ln_tc	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ln_cc	.2606376	.0431765	6.04	0.000	.1760133	.3452619
ln_labor	.6761073	.3296488	2.05	0.040	.0300075	1.322207
ln_output	-.0054791	.1884579	-0.03	0.977	-.3748499	.3638917
sigma_u	.40830649					
sigma_v	.09222207					

As the results above show, capital and labour costs are statistically significant, with a P-Value of less than 0.05, but output is not. For every 1% increase in capital costs, there is a 0.26% increase in total costs, and for every 1% increase in labour costs, there is a 0.68% increase in total costs, ceteris paribus.

The same fixed effect model by Cornwell, Schmidt and Sickles (1990) was run again, but with one difference. For this regression, GPDM2 represents the time period 2011-2014; and GPDM3 represents the time period 2014-2018, both of which are to be compared against 2008-2011, the start of the corporatisation process. These represent the rough stages of water corporatization in Jordan: before 2011, only two states (Amman and Aqaba) were corporatized; in 2011, YWC was created (corporatizing four states' water supplies); and by 2018, there were only four non-corporatized states left. Again, the dependent variable was total cost, and independent variables were capital costs, labour costs and output. The results are shown below:

Table 37 Fixed Effects Model, Cornwell, Schmidt and Sickles **(1990)**, With Time-Periods for Dummy Variables, Total Costs Jordanian Water Sector

```
Time-varying fixed-effects model (CSS Modified-LSDV) Number of obs =        41
Group variable: FirmID                              Number of groups =        4
Time variable: Year                                 Obs per group: min =      8
                                                                  avg =    10.2
                                                                  max =      11
```

ln_tc	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ln_cc	.2286994	.0500102	4.57	0.000	.1306813	.3267176
ln_labor	.7738149	.3611118	2.14	0.032	.0660487	1.481581
ln_output	.1214712	.1960022	0.62	0.535	-.2626861	.5056286
year_gpdm2	.0360647	.0762569	0.47	0.636	-.1133961	.1855255
year_gpdm3	.1766875	.1112993	1.59	0.112	-.0414551	.39483
sigma_u	.35658116					
sigma_v	.08963088					

As the results above show, by separating the years into three distinct groups, both capital and labour costs become significant in the fixed effects model. For every 1% increase in capital costs, total costs increase by 0.23%, and for every 1% increase in labour costs, total costs increase by 0.77%, ceteris paribus. Output is still statistically insignificant.

Normal SFA panel data models do not separate inefficiency from the unit-specific heterogeneity. Such models may only capture the joint effect of inefficiency and heterogeneity, with heterogeneity being mistaken for inefficiency. Therefore, inefficiency estimates may not be as accurate or reliable as previously assumed. In response to this problem, the True Fixed Effects (TFE) Model was developed by Greene W. (2005), cited in (Kutlu, Tran, & Tsionas, 2019). This is a fixed effects model which can separate heterogeneity and the inefficiency effect. That is, heterogeneity is shown through unit-specific dummy variables and inefficiency is shown through a one-sided error term (Kutlu, Tran, & Tsionas, 2019). Thus, the following regression will be a TFE, hopefully being able to separate heterogeneity from inefficiency and shed further light on water efficiency.

In the following regression, the dependent variable is total costs, and the independent variables are capital costs, labour costs, output, NoC and NRW. However, variables will be included for specific time periods: GPDM2 for 2011 to 2014; and GPDM3 for 2014 to 2018 (each compared against costs in 2008-2011).

Table 38 True Fixed Effects Model, Total Costs Jordanian Water Sector, with Time Periods

```
True fixed-effects model (exponential)          Number of obs =        41
Group variable: FirmID                        Number of groups =         4
Time variable: Year                         Obs per group: min =         8
                                                           avg =      10.2
                                                           max =        11

                                                Prob > chi2   =    0.0000
Log likelihood =    12.7076                     Wald chi2(7)  = 192333.24
```

ln_tc	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Frontier						
ln_cc	.4565571	.0645397	7.07	0.000	.3300617	.5830525
ln_labor	.3093582	.2081231	1.49	0.137	-.0985557	.717272
ln_output	.7005581	.2077302	3.37	0.001	.2934144	1.107702
ln_NRW	.9136374	.3277913	2.79	0.005	.2711782	1.556097
ln_NoC	-.1397717	.2157027	-0.65	0.517	-.5625413	.2829978
year_gpdm2	.3523888	.1073131	3.28	0.001	.1420589	.5627186
year_gpdm3	.4472371	.1125069	3.98	0.000	.2267276	.6677466
Usigma						
_cons	-3.195598	.	.	.	.	.
Vsigma						
_cons	-5.345959	.8539741	-6.26	0.000	-7.019718	-3.672201
sigma_u	.2023414	.	.	.	.	.
sigma_v	.0690462	.0294818	2.34	0.019	.0299011	.159438
lambda	2.930522	.	.	.	.	.

As Table 38 above shows, all variables, with the exception of NoC and labour costs, are statistically significant. For every 1% increase in capital costs, there is a 0.46% increase in total costs, ceteris paribus. For every 1% increase in output, there is a 0.7% increase in total costs, ceteris paribus. Also, for every 1% increase in NRW, total costs increase by 0.91%. The GDMP2 variable shows that the years 2011-2014 saw 35.2% more total costs than 2008-2011. Also, for the years 2014-2018, there were 44.7% more total costs than 2008-2011.

10.4.4 Random Effects Panel Data Regressions

Having explored the various aspects of SFAs, using Fixed Effects Models, this section now turns to Random Effects (RE) Panel Data SFAs. Unlike in Fixed Effects, RE Models have unit-specific effects whereby there is no correlation between random variables and explanatory variables (Schmidheiny, 2020). This will be explored in this section.

The following regression is also a stochastic frontier, time varying parametric model (half-normal), based on (Kumbhakar, 1990). This model was chosen because it relaxes the assumptions of time-varying efficiency, and it is conducted as a random effects model.

In the following regression, the dependent variable is total costs, and independent variables are: capital costs, labour costs, output, NRW and NoC. The results are shown below:

Table 39 Random-Effects, Time-Varying Parametric Model, Kumbhakar **(1990)**, Total Costs Jordanian Water Sector

```
Time-varying parametric model (half-normal)        Number of obs =        41
Group variable: FirmID                          Number of groups =         4
Time variable: Year                           Obs per group: min =         8
                                                             avg =      10.2
                                                             max =        11

                                                   Prob > chi2   =    0.0000
Log likelihood =    17.3046                        Wald chi2(5)  =    240.94
```

ln_tc	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Frontier						
ln_cc	.3191968	.0435507	7.33	0.000	.233839	.4045546
ln_labor	.5196012	.1261415	4.12	0.000	.2723684	.7668341
ln_output	.3169281	.0936772	3.38	0.001	.1333242	.5005319
ln_NoC	.0634769	.0499842	1.27	0.204	-.0344903	.1614441
ln_NRW	.9007787	.2732094	3.30	0.001	.3652981	1.436259
_cons	-.4955498	1.780697	-0.28	0.781	-3.985653	2.994553
Bt						
b	.3577515	.0966393	3.70	0.000	.1683419	.5471611
c	-.0222274	.007123	-3.12	0.002	-.0361883	-.0082665
/sigmau_2	9.803172	7.477864	1.31	0.190	-4.853172	24.45952
/sigmav_2	.0159396	.0037431	4.26	0.000	.0086033	.0232759
sigma_u	3.131002	1.194165	2.62	0.009	4.945656	.
sigma_v	.1262521	.0148238	8.52	0.000	.0927541	.1525643
lambda	24.7996	1.193967	20.77	0.000	22.45946	27.13973

As Table 39 above shows, most variables are statistically significant with P-Values below 0.05, with the exception of NoC. For every 1% increase in capital costs and labour costs, there is respectively a 0.32% and 0.52% increase in total costs, ceteris paribus. For every 1% increase in output, there is a 0.32% increase in total costs, and for every 1% increase in NRW, there is a 0.9% increase in total costs.

In the following regression, a stochastic frontier using panel data is performed. This will be a time-varying decay model (truncated-normal), based on the work of Battese and Coeli (1992), which introduces the time-decay inefficiency component. This proposes that over time, suppliers understand the sources of their inefficiencies, and therefore implement technology and best practices to maximise efficiency (Lavado & Barrios, 2010).

Again, the dependent variable is total costs, and the independent variables are capital costs, labour costs, output, NoC and NRW. Also, variables will be included for specific time periods: GPDM2 for 2011 to 2014; and GPDM3 for 2014 to 2018 (each compared against costs in 2008-2011).

Table 40 Time-Varying Decay Model, Random-Effects, Battese and Coelli **(1992)**, Total Costs Jordanian Water Sector

```
Time-varying decay model (truncated-normal)        Number of obs    =        41
Group variable: FirmID                          Number of groups    =         4
Time variable: Year                           Obs per group: min    =         8
                                                             avg    =      10.2
                                                             max    =        11

                                                   Prob > chi2      =    0.0000
Log likelihood =     7.6840                        Wald chi2(7)     =    879.41
```

ln_tc	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Frontier						
ln_cc	.4378872	.056678	7.73	0.000	.3268005	.548974
ln_labor	.2815564	.2662585	1.06	0.290	-.2403007	.8034135
ln_output	.791956	.1127957	7.02	0.000	.5708805	1.013031
ln_NoC	-.2337366	.0431274	-5.42	0.000	-.3182648	-.1492084
ln_NRW	.8233503	.3559063	2.31	0.021	.1257867	1.520914
year_gpdm2	.1936386	.1405943	1.38	0.168	-.0819213	.4691984
year_gpdm3	.3401174	.1724719	1.97	0.049	.0020786	.6781561
_cons	2.742825	2.896999	0.95	0.344	-2.935189	8.420839

/lnsigma2	-3.300884	1.165573	-2.83	0.005	-5.585366	-1.016402
/ilgtgamma	-2.761903	19.50658	-0.14	0.887	-40.9941	35.47029
/mu	-.2407141	4.984566	-0.05	0.961	-10.01028	9.528855
/eta	.3897402	.154731	2.52	0.012	.0864731	.6930074
sigma2	.0368506	.0429521			.0037524	.3618947
gamma	.0594179	1.090172			1.57e-18	1
sigma_u2	.0021896	.0426782			-.0814582	.0858374
sigma_v2	.034661	.0080055			.0189705	.0503515

As Table 40 above shows, all variables, with the exception of labour costs and the variable for the years 2011-2014, are statistically significant. For every 1% increase in capital costs, there is a 0.44% increase in total costs, ceteris paribus. For every 1% increase in output, there is a 0.79% increase in total costs; also, for every 1% increase in NoC, there is a 0.23% drop in total costs, ceteris paribus. It should be noted that this time, NoC is statistically significant, a change from the preceding regressions. Additionally, for every 1% increase in NRW, total costs increase by 0.82%, ceteris paribus. The variable GPDM3 for the year group 2014-2018 is statistically significant (although just on the border, with a P-Value of 0.049). Total costs were 34% higher during this period over the 2008-2011 period, when corporatisation was taking off.

In the following regression, a stochastic frontier using panel data is performed. This will be an inefficiency effects model (truncated-normal), based on the work of Battese & Coelli (1995). Building on their 1992 work, Battese and Coelli (1995) argue that inefficiency is primarily a result of exogenous factors, and apply the maximum likelihood technique (Lavado and Barrios 2010).

Again, the dependent variable is total costs, and the independent variables are capital costs, labour costs, output, NoC and NRW. However, variables will be included for specific time periods: GPDM2 for 2011 to 2014; and GPDM3 for 2014 to 2018 (each compared against costs in 2008-2011).

Table 41 Inefficiency Effects Model, Random-Effects, Battese and Coelli **(1995)**, with Time-Period Dummy Variables

```
Inefficiency effects model (truncated-normal)       Number of obs    =        41
Group variable: FirmID                            Number of groups   =         4
Time variable: Year                               Obs per group: min =         8
                                                                 avg =      10.2
                                                                 max =        11

                                                  Prob > chi2      =    0.0000
Log likelihood =    11.1813                       Wald chi2(7)     =  1.20e+08
```

ln_tc	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Frontier						
ln_cc	.4684811	.0065809	71.19	0.000	.4555828	.4813794
ln_labor	.338289	.0027196	124.39	0.000	.3329587	.3436194
ln_output	.8304995	.015608	53.21	0.000	.7999085	.8610906
ln_NRW	.6149065	.0223428	27.52	0.000	.5711155	.6586976
ln_NoC	-.2439741	.0089696	-27.20	0.000	-.2615542	-.2263941
year_gpdm2	.5212957	.0052956	98.44	0.000	.5109166	.5316749
year_gpdm3	.4396509	.0054634	80.47	0.000	.4289427	.450359
_cons	2.081035	.	.	.	.	.
Mu						
_cons	-2.453187	2.659211	-0.92	0.356	-7.665144	2.75877
Usigma						
_cons	-.1692934	.9028216	-0.19	0.851	-1.938791	1.600204
Vsigma						
_cons	-16.76577	6.030805	-2.78	0.005	-28.58593	-4.945606
sigma_u	.9188368	.4147729	2.22	0.027	.3793122	2.225768
sigma_v	.0002287	.0006898	0.33	0.740	6.20e-07	.0843481
lambda	4016.784	.41478	9684.13	0.000	4015.971	4017.597

As Table 41 above shows, all variables are statistically significant. For every 1% increase in capital costs and labour costs, there is respectively a 0.47% and 0.34% increase in total costs, ceteris paribus. For every 1% increase in output, there is a 0.83% increase in total costs; for every 1% increase in NRW, there is a 0.61% increase in total costs; and for every 1% increase in NoC, a 0.24% drop in total costs, ceteris paribus. Compared to the years 2008-2011, 2011-2014 showed 52.1% greater total costs, and 2014-2018 showed 44% greater total costs.

In the following regression, a true random-effects model (exponential) is used, based on the work of Greene (2005). A 'true' random effects SFA can examine time-varying inefficiencies and separate them from (unobserved) time-invariant heterogeneity (Hailu & Tanaka, 2015). Again, the dependent variable is total costs, and independent variables are: capital costs, labour costs, output, NRW and NoC. The results are shown below:

Table 42 True Random-Effects Model Greene **(2005)**, Total Costs Jordanian Water Sector

```
True random-effects model (exponential)          Number of obs =         41
Group variable: FirmID                        Number of groups =          4
Time variable: Year                        Obs per group: min =           8
                                                          avg =        10.2
                                                          max =          11

                                                Prob > chi2    =     0.0000
Log simulated-likelihood =    -0.0788           Wald chi2(5)   =    2925.27

Number of Pseudo Random Draws = 250
```

ln_tc	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Frontier						
ln_cc	.3390184	.0323719	10.47	0.000	.2755707	.4024661
ln_labor	.9814268	.1046854	9.38	0.000	.7762471	1.186606
ln_output	.6082728	.0761232	7.99	0.000	.459074	.7574716
ln_NoC	-.3192123	.0475459	-6.71	0.000	-.4124005	-.2260241
ln_NRW	.607983	.360819	1.69	0.092	-.0992092	1.315175
_cons	-3.902391	.9295663	-4.20	0.000	-5.724307	-2.080474
Usigma						
_cons	-2.302394	.3662198	-6.29	0.000	-3.020172	-1.584616

Vsigma						
_cons	-5.774908	.9510016	-6.07	0.000	-7.638837	-3.910979
Theta						
_cons	.0009909	.0310004	0.03	0.975	-.0597688	.0617506
sigma_u	.316258	.05791	5.46	0.000	.220891	.4527984
sigma_v	.0557179	.0264939	2.10	0.035	.0219406	.1414952
lambda	5.676057	.0712558	79.66	0.000	5.536398	5.815716

As Table 42 above shows, all variables, with the exception of NRW, are statistically significant. For every 1% increase in capital costs and labour costs, there is respectively a 0.34% and 0.98% increase in total costs, ceteris paribus. For every 1% increase in output, there is 0.61% increase in total costs, and for every 1% increase in NoC, there is a 0.32% drop in total costs, ceteris paribus.

The final regression in this section is a GLS random effects model. GLS is used instead of OLS in order to account for the possibility of heteroscedasticity or correlation between residuals in the model (Taboga, 2017).

In the following regression, a time-invariant random-effects GLS model is used. Again, the dependent variable is total costs, and independent variables are: capital costs, labour costs, output, NRW and NoC. However, variables will be included for specific time periods: GPDM2 for 2011 to 2014; and GPDM3 for 2014 to 2018 (each compared against costs in 2008-2011). The results are shown below:

Table 43 Generalised Least Squares Regression, Total Costs of the Jordanian Water Sector

```
Time-invariant Random-effects model (FGLS)          Number of obs =         41
Group variable: FirmID                            Number of groups =          4
Time variable: Year                              Obs per group: min =          8
                                                               avg =       10.2
                                                               max =         11
```

ln_tc	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ln_cc	.4717405	.0665881	7.08	0.000	.3412303	.6022507
ln_labor	-.0913435	.2503358	-0.36	0.715	-.5819926	.3993056
ln_output	.8574698	.1273964	6.73	0.000	.6077774	1.107162
ln_NRW	.6535533	.4477955	1.46	0.144	-.2241097	1.531216
ln_NoC	-.1563064	.0429896	-3.64	0.000	-.2405645	-.0720482
year_gpdm2	.4585633	.1418415	3.23	0.001	.180559	.7365676
year_gpdm3	.6571692	.1598241	4.11	0.000	.3439197	.9704186
_cons	7.281749	2.420795	3.01	0.003	2.537078	12.02642
sigma_u	0					
sigma_v	.13069366					

As Table 43 above shows, all variables, with the exception of labour costs and NRW, are statistically significant. For every 1% increase in capital costs, total costs increase by 0.47%; for every 1% increase in output, total costs increase by 0.86%; and for every 1% increase in NoC, total costs drop by 0.16%, ceteris paribus. Also, 2011-2014 saw 45.9% more costs than the years 2008-2011, and 2014-2018 saw 65.7% more costs than the years 2008-2011, ceteris paribus.

10.4.5 Summary of Panel-Data Regression Results

In summary, capital costs are statistically significant across most the panel-data regressions discussed in this section (both fixed effects and random effects). Labour costs, however, are not statistically significant in some of the fixed-effect regressions, but are in most of the random-effect regressions. Finally, output is statistically significant in some of the random-effects models, but only two of the fixed effects models. Table 44 below summarizes the results of the different stochastic frontiers, with the

Coefficient of each variable listed; all statistically significant variables are in bold.

Table 44 Summary of SFA Coefficients, with Total Costs as Dependent Variable

	Capital Costs	Labour Costs	Output	NRW	NoC	GDMP 2	GDMP 3	Cons
Cross-Sectional Regression	**0.332**	**0.623**	**0.421**	N/A	N/A	N/A	N/A	**1.026**
Time-Invariant Fixed Effect Cross-Sectional Regression	**0.253**	**0.691**	-0.126	N/A	N/A	N/A	N/A	3.22
Time-Invariant Fixed Effect Model, Battese and Coelli (1988)	**0.423**	-0.082	**0.583**	**0.647**	-0.013	**0.426**	**0.574**	**7.63**
Time-Varying Fixed Effects Model, based on work of Cornwell, Schmidt and Sickles (1990), Total Costs Water Sector, Jordan	**0.26**	**0.676**	-0.005	N/A	N/A	N/A	N/A	N/A
Fixed Effects Model, Cornwell, Schmidt and Sickles (1990), With Time-Periods for Dummy Variables, Total Costs Jordanian Water Sector	**0.229**	**0.774**	0.121	N/A	N/A	0.036	0.177	N/A
True Fixed Effects Model, Total Costs Jordanian Water Sector, with Time Periods	**0.457**	0.309	**0.701**	**0.914**	-0.134	**0.352**	**0.447**	N/A
Random-Effects, Time-Varying Parametric Model, Kumbhakar (1990), Total Costs Jordanian Water Sector	**0.319**	**0.52**	0.317	**0.901**	0.063	N/A	N/A	-0.496
Time-Varying Decay Model, Random-Effects, Battese and Coelli (1992), Total Costs Jordanian Water Sector	**0.438**	0.282	**0.792**	**0.823**	**-0.234**	0.194	**0.34**	2.74
Inefficiency Effects Model, Random-Effects, Battese and Coelli (1995), with Time-Period Dummy Variables	**0.468**	**0.338**	**0.83**	**0.615**	**-0.244**	**0.521**	**0.44**	2.08

True Random-Effects Model, Total Costs Jordanian Water Sector	**0.339**	**0.981**	**0.608**	0.608	**-0.319**	N/A	N/A	**-3.9**
Generalised Least Squares Regression	**0.472**	-0.913	**0.857**	0.653	**-0.156**	**0.459**	**0.657**	**7.28**

As Table 44 above shows, in most cases, there is a positive relationship between output and total costs, except for the Time-Invariant Fixed Effect Cross-Sectional Regression (which was statistically insignificant). There was also a positive relationship between NRW and total costs, and a mostly negative relationship between NoC and total costs (this will be explored below). The year groupings showed a positive relationship, implying that the years 2011-2014 and 2014-2018 showed increased total costs, compared to the years 2008-2011. This shows that the years of corporatisation did in fact result in increased costs, relative to 2008-2011, when the corporatisation process was just beginning.

Regarding the statistically significant relationship between output and total costs, these ranged from 0.583-0.701, whereas random effects ranged from 0.608-0.83. Thus, the random effects model gives a wider range, and overall higher values than fixed effects. Regarding NRW, the statistically significant fixed effects SFAs ranged from 0.647-0.914, whereas random effects ranged from 0.615-0.901, a wider range and lower results. Thus, the random effects method found that NRW had a lower impact on total costs. Regarding NoC, there were no statistically significant fixed effects results, and for random effects, the statistically significant results ranged from -0.234 to -0.244. For GDMP2, the fixed effect statistically significant range was 0.352-0.426 and the random effects was 0.521. For GDMP3, the fixed effect statistically significant range was 0.447-0.574 and the random effects range was 0.34-0.44. This shows that fixed effects picked up higher costs in GDMP2 (2011-2014), but random effect picked up higher costs in GDMP3 (2014-2018).

10.5 Analysis

As the results above show, total costs are primarily correlated with capital, and less so with labour costs. Thus, capital costs are the most important component of the cost structure of water suppliers in Jordan. Also, output is statistically significant in the random-effects models, but not in the fixed effects models. Thus, the relationship between total costs and output is not as clear-cut as previously thought. That is, one would assume a positive, statistically significant relationship between output and total costs. However, if the relationship between total costs and output is not statistically significant, then it implies that costs can grow independent of output.

In most cases, there was a statistically significant relationship between costs and the number of home connections, albeit a negative relationship. That is, as more users are connected, then average costs (cost per user) declines. This result possibly indicates that connecting homes to the water supply network benefits from economies of scale, with decreasing cost per home connection.

In order to confirm this, new regressions were run, this time with the number of home connections as the dependent variable, as shown below. All statistically significant results are in bold.

Table 45 Summary of SFA Coefficients, with Number of Water Connections as Dependent Variables

	Fixed Effects (Exponential Distribution)	PL81	BC88	BC92	REGLS
TC	-0.052	-0.112	-0.261	**-1.84**	**-1.33**
CC	0.001	0.061	0.054	**0.82**	0.242
LC	0.861	**1.01**	**1.05**	**2.17**	**2.53**
Output	**-0.611**	**-0.576**	**-0.635**	**1.44**	**0.949**
NRW	-1.06	-0.864	-0.925	**2.02**	1.5

Cons	5.95	4.78	7.15	**-15.8**	**-17.7**

As Table 45 above shows, the Battese and Coelli (1992) model offers the most statistically significant results. In the Battese and Coelli (1992) and the Random Effects GLS SFA, total costs are statistically significant, and have a negative relationship with NoC.

As the results above show, as the number of homes connected to water increases, total costs decrease. This further supports the idea that increasing the number of homes connected to water benefits from economies of scale. Some studies state that adding home connections results in decreasing cost per connection, especially in urban areas with many connections/km^2 (Nauges & Van Den Berg, 2009); (Wenban-Smith, 2009). Other studies find that economies of scale exist only up to a certain point, after which decreasing returns or diseconomies of scale set in (Ferro, Lentini, & Mercadier, 2011); (Saal, Arocena, & Maziotis, 2013).

Also, there was a statistically significant relationship between NoC and NRW, (just as there was between total costs and NRW). Thus, the more NRW there is, the greater the impacts on costs, and the greater the number of home connections there are. This implies that NRW not only increases total costs, but that it increases with the number of homes connected.

10.6 Analysis of Efficiency

This chapter has so far analysed many factors affecting the efficiency of water suppliers in Jordan, but has not yet distinguished the efficiency of each water supplier. Thus, this section will analyse the efficiency of the individual suppliers.

10.6.1 Predictions and Efficiency

The 'Predict' function in Stata offers fitted values for the model (UCLA, N.D.). Fitted values are based on the mean response value of inputs (Frost, N.D.). By using the 'Predict' function, one can obtain the average technical efficiency of each firm, in this case using a half-normal true fixed effects model, as shown below:

Table 46 Predicted Efficiency for Each Water Supplier in Jordan

```
Summary for variables: tfehalf_inefficiency_hn
     by categories of: Firm (Firm)

     Firm |       mean
----------+----------
      AWC |  .4619538
 Miyahuna |  .6391623
      WAJ |  .5888544
      YWC |  .2647816
----------+----------
    Total |  .5050708
---------------------
```

As the results above show, Miyahuna has the highest average technical efficiency, followed by WAJ, with YWC as the least technically efficient firm. With a mean of 0.505, AWC and YWC are below the mean, at 0.462 and 0.265 respectively.

10.6.2 Separating Inefficiency from Random Noise

Having discussed the efficiency of each firm, one can now examine the causes of the inefficiency. That is, are the inefficiencies due to issues of technical efficiency, or random external shocks? With a fixed effect model, one can differentiate the u_{it} and v_{it}. This allows one to separate the technical efficiency from random or unobserved errors. In other words, one can separate inefficiencies due to external (exogenous) shocks or the supplier's own inefficiencies. This can be done through a correlation analysis, in order to understand whether technical efficiency is highly correlated with the supplier's factors (in this case output, TC, CC and LC). The results are shown below:

Table 47 Correlation Analysis, Technical Efficiency with Multiple Variables

. corr bc_efficiency ln_tc ln_cc ln_labor ln_output (obs=41)

	bc_efficiency	ln_tc	ln_cc	ln_labor	ln_output
bc_efficiency	1.0000				
ln_tc	0.5406	1.0000			
ln_cc	0.2822	0.9396	1.0000		
ln_labor	0.4336	0.9182	0.8772	1.0000	
ln_output	0.8035	0.5561	0.3781	0.5670	1.0000

As Table 47 above shows, technical efficiency is highly correlated with the supplier's output, at 0.8035, so the observed inefficiencies are mostly a result of the supplier's own structural issues. Thus, external shocks can be ruled out as a main cause of inefficiency in Jordanian water supply.

10.6.3 Results Compared to the Literature

Having examined the efficiency of the water sector, both as a whole and between suppliers, this section will compare these results to that of the literature. By comparing different studies to this chapter's results, and exploring the differences therein, one's understanding of efficiency in water can be enhanced.

This section compares the results of the chapter to three studies: Estruch-Juan, Cabrera, Molinos-Senante and Maziotis (2020); Bonifaz and Itakura (2014); and Murwirapachena, Mahabir, Mulwa and Dikgang (2019). These three studies are discussed previously in the 'Literature Review' Section 10.2 of this chapter.

It is instructive to begin with studies which mostly concur with this chapter's results. Estruch-Juan, Cabrera, Molinos-Senante and Maziotis (2020), in their study of 194 water utilities in Portugal (although 108 utilities were used for the SFA), analyse the major cost drivers of water utilities. They find that the major driver of costs in these utilities is the amount of water being supplied, and then the number of home connections.

Also, the authors find that NRW had a statistically significant impact on total costs. These results concur with the findings of this chapter, with the amount of water supplied being one of the main driver of costs, and depending on the model, followed by NRW. The main difference is that, in my SFA, there is a negative relationship between total costs and the number of connections. Otherwise, the results of Estruch-Juan, Cabrera, Molinos-Senante and Maziotis (2020) were similar to the results of my chapter, even though Portugal is a developed country, with no severe water shortages. However, even studies of developing countries offer similar findings to the results of this chapter. Many of the findings regarding the water sector in developed countries are not dissimilar to the findings of developing countries.

This is the case with Bonifaz and Itakura (2014). The authors, using a stochastic frontier to 12 Latin American analyse water utilities, find that the number of connections is positively correlated with costs. Again, this differs with the findings in my chapter, which shows a negative, statistically significant relationship between the number of connections and costs. Another area where their findings differ is that the authors maintain that publicly owned and managed firms show greater efficiency, whereas my chapter maintains that a corporatised firm (Miyahuna) is the most efficient firm.

Having discussed studies with outcomes similar to the results of my chapter, it is worth examining studies whose results diverge from those of this chapter. Murwirapachena, Mahabir, Mulwa and Dikgang (2019) offer a detailed examination of the efficiency of 102 water utilities in South Africa, using DEA, SFA and StoNED techniques. This study is one of the first to apply three different econometric techniques (parametric and non-parametric) to the water sector, and it is a robust analysis of water efficiency. Furthermore, the methodology of this study is similar to my own (though I use DID analysis instead of StoNED). Thus, an in-depth comparison of this paper and my results may highlight noteworthy differences in the study of water efficiency.

Murwirapachena, Mahabir, Mulwa and Dikgang (2019) found that, using SFA, half of their sample reported efficiency scores above the mean. Using DEA, only 37% of suppliers reported scores above the mean. In other words, SFA resulted in a greater number of firms showing at least average efficiency. However, in my DEA chapter, it was the DEA results which showed higher levels of efficiency, rather than SFA (a mean of 0.9025 against a mean of 0.505 respectively).

Another finding of note is that using SFA, the larger companies are more efficient (Miyahuna and WAJ are more efficient than AWC and YWC). Using DEA, it was WAJ and YWC which were the most efficient, with Miyahuna being only the third most efficient, and AWC being least efficient. Murwirapachena, Mahabir, Mulwa and Dikgang (2019) stated that SFA found large utilities as more efficient, while DEA found small utilities as more efficient. The findings of this thesis confirm Murwirapachena, Mahabir, Mulwa and Dikgang (2019) in that SFA finds larger firms more efficient, but it does not confirm that DEA finds smaller firms more efficient (WAJ is a large firm, but YWC is not).

Finally, Murwirapachena, Mahabir, Mulwa and Dikgang (2019) argue that StoNED is the best method for analyzing water efficiency in heterogeneous cases, followed by SFA and DEA. The authors maintain that when there is a highly heterogeneous sample, DEA is the least suitable method. My findings also support the idea that SFA is better than DEA for analyzing water supply efficiency. This is because DEA offers an overly optimistic view of Jordanian water efficiency as opposed to SFA (0.9025 against 0.505 respectively). This may indeed be due to the heterogeneity of the Jordanian water supply sector. Even though there are only four suppliers, there are significant differences in terms of size and efficiency (as shown in this and previous chapters).

10.6.4 Limitations of the Chapter

The limitations of this chapter included the fact that few variables are used. That is, the independent variables amounted to capital costs, labour costs, output, NRW, NoC and the year groupings. Also, a limited data-set was used, with only four suppliers, and a ten-year period, from 2008-2018; having more years would have increased the sample size.

10.7 Conclusion

This Chapter used SFA to gauge the cost effectiveness of the Jordanian water sector. This chapter shows that depending on which model is used, there is a statistically significant relationship between total costs and NRW. Also, there is a statistically significant relationship between total costs and Number of Connections, but it is a negative relationship. That is, as the NoC increases, total costs actually decrease. Regarding the relationship between total costs and output, there is a statistically significant relationship mainly in the random-effects models. Most of the fixed-effects models did not show a statistically significant relationship between total costs and outputs.

The period of corporatisation (roughly 2011 to 2018) saw significant increases in total costs, compared to 2008-2011. Also, the inefficiencies found in this study are largely a result of the firm inefficiencies themselves, as opposed to exogenous factors. Additionally, the chapter finds Miyahuna and WAJ as the most cost efficient water suppliers.

11. Comparison of Results Across the Chapters

This chapter will compare the results across the three chapters. In doing so, and examining the differences in efficiencies across the chapters, an overall picture of efficiency can be created. This will also shed light on the use of the three methods, especially if results diverge. In order for a comparison to be made, the results of the three empirical chapters will first be summarised.

11.1 Data Envelopment Analysis

This section details the results of the chapter using Data Envelopment Analysis (DEA) methods. Table 48 below compares the average efficiency of corporatised firms against the state-run supplier, under terms of CRS and VRS.

Table 48 DEA Results, Constant and Variable Returns to Scale, Comparing Corporatised vs State-Run Firms

	Constant Returns to Scale		**Variable Returns to Scale**	
	Corporatised Efficiency (Average) (%)	**State Owned Efficiency (WAJ) (%)**	**Corporatised Efficiency (Average) (%)**	**State Owned Efficiency WAJ (%)**
2011	95.0	100.0	99.0	100.0
2012	89.7	97.8	93.0	100.0
2013	92.2	98.0	94.7	100.0
2014	62.2	38.0	73.0	90.0
2015	91.7	100.0	98.3	100.0
2016	68.2	90.9	77.3	98.0
2017	85.6	90.5	97.0	100.0
2018	86.5	77.5	96.7	100.0

As Table 48 above shows, under both conditions of CRS and VRS, the state-run utility usually showed greater levels of efficiency than the corporatised firms.

Using CRS, water suppliers were considered to be 100% efficient six times between 2011 to 2018, as opposed to fifteen times using VRS. This raises some questions as to whether the corporatised firms had some success in exploiting economies of scale. Should economies of scale exist, then conditions of CRS are biased towards larger DMUs; that is, smaller DMUs will seem more inefficient. However, under conditions of VRS (and economies of scale), smaller DMUs appear to be more efficient (Harton, 2010). In the results shown above, under conditions of CRS, the smallest DMU, the AWC, was inefficient, whereas the WAJ and Miyahuna both showed high levels of efficiency. Under conditions of VRS, the largest organisation, WAJ, was the most consistently efficient. Thus, it appears that the DMUs do exploit economies of scale under conditions of CRS, but not under conditions of VRS.

Dividing the CRS over VRS shows each firm's 'scale efficiency.' The more the scale efficiency, the more that a firm can cut costs, while maintaining output levels. This is shown in Table 49 below:

Table 49 Scale Efficiencies of the Main Water Providers in Jordan, 2011-2018

	Miyahuna	**AWC**	**YWC**	**WAJ**
2011	0.89	0.99	1.00	1.00
2012	0.94	0.96	1.00	0.98
2013	0.99	0.96	0.98	0.98
2014	0.84	0.70	0.99	0.42
2015	1.00	0.84	0.96	1.00
2016	0.83	0.81	0.97	0.93
2017	0.97	0.68	1.00	0.91
2018	1.00	0.67	1.00	0.78

Average Scale Efficiency, 2011 to 2018	0.93	0.82	0.99	0.87

As Table 49 above shows, AWC has the biggest potential for decreasing its inputs (18%) while keeping its output the same. Miyahuna can do the same at 7%, and WAJ at 13%. YWC has little room to improve its inputs while maintaining output.

Having discussed scale efficiency, it is instructive to investigate efficiency in practical terms. That is, how much is inefficiency costing the firm in real terms? This is shown in Table 50 below:

Table 50 Financial Costs of Inefficiency, per Water Supplier

	Miyahuna	**AWC**	**YWC**	**WAJ**
CAPEX, USD	-3,948,958	-670,966	-894,906	-32,050,391
OPEX, USD	-24,980,949	-3,685,890	3,787,451	-31,884,290
Water Volume, M³	-	-	3	-
Population Served, Households	2,311,271	511,877	314,889	1,532,193

As Table 50 above shows, should each company have been operating at peak efficiency (compared to the other companies), there would have been no significant improvement in water supply. However, there would have been reductions in both capital and operating costs across the board. Finally, operating at peak efficiency would have increased the number of households with water connections by: almost 315,000 homes for YWC; almost 512,000 homes for AWC; 1.5 million homes for WAJ and 2.3 million homes for Miyahuna.

Thus, corporatisation can be seen to have significantly improved efficiency, but there is still significant room for improvement. This is particularly true in terms of costs and the number of homes with a water connection. However, corporatisation is unlikely to increase the supply of water substantially.

11.2 Difference-in-Difference Analysis

This DID analysis chapter, as opposed to examining the performance of the water utilities, focused on the performance of Jordanian governorates. Specifically, it examines the performance of those governorates which corporatised their water utilities, against those which did not.

This chapter, using a simple DID regression, found that corporatisation increased Jordanian water supply by 9 million cubic meters of water. When a variable signifying the interaction between time and treatment was added, it was found that corporatisation increased water supply by 18 million cubic meters. Using a Random Effects Generalised Least Squares (GLS) regression, corporatisation increased supply by 8.9 million cubic meters of water. By splitting the data into 'pre' and 'post' implementation periods, corporatisation increased water supply by 7.9-32 million cubic meters, depending on the governorate.

After the analyses involving all governorates, DID regressions were done examining specific governorates. That is, these DID regressions examined four governorates each, two from governorates that had corporatised and two that had not yet corporatised. The first DID regression examined Madaba and Irbid versus Zarqa and Balqa: corporatisation brought to Madaba and Irbid (compared to Zarqa and Balqa) 32-34.9 million more cubic meters of water. However, Madaba's water supply actually decreased slightly after corporatisation. The increased supply from Irbid offset the drop in Madaba's supply. The second DID regression analysed Mafraq and Irbid versus Tafileh and Balqa: corporatisation increased the water supply of the treated group (Mafraq and Irbid) over the control group (Tafileh and Balqa), by over two million cubic meters.

The findings of this chapter concur with those of the DEA chapter. That chapter, examining the water supplying companies, instead of the governorates, also found that corporatisation did not increase water supply, overall. However, when looking at certain governorates, specifically those with parallel trends, corporatisation did improve supply. Specifically, Ajloun, Balqa, Irbid, Karak, Ma'an and Mafraq all showed improved water supplies, with corporatisation. In another regression, Madaba and Irbid (treatment group) versus Balqa and Zarqa (control group) also showed a positive relationship between corporatisation and water supply. Thus, it appears that there is a relationship between corporatisation and water supply in the *poorer* governorates. It appears that corporatisation did not significantly improve water supply in the country's largest and most prosperous governorate, Amman, or the second largest governorate, Zarqa.

11.3 Stochastic Frontier Analysis

This section discusses the Stochastic Frontier Analysis Chapter. This chapter used SFA to measure how a set of variables impacted the total costs, water supply and the number of homes connected, of the four main Jordanian water utilities. The results are discussed below.

11.3.1 Summary of Panel-Data Regression Results

In summary, capital costs are statistically significant across most the panel-data regressions discussed in this section (both fixed effects and random effects). Labour costs, however, are not statistically significant in some of the fixed-effect regressions, but are in the random-effect regressions. Finally, output is statistically significant in some of the random-effects models, but only two of the fixed effects models. Table 51 below summarizes the results of the different stochastic frontiers, with the

Coefficient of each variable listed; all statistically significant variables are in bold.

Table 51 Summary of SFA Coefficients, with Total Costs as Dependent Variable

	Capital Costs	Labour Costs	Output	NRW	NoC	GDMP 2	GDMP 3	Cons
Cross-Sectional Regression	**0.332**	**0.623**	**0.421**	N/A	N/A	N/A	N/A	**1.026**
Time-Invariant Fixed Effect Cross-Sectional Regression	**0.253**	**0.691**	-0.126	N/A	N/A	N/A	N/A	3.22
Time-Invariant Fixed Effect Model, Battese and Coelli (1988)	**0.423**	-0.082	**0.583**	**0.647**	-0.013	**0.426**	**0.574**	**7.63**
Time-Varying Fixed Effects Model, based on work of Cornwell, Schmidt and Sickles (1990), Total Costs Water Sector, Jordan	**0.26**	**0.676**	-0.005	N/A	N/A	N/A	N/A	N/A
Fixed Effects Model, Cornwell, Schmidt and Sickles (1990), With Time-Periods for Dummy Variables, Total Costs Jordanian Water Sector	**0.229**	**0.774**	0.121	N/A	N/A	0.036	0.177	N/A
True Fixed Effects Model, Total Costs Jordanian Water Sector, with Time Periods	**0.457**	0.309	**0.701**	**0.914**	-0.134	**0.352**	**0.447**	N/A
Random-Effects, Time-Varying Parametric Model, Kumbhakar (1990), Total Costs Jordanian Water Sector	**0.319**	**0.52**	0.317	**0.901**	0.063	N/A	N/A	-0.496
Time-Varying Decay Model, Random-Effects, Battese and Coelli (1992), Total Costs Jordanian Water Sector	**0.438**	0.282	**0.792**	**0.823**	**-0.234**	0.194	**0.34**	2.74
Inefficiency Effects Model, Random-Effects, Battese and Coelli (1995), with Time-Period Dummy Variables	**0.468**	**0.338**	**0.83**	**0.615**	**-0.244**	**0.521**	**0.44**	2.08

True Random-Effects Model Greene (2005a), Total Costs Jordanian Water Sector	**0.339**	**0.981**	**0.608**	0.608	**-0.319**	N/A	N/A	**-3.9**
Generalised Least Squares Regression	**0.472**	-0.913	**0.857**	0.653	**-0.156**	**0.459**	**0.657**	**7.28**

As Table 51 above shows, in most cases, there is a positive relationship between output and total costs, except for the Time-Invariant Fixed Effect Cross-Sectional Regression (which was statistically insignificant). There was also a positive relationship between NRW and total costs, and a mostly negative relationship between NoC and total costs (this will be explored below). The year groupings showed a positive relationship, implying that the years 2011-2014 and 2014-2018 showed increased total costs, compared to the years 2008-2011. This shows that the years of corporatisation did in fact result in increased costs, relative to 2008-2011, when the corporatisation process was just beginning.

Regarding the statistically significant relationship between output and total costs, these ranged from 0.583-0.701, whereas random effects ranged from 0.608-0.83. Thus, the random effects model gives a wider range, and overall higher values than fixed effects. Regarding NRW, the statistically significant fixed effects SFAs ranged from 0.647-0.914, whereas random effects ranged from 0.615-0.901, a wider range and lower results. Thus, the random effects method found that NRW had a lower impact on total costs. Regarding NoC, there were no statistically significant fixed effects results, and for random effects, the statistically significant results ranged from -0.234 to -0.244. For GDMP2, the fixed effect statistically significant range was 0.352-0.426 and the random effects was 0.521. For GDMP3, the fixed effect statistically significant range was 0.447-0.574 and the random effects range was 0.34-0.44. This shows that fixed effects picked up higher costs in GDMP2 (2011-2014), but random effect picked up higher costs in GDMP3 (2014-2018).

11.3.2 Analysis

As the results above show, total costs are primarily correlated with capital, and less so with labour costs. Thus, capital costs are the most important component of the cost structure of water suppliers in Jordan.

Output is statistically significant in the random-effects models, but not in the fixed effects models. Thus, the relationship between total costs and output is not as clear-cut as previously thought. That is, one would assume a positive, statistically significant relationship between output and total costs. However, if the relationship between total costs and output is not statistically significant, then it implies that costs can grow independent of output.

In most cases, there was a statistically significant relationship between costs and the number of home connections, albeit a negative relationship. That is, as more users are connected, then average costs (cost per user) declines, because of an economies of scale effect. This result possibly indicates that connecting homes to the water supply network benefits from economies of scale, with a decreasing cost per home connection.

In order to confirm this, new regressions were run, this time with the NoC as the dependent variable, as shown below. All statistically significant results are in bold.

Table 52 Summary of SFA Coefficients, with Number of Water Connections as Dependent Variables

	Fixed Effects (Exponential Distribution)	PL81	BC88	BC92	REGLS
TC	-0.052	-0.112	-0.261	**-1.84**	**-1.33**
CC	0.001	0.061	0.054	**0.82**	0.242
LC	0.861	**1.01**	**1.05**	**2.17**	**2.53**
Output	**-0.611**	**-0.576**	**-0.635**	**1.44**	**0.949**

NRW	-1.06	-0.864	-0.925	**2.02**	1.5
Cons	5.95	4.78	7.15	**-15.8**	**-17.7**

As Table 52 above shows, the Battese and Coelli (1992) model offers the most statistically significant results. In the Battese and Coelli (1992) and the Random Effects GLS SFA, total costs are statistically significant, and have a negative relationship with NoC.

As the results show, as the number of homes connected to water increases, total costs decrease. This further supports the idea that increasing the number of homes connected to water benefits from economies of scale. Some studies state that adding home connections results in decreasing cost per connection, especially in urban areas with many connections/km^2 (Nauges & Van Den Berg, 2009); (Wenban-Smith, 2009). Other studies find that economies of scale exist only up to a certain point, after which decreasing returns or diseconomies of scale set in (Ferro, Lentini, & Mercadier, 2011); (Saal, Arocena, & Maziotis, 2013).

Also, there was a statistically significant relationship between NoC and NRW, (just as there was between total costs and NRW). Thus, the more NRW there is, the greater the impacts on costs, and the greater the number of home connections there are. This implies that NRW not only increases total costs, but that it increases with the number of homes connected.

11.3.3 Analysis of Efficiency

This section analyses the efficiency of the individual suppliers. The 'Predict' function in Stata offers fitted values for the model (UCLA, N.D.). Fitted values are based on the mean response value of inputs (Frost, N.D.). By using the 'Predict' function, one can obtain the average technical efficiency of each firm, in this case using a half-normal true fixed effects model, as shown below:

Table 53 Predicted Efficiency for Each Water Supplier in Jordan

```
Summary for variables: tfehalf_inefficiency_hn
     by categories of: Firm (Firm)

     Firm |      mean
----------+----------
      AWC |  .4619538
 Miyahuna |  .6391623
      WAJ |  .5888544
      YWC |  .2647816
----------+----------
    Total |  .5050708
---------------------
```

As the results above show, Miyahuna has the highest average technical efficiency, followed by WAJ, with YWC as the least technically efficient firm. With a mean of 0.505, AWC and YWC are below the mean, at 0.462 and 0.265 respectively.

11.3.4 Separating Inefficiency from Random Noise

Having discussed the efficiency of each firm, one can now examine the causes of the inefficiency. That is, are the inefficiencies due to issues of technical efficiency, or random external shocks? With a fixed effect model, one can differentiate the u_{it} and v_{it}. This allows one to separate the technical efficiency from random or unobserved errors. In other words, one can separate inefficiencies due to external (exogenous) shocks or the supplier's own inefficiencies. This can be done through a correlation analysis, in order to understand whether technical efficiency is highly correlated with the supplier's factors (in this case output, TC, CC and LC). The results are shown below:

Table 54 Correlation Analysis, Technical Efficiency with Multiple Variables

. corr bc_efficiency ln_tc ln_cc ln_labor ln_output (obs=41)

	bc_efficiency	ln_tc	ln_cc	ln_labor	ln_output
bc_efficiency	1.0000				
ln_tc	0.5406	1.0000			
ln_cc	0.2822	0.9396	1.0000		
ln_labor	0.4336	0.9182	0.8772	1.0000	
ln_output	0.8035	0.5561	0.3781	0.5670	1.0000

As Table 54 above shows, technical efficiency is highly correlated with the supplier's output, so the observed inefficiencies are mostly a result of the supplier's own inefficiencies. Thus, external shocks can be ruled out as a main cause of inefficiency in Jordanian water supply. Also, as the results above show, for every 1% increase in NRW, total costs increase by anywhere between 61% to 109.2%. It should also be remembered that the NRW rate in Jordan reaches up to 50% in many areas (Qtaishat, 2020). Thus, in order to reduce the costs to the Jordanian water sector, heavy investment in capital infrastructure is required.

11.4 Comparison Between Three Chapters

As the results of this thesis have shown, the efficiency of water suppliers can vary with the econometric method used. Indeed, even with the same sample (four Jordanian water suppliers), examining similar time periods (2008-2018), a different model can produce widely diverging results.

The findings of the DID were similar to those of the DEA. Both found that, overall, there was a weak link between corporatisation and improvements to water supply. However, the DID analysis did show that, when examining specific states in Jordan (Ajloun, Balqa, Irbid, Karak, Ma'an and Mafraq) corporatisation did improve supply. Thus, it appears that while corporatisation did increase water supply in the poorer governorates, it did not increase supply effectively in the largest governorates, Amman and Zarqa. The SFA showed a relationship between total costs and supply, and this relationship is more pronounced during the years of corporatisation. The fact that the GDMP2 and GDMP3 variables (showing the time periods 2011-2014 and 2014-2018 respectively) were statistically significant shows that there is a correlation between total costs and these specific time periods. In other words, the time periods of the corporatisation process saw increased total costs.

The DEA showed that corporatisation significantly increased the number of homes with connections to water supply. Furthermore, SFA showed that the number of connections benefits from economies of scale, with more home connections resulting in reduced costs overall. Also, this phenomenon increased during the years of corporatisation.

The SFA showed that the most cost efficient firms were Miyahuna and WAJ. These are the firms supplying water to Amman, Zarqa and the poorer, state-run governorates; AWC and YWC are the least cost-efficient firms. With DEA, it was WAJ which showed the most consistent efficiency, and Miyahuna and YWC showed above average efficiency amongst corporatized firms. Also, both the DEA and SFA found larger suppliers to be more efficient than smaller suppliers. Using SFA, two out of four Jordanian water suppliers had efficiency scores above the mean of 0.505 (AWC and YWC were below, at 0.462 and 0.265 respectively). The DEA offered a mean scale efficiency of 0.9025 (the scale efficiency shows whether a supplier is operating efficiently, or whether there is scope to reduce inputs while maintaining outputs). In the DEA, it was Miyahuna and YWC which surpassed the mean, at 0.93 and 0.99 respectively. AWC and WAJ did not reach the mean efficiency, at 0.82 and 0.87 respectively. Thus, the SFA and the DEA showed that half of suppliers achieved above average efficiency. Another point worth mentioning is the difference in the means themselves: SFA offered a mean efficiency of 0.505, but DEA offered an optimistic mean efficiency of 0.9025. This finding goes against much of the literature, wherein it is SFA which usually offers higher efficiencies, instead of DEA.[2]

However, the overall thrust of the literature concurs with the findings of this thesis. As the Literature Review in Section 3.2 discussed, the literature supports the idea that corporatising water providers will improve supply efficiency. This is because corporatisation allows companies to cut waste, reduce costs, avoid political pressures and employ best business practices. Also, one of the most notable advantages of the corporatised companies over the state-run suppliers, is that of cost recovery, through collecting bills. The corporatised companies have greater incentive to collect water bills than state-run suppliers.

The results of this thesis seem to support this proposition. Indeed, corporatisation has improved water supply efficiency, specifically in the governorates which are frequently cited as the poorest and most inefficient. However, another interpretation is that these governorates were already starting from such a low vantage point, that they were naturally going to show the most progression.

On the other hand, while corporatisation does improve water supply, another issue is whether these improvements are significant, in light of Jordan's water scarcity. That is, Jordan faced water deficits of 373 million cubic meters in 2018, and improvements of 7.9-32 million cubic meters (as shown in the DID chapter) are not enough to bridge that gap. Also, total costs are correlated with the period of corporatisation in Jordan. That is, total costs *increased* with the period of corporatisation. Indeed, there is significant scope for reducing capital and operating costs in Jordanian water supply, without negatively impacting output. However, corporatisation has only modestly impacted the supply of water in the country, and the costs of water supply remain extensive. Thus, corporatisation has not significantly impacted the supply efficiency of water in Jordan, if efficiency is defined as outputs per unit of input. However, this thesis has shown that

[2] For example, see Murwirapachena, Mahabir, Mulwa and Dikgang (2019)

corporatisation is actually very good for improving the *reach* of water, as opposed to *supply*. That is, the main success of water corporatisation in Jordan's is in increasing the number of homes with a water connection. However, there is still room for improvement, and improving the efficiency of these companies can increase the number of home connections even more.

12. Differences in the Customer Orientation of Jordanian Water Suppliers

12.1 Introduction

The previous chapters compared the efficiency of each Jordanian water supplier. This chapter discusses a possible reason for efficiency differences by examining each supplier's customer orientation. While there are many similarities among the Jordanian water suppliers (especially the corporatised suppliers), there are differences in terms of customer orientation. These differences, while subtle, do add up and have notable impacts on their efficiency over time. Particularly, the aspect in which suppliers show the most differences (and which possibly explains some of the differences in efficiency), is in customer service. By examining these differences in the margins, this chapter will show that small differences in customer orientation can have profound impacts on performance and efficiency.

12.2 Literature Review

12.2.1 Customer Orientation Defined

This section offers a brief outline of the concept of customer orientation, so as to have a precise definition when studying its impacts on water supply efficiency. Vij (2015) provides a concise definition of customer orientation as putting the needs of the consumer at the forefront of a company's strategic thinking. The staff (in particular those in sales and consumer relations) are dedicated to discovering and meeting the desires of consumers, so as to obtain new customers and maximise customer retention (Vij, 2015). The main challenge in this definition is that is too broad and vague, with most activities in a company dedicated to pleasing the consumer. That is, with this definition, virtually anything a company does can be considered to be customer orientated.

Racela (2014) offers a more focused definition. Customer orientation is the strategic capability of a company to offer high-quality customer value through the use of acquired customer intelligence and using this intelligence to meet consumer needs. It is also about the capacity to supply a consumer's latent needs and desires and ascertain potential future needs and desires. This definition has the opposite problem to that of Viji (2015), as it is too focused and narrow, focusing only on the gathering and use of market intelligence. While market intelligence is essential, it primarily focuses on the data gathering side, leaving out all the things a firm has to do once it has the market intelligence.

Santos, Perin, Simoes and Sampaio (2020) offers a similar definition, maintaining that customer orientation is simply the strategy of obtaining, collating and implementing data about consumers. While this theory may have broken off from the theory of market orientation, it is now a unique field and discipline, and a strategic asset in achieving market success in its own right. This definition suffers from similar issues to Racela (2014), having too narrowly focused on gathering customer intelligence.

Duffy, Bruce, Moroko and Groeger (2020) show that the essence of customer orientation is to re-orient a business away from being a goods-producing organisation, to one that creates value for customers. It should be noted however, that while customer-orientation does put the consumer's interests at the forefront of an organisation's thinking, it does not ignore other essential stakeholders, such as staff, owners, shareholders or the environment. This definition is useful in that the purpose of customer orientation is not just the collation and use of data on consumers, but the process of creating value for consumers, which should be at the heart of any definition of the concept. Gonu, Agyei, Richard and Asare-Larbi (2023) offer a perspective very similar to view Duffy, Bruce, Moroko and Groeger (2020). That is, customer orientation as part of a wider strategy to direct a firm's resources to meet the needs and desires of revenue-generating customers.

Piskoti and Nagy (2009) offer a much needed addendum to the points discussed above. The authors discuss the various definitions of customer orientation that exist in the literature. Ultimately, customer orientation delineates to what extent a firm puts its customers' needs at the forefront of its activities. However, the authors show that in reality, it is not clear that customers can communicate to producers their actual needs, as they have limited understanding of the products, services or tech offered.

While the critique by Piskoti and Nagy (2009) is valid, there is another issue with the definitions of customer orientation discussed above. Many of them focus on attracting and retaining customers, especially high-income customers, so as to maximise revenues. However, there is little mention of customer orientation for reasons other than increasing value added or revenue maximisation. This leaves out many organisations that are customer-oriented, for reasons other than maximising revenues. Indeed, many water utilities are not run on a profit-seeking basis (as discussed in Chapters 2 and 3), but still show customer orientation (as will be discussed later in this chapter).

12.2.2 Customer Orientation and Impacts on Performance

After discussing the concept of customer orientation, Piskoti and Nagy (2009) then show that applying customer orientation to companies will improve chances of market success, theoretically and in actuality too.

Santos, Perin, Simoes and Sampaio (2020) analyse how customer orientation impacts a company's financial performance. This paper uses a cross-sectional survey, based on questionnaires answered by 2,500 medium-sized Brazilian companies (with 100 to 499 employees) across a variety of markets. The paper finds that highly customer-orientated firms are more proficient at collecting data and knowledge about their respective markets. Thus, they are more likely to offer consumers what they require, thereby improving sales and overall performance. A statistically significant, positive relationship is found between customer orientation and business performance.

Hawa (2015) analyses the impacts of customer orientation on a pharmaceutical retail chain in Jordan, based on 248 questionnaires. It is found that there is a statistically significant, positive link between customer orientation and customer satisfaction, as well as customer orientation and service quality.

Gonu, Agyei, Richard and Asare-Larbi (2023) study the impacts of customer orientation on performance, by analysing surveys answered by 381 customers, across six banks in Ghana. Results showed that customer orientation had a significant, positive effect on customer satisfaction and service quality in these banks. Indeed, it was shown that customer orientation played a vital part in improving customer services, mirroring the results of the studies discussed up to now.

Lee, Chen, Chen and Chen (2010) offer similar results in discussing the impacts of adopting customer orientation on Taiwanese hospitals, by examining 318 questionnaires given to hospital patients. The results show significant, positive correlations between customer orientation, the quality of medical service and the value of service patients received. Also, patient satisfaction was significantly impacted by these variables.

Grant, Nasution and Pickett (2020) in researching Australian SMEs, analyse how the mechanisms of market orientation, including customer orientation, impacts sales effectiveness. It was found that customer orientation did positively affect sales effectiveness, in line with the other studies in this literature review.

Kotcharin (2013) offers a slightly different take on the impacts of customer orientation than most of the previously discussed papers. The author analyses the Thai automobile industry, showing that customer orientation can indirectly improve business processes. That is, while customer orientation did not directly improve processes or flexibility, it did do so indirectly, by first promoting customer integration. This in turn improved the industry’s processes, in turn improving corporate performance. The conclusions of this paper are a departure from the previously discussed papers, as it denies any direct link between customer orientation and efficiency (although it still posits an indirect effect).

Windarti, Alhadi, Zahara and Andriani (2020) analyses the impacts of customer orientation on Indonesian banks. The authors find a significant, positive relationship between customer orientation and the trust customers have in the bank. There is also a significant, positive relationship between customer orientation, service quality and customer loyalty.

Frambach, Fiss and Ingenbleek (2016) use econometric techniques to study various types orientation (customer, competitor, technological), market contexts and styles of strategy. They find that in no mix of variables is there a case of solid performance without customer orientation.

In having reviewed the literature, there seems to be a general agreement that more customer oriented firms offer higher customer satisfaction, which in turn leads to improved sales, trust, repeat business and revenues. However, the methodology seems to be primarily surveying and interviewing customers (and sometimes employees). While surveying can be generally a robust method of gathering data, care should be taken to balance surveys with other methods of data collection (both primary and secondary). This not only offers triangulation across forms of evidence, but allows the researcher to further support their survey findings.

12.2.3 Customer Orientation in Water Supply

This section examines the role customer orientation plays in the performance of water utilities, although the literature focusing primarily on customer orientation in water supply is sparse. For example, Schwartz (2006) does not specifically focus on customer orientation in water supply. However, the author does devote a section of the PhD to the extent to which five Mexican water utilities exhibit customer orientation, and how such orientation impacts performance. The author measures customer orientation using a checklist with nine points. These include, but are not limited to, the extent to which suppliers depend on customers for revenue (as opposed to the state), the extent of complaints (and how they are dealt with) and the extent to which employees are trained. The author finds that high performance utilities showed customer orientation and financial independence, and that these traits were missing in the low performance utilities.

Wanyakala (2011) analyses the impacts of reforms geared towards customer orientation in the Ugandan Water Sector. The author distributed surveys to the customers of the country's main urban water supplier, the National Water and Sewerage Corporation, asking whether reforms had made the supplier more customer oriented. If respondents answered in the affirmative, they were then asked how this affected their satisfaction and customer loyalty to the supplier. The author found that such reforms increased access to water, as well as increasing customer care, without a spike in prices. There was also a significant, positive relationship between the degree to which complaints were tackled and customer satisfaction and loyalty. Thus, Wanyakala's findings were similar to Schwartz's, with both showing that customer orientation had positive impacts on water utility performance.

Mukokoman and Ssemwogere (2012) use DEA to study 30 decision-making units within water suppliers in Uganda and Tanzania. The authors find a statistically significant, positive relationship between customer orientation and efficiency. The authors also find a positive, though not statistically significant, relationship between customer orientation and customer satisfaction. These results are consistent with the literature, both regarding impacts of customer orientation on water and other industries.

Li, Pomegbe, Dogbe and Novixoxo (2019) surveyed 350 Ghanaian SMEs, which were corporate users of water, to understand their experiences in interacting with water suppliers in Ghana. The authors found that, as Ghanaian water suppliers already had an established consumer base, the perceived need for customer orientation (amongst suppliers) was diminished. Even so, the degree to which employees were customer orientated did affect the consumer's service quality and satisfaction.

In summary, the literature is consistent that customer orientation in water utilities generally improves their performance. Indeed, it was even found that, in the case of Uganda, this increase in performance came without a concurrent increase in prices, thus maintaining access to water.

12.2.4 Customer Service in Jordanian Water Supply

This section analyses customer service in Jordanian water. There is no literature on the impacts of customer orientation in Jordanian water supply. However, there is a paper on the impacts of customer service on Jordanian water, which merits scrutiny, as there are a number of ways by which effective customer service can improve efficiency. It can be argued that retaining existing customers is in fact cheaper than searching for, advertising to and attracting new customers. Additionally, consumers are more willing to pay firms who offer greater customer services and are more willing to repeat their business there. All this leads to improved sales, and therefore revenues (Amaresan, 2022). Also, a firm which makes the effort to learn about the needs and desires of its customers has an advantage over its competition, which may lead to reduction in customer care costs in the long-term (Zendesk, 2021).

The most comprehensive study regarding customer satisfaction with Jordanian water suppliers was conducted by Ogata, Mahasneh, Alananbeh and Fuji (2022). This article discusses the correlation between supplier performance and consumer satisfaction, and the relationship between service quality and willingness to pay for water. By surveying 914 customers across the 12 governorates, this study finds a significant correlation between customer satisfaction and the revenue to cost ratio. This shows the degree to which customer perception can have an impact on supplier efficiency. The results of the survey are summarised:

- The tariff collection ratio ranged from 0.66-1.53, averaging 1.
- Overall customer satisfaction ranged from 28%-93%, averaging 51%.
- Accuracy of the announced water supply time ranged from 46%-90%, averaging 67%.
- Satisfaction with the quantity of water ranged from 35%-94%, averaging 58%.
- Satisfaction with water pressure ranged from 19% to 94%, averaging 54%.

- Satisfaction with answering complaints ranged from 21%-78%, averaging 46%.
- The number of hours/week of supply fluctuated between 0-168, with the average being 29 hours/week.

The survey conducted for the study also noted some significant discrepancies from the reporting of suppliers. For example, the utilities maintained that supply hours were between 1.03-3.09 times longer than the hours stated by customers in the survey. Also, just over half of customers (at 56%) were content with water quality.

The authors conducted a correlation analysis between overall satisfaction and certain KPIs. There was a significant correlation between satisfaction and staff ratio, metered ratio, water loss, consumption, bill collection and supply hours. Also, there was a significant correlation between operating ratio and weekly supply hours.

12.3 Methodology

Previous chapters used quantitative analyses to compare the efficiency of Jordanian water suppliers. This chapter will use a more qualitative analysis to discuss the reasons for the variations in efficiency shown in those previous chapters. This chapter will show how the suppliers differ in customer orientation, and how such differences impacts the performance of suppliers. This qualitative analysis will allow for a deeper understanding of the workings of these suppliers, showing how subtle differences in their orientation may contribute to widely varying results.

First, the customer orientation of the suppliers will be measured. This will be done using the framework of Schwartz (2006), discussed previously in the Literature Review. In his PhD thesis, Schwartz developed a framework for the analysis of customer orientation, using a checklist with nine points. Schwartz (2006) discusses the customer orientation of a utility, based on several criteria, including but not limited to:

1. To what extent is the supplier dependent on consumers in order to break even?

    a. To what extent are suppliers, conversely, dependent on the government to break even, through subsidies and soft budgets?
2. How many possible methods are there for consumers to pay bills?
3. Does the supplier perform customer research surveys proactively?
4. If so, how else do suppliers attempt to understand the consumer's perspective?
5. How are complaints from the consumer tackled?
6. How can consumers engage with the supplier, to influence the decision-making process?
7. How does the supplier train staff to deal with consumers?
8. How does the supplier notify consumers about important issues regarding water supply?

This Chapter will adapt the aforementioned criteria and apply it to the Jordanian water sector. However, some of these points will be dropped, because they are either inapplicable to Jordan, or suppliers show no meaningful difference. For example, each supplier offers the same methods to pay their bills, suppliers rarely conduct customer surveys and the only way to engage with the supplier is to file a complaint (however, there are differences between suppliers as to how complaints are tackled). Also, training specifically for customer care is limited, and there are few avenues for informing customers about important issues.

Simultaneously, Schwartz's list leaves out a crucial element. That is, many of the problems facing the customers of Jordanian water suppliers, and may in fact prohibit helping customers, is dilapidated water infrastructure. These problems result in significant levels of NRW, as shown in Chapter 6. Thus, any analysis of customer orientation in Jordanian water supply must look at multiple elements, beyond the narrowly confined ones proscribed by Schwartz (2006). Thus, this chapter will also discuss how customer orientation is impacted by the high levels of NRW in Jordan, and the conditions that lead to such high NRW.

The following criteria is for an analysis of customer orientation, specifically suited to the water system of a developing country with limited resources, such as Jordan. The revised list for customer orientation in Jordanian water suppliers:

1. To what extent is the supplier dependent on consumers in order to break even?
2. How do suppliers respond to complaints from consumers?
3. How do suppliers attempt to minimise NRW, so as to benefit customer service?
    a. What are NRW levels across the suppliers?
    b. What efforts do suppliers make to prevent further damage to the water supply network?

In answering these questions, for each supplier, one can understand how customer oriented each supplier is, and if there are noticeable impacts on performance.

Schwartz (2006) used surveys to ascertain his results, but this chapter will rely on secondary data, while using the author's framework. This data will come from an array of secondary sources, including but not limited to:

- Budget Reports of Each Supplier, from the General Budget Department, from 2011-2020
- Utilities Performance Monitoring Unit (UPMU) Reports 2019-2020, from the MWI
- Annual Reports from the Suppliers, 2011-2020
- Previous Research into Jordanian water suppliers, for example, Ogata, Mahasneh, Alananbeh and Fuji (2022)

From these reports, data will be obtained, relating to:

- Net income of suppliers
    - To what extent suppliers are dependent on their customers or the government for payments
- Complaints received by the suppliers
- NRW
    - Water loss per subscriber
- Collection of bills from customers
- Continuity of water supply
- Attempts made to tackle NRW
    - Preventive maintenance of the piped network

- Metering

Once this data has been gathered for each supplier, it will be analysed. Specifically, each utility will be studied in depth, first showing its revenue to cost ratio, thus providing an overview of the firm's financial performance. Then, an analysis will be conducted into the customer orientation of the firm. This will show how customer oriented the firm is, including but not limited to its dependence on customers or the government for revenues, metering, continuity of supply, complaints and so on. Once the customer orientation of the supplier is established, then the impacts of customer orientation on the firm's performance will be assessed.

12.4 Results

This section examines the customer orientation of Jordanian water suppliers, against the criteria discussed in the Methodology Section 12.3. The first is the degree to which the supplier is dependent on customer versus government funding.

12.4.1 Financial Independence of Utilities

None of the suppliers can break even based on revenues from sales alone (with the exception of AWC). This is partially because suppliers cannot raise the price of water without approval from Parliament. Thus, they have two options, the first of which is to increase revenues by maximising sales and bill collections, and make up the difference with subsidies from the Government. Conversely, the second option is to focus on cost reduction. One of the main ways suppliers can do this is by tackling NRW, which is discussed later in this chapter.

Table 55 Net Income, 000’s JD

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Miyahuna	-3,456	2,337	20,691	-10,626	-22,838	15,541	9,689	-497	10,494
AWC	-24	2,265	3,201	6,021	345	-57	3,152	1,184	3,227
YWC	-17,300	-17,290	-21,694	-29,256	-22,846	-1,098	-2,551	6,515	-2,344
WAJ	-112,435	-116,880	-184,124	-229,479	-244,235	-239,947	-258,429	-266,802	-188,93

Source: GBD, “Miyahuna” 2012-2020; GBD, “AWC” 2012-2020; GBD, “YWC” 2012-2020; GBD, “WAJ” 2012-2020

Table 55 above shows the net income of each Jordanian water supplier. Miyahuna and AWC show widely fluctuating profits and losses, between 2012 and 2020. Miyahuna showed mostly losses between 2012 and 2016, but between 2017 and 2020 showed only one year in deficit. AWC only showed two years in deficit, between 2012 and 2020. On the other hand, YWC has only shown profit once during this time period, and WAJ none at all.

In 2020, Miyahuna and AWC made a profit of 10.5 million JD, a significant improvement over the loss of 3.5 million JD in 2012, which had to be funded through subsidies. AWC also improved significantly during this time period, from a loss of 24,000 JD in 2012 to a profit of 3.2 million JD in 2020. YWC’s losses have reduced substantially, from 17.3 million JD in 2012 to needing 2.3 million JD in funding in 2020. WAJ’s losses however have increased, from 112.4 million JD in 2012 to 188.9 million JD in 2020.

These results are particularly noteworthy, in that 2020 was the beginning of the Coronavirus Disease (COVID-19) epidemic, a particularly challenging period around the world. Even during such a period, both Miyahuna and AWC showed profits, negating the need for subsidies.

Thus, Miyahuna and AWC show gradually reduced financial dependence on the MWI, requiring less subsidies to cover their operating expenses. On the other hand, YWC only broke even once during the 2012 to 2020 period, and WAJ could not at all break-even; they still operate on soft budgets.

This leads to the question of why Miyahuna and AWC did significantly better than YWC and WAJ, financially. In order to do this, the suppliers' financial performance will be discussed in turn.

12.4.1.1 Miyahuna

Table 56 Miyahuna, Revenues and Costs (Millions JD) and the Revenue to Cost Ratio

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Revenues	90.4	108.2	130.6	113.7	154.8	162.6	157.0	160.7	141.9
Costs	93.8	105.9	110.0	124.3	177.7	147.0	147.3	161.2	131.4
Revenue to Cost Ratio	0.96	1.02	1.19	0.91	0.87	1.11	1.07	1.00	1.08

Source: GBD, "Miyahuna" 2012-2020

As Table 56 above shows, Miyahuna has gradually increased its revenue to cost ratio, which was steadily greater than '1' after 2017. It should be noted that, while Miyahuna's revenues increased from 2012 to 2017, they actually dropped from 2017 to 2020. However, costs also increased between 2012 to 2017, and dropped even more than revenues, from 2017 to 2020, giving Miyahuna its positive revenue to cost ratio. Thus, it appears that the company made great strides in reducing costs, particularly after the unusually high costs in 2016. This may be because in 2017, Miyahuna began tackling NRW in earnest, as a result of the 'Five Year NRW Strategic Plan,' which started in 2017. This plan was developed to significantly reduce NRW, through a variety of strategies. Such strategies and their impacts will be discussed in Section 12.5.1). This plan shows that the utility has taken a concerted effort to improve its service to its customers, as well as reduce water loss and improve performance. Thus, Miyahuna has less need to rely on financing from the Ministry of Water and Irrigation, and showed increasing signs of cost recovery.

12.4.1.2 AWC

Table 57 AWC, Revenues and Costs (Millions JD) and the Revenue to Cost Ratio

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Revenues	13.3	15.8	18.6	19.7	19.5	16.4	17.6	15.0	15.7
Costs	13.3	13.6	15.4	13.7	19.1	16.5	14.4	13.8	12.5
Revenue to Cost Ratio	1.00	1.17	1.21	1.44	1.02	1.00	1.22	1.09	1.26

Source: GBD, "AWC" 2012-2020

As Table 57 above shows, AWC is consistently breaking even or making a profit between 2012 to 2020, with every year a '1' or greater. This shows that AWC is the firm least dependent on subsidies, and the firm most likely to achieve cost recovery. While there are multiple reasons for AWC's financial prowess, it is pertinent to note that AWC supplies to business and industry, whereas the other companies supply primarily households (UPMU 2020). The fact that it is the only Jordanian water supplier with a significant industrial customer base offers it an advantage over the other suppliers; it is able to sell much more water per subscriber than the other suppliers. For example, in 2020, water consumption per capita per day was 125.4 litres per capita per day for Miyahuna, 97.4 litres per capita per day for YWC and 369.1 litres per capita per day for AWC (UPMU 2020).

12.4.1.3 YWC

Table 58 YWC, Revenues and Costs (Millions JD) and the Revenue to Cost Ratio

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Revenues	26.5	30.5	33.4	30.5	36.3	38.5	36.7	37.2	32.3
Costs	43.8	47.8	55.1	59.7	59.1	39.6	39.2	30.6	34.6
Revenue to Cost Ratio	0.61	0.64	0.61	0.51	0.61	0.97	0.94	1.21	0.93

Source: GBD, "YWC" 2012-2020

As Table 58 above shows, YWC made a profit only once between 2012 to 2020. This shows that YWC is still very much dependent on funding from the MWI, and that it makes use of soft budget constraints.

However, while it may not be making a profit, it has shown noteworthy improvement in profitability. That is, between 2012 to 2016, the firm's revenue to cost ratio was between 0.51 to 0.64. Between 2017 to 2020, the firm's revenue to cost ratio ranged between 0.93 to 1.21; it even managed to make a profit in 2019. There are many possible reasons for the firm's uptake in profitability, between 2012 to 2020. These will be explored in Section 12.5.3.

12.4.1.4 WAJ

Table 59 WAJ, Revenues and Costs (Millions JD) and the Revenue to Cost Ratio

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Revenues	96.2	110.8	120.0	133.4	98.7	75.4	83.6	62.3	62.2
Costs	208.7	227.7	304.1	362.8	342.9	315.3	342.0	329.1	251.1
Revenue to Cost Ratio	0.46	0.49	0.39	0.37	0.29	0.24	0.24	0.19	0.25

Source: GBD, "WAJ" 2012-2020

As Table 59 above shows, WAJ struggles to cover its costs, having not broken even once between 2012 to 2020. Indeed, the revenue to cost ratio decreases steadily during that time period, reaching 0.25 in 2020. Revenues show a modest increase between 2012 to 2015, after which they fall gradually. Costs, on the other hand, grew consistently between 2012 to 2015, after which they remained steady, only dropping in 2020. Thus, between 2015 to 2019, revenues plummeted, but costs remained relatively constant.

As was shown above, the three corporatised utilities were able to significantly increase their revenue to cost ratios between 2012 to 2020. WAJ was the only supplier unable to do so, in fact showing a mostly decreasing revenue to cost ratio. It is clear that WAJ operates on a soft budget constraint; its losses have to be subsidised by the Ministry of Water and Irrigation. The possible reasons for these results will be discussed in Section 12.5.4

12.4.2 Engaging with the Supplier

The next aspect of customer orientation to be examined, in the framework of Schwartz (2006) is that of customer engagement. The more a supplier engages with the customer, the more it is able to gauge customer desires and needs, and respond accordingly. In Jordanian water supply, lodging complaints appears to be the main avenue through which consumers can voice their frustrations to suppliers. Typically, complaints are about a lack of water.

Indeed, as previous chapters have shown, a lack of water is one of the main challenges facing Jordan. Even with water being available intermittently, suppliers struggle to offer a steady supply of water on those days when water should be available. One of the few ways consumers can voice their frustrations to suppliers is through making 'No water' complaints.

Table 60 "No Water" Complaints, per 1000 Subscribers, Jordan

	2017	2018	2019	2020
Miyahuna	133	146	191	250
AWC	N/A	N/A	71	57
YWC	87	80	81	85
WAJ	197	195	140	131

Sources: GBD (2018c); GBD (2018d); GBD (2019c); GBD (2019d); GBD (2020c); GBD (2020d); JICA (2017); Miyahuna (2021); Ogata (2022); UPMU, (2019); (2020)

As Table 60 above shows, the number of 'no water' complaints, per 1000 subscribers, given to Miyahuna increased from 133 in 2017 to 250 in 2020. In other words, the number of 'no water' complaints to Miyahuna almost doubled in four years.

While there are only two years available for AWC, they show a drop from 71 complaints per 1000 subscribers in 2019, to 57 complaints per 1000 subscribers in 2020.

The number of ‘no water’ complaints for YWC remained relatively constant, from 87 complaints per 1000 subscribers in 2017 to 85 complaints per 1000 subscribers in 2020.

The number of ‘no water’ complaints for WAJ actually dropped significantly, from 197 complaints per 1000 subscribers in 2017 to 131 complaints per 1000 subscribers in 2020.

As the results above show, not only did Miyahuna have the largest number of complaints in 2020, but it was the only supplier to experience an increase between 2017 to 2020. The other suppliers either experienced either a drop or remained constant.

In explaining why Miyahuna experienced almost double the number of complaints between 2017 to 2020, it should be noted that the most extensive jump occurred between 2019 and 2020. These two years saw an increase of nearly 60 complaints per 1000 subscribers. 2020 saw the beginning of the COVID-19 epidemic, and Miyahuna supplies water to the most populated (and densely populated) governorates in Jordan. Thus, the epidemic, and ensuing lack of manpower, would most likely hurt the governorates with the most intricate water supply systems. Leaving the water supply systems in Miyahuna’s governorates unattended for long periods of time would exacerbate already great challenges.

It appears that AWC and YWC are the companies most responsive to customer complaints, although WAJ actually made the most progress in reducing complaints.

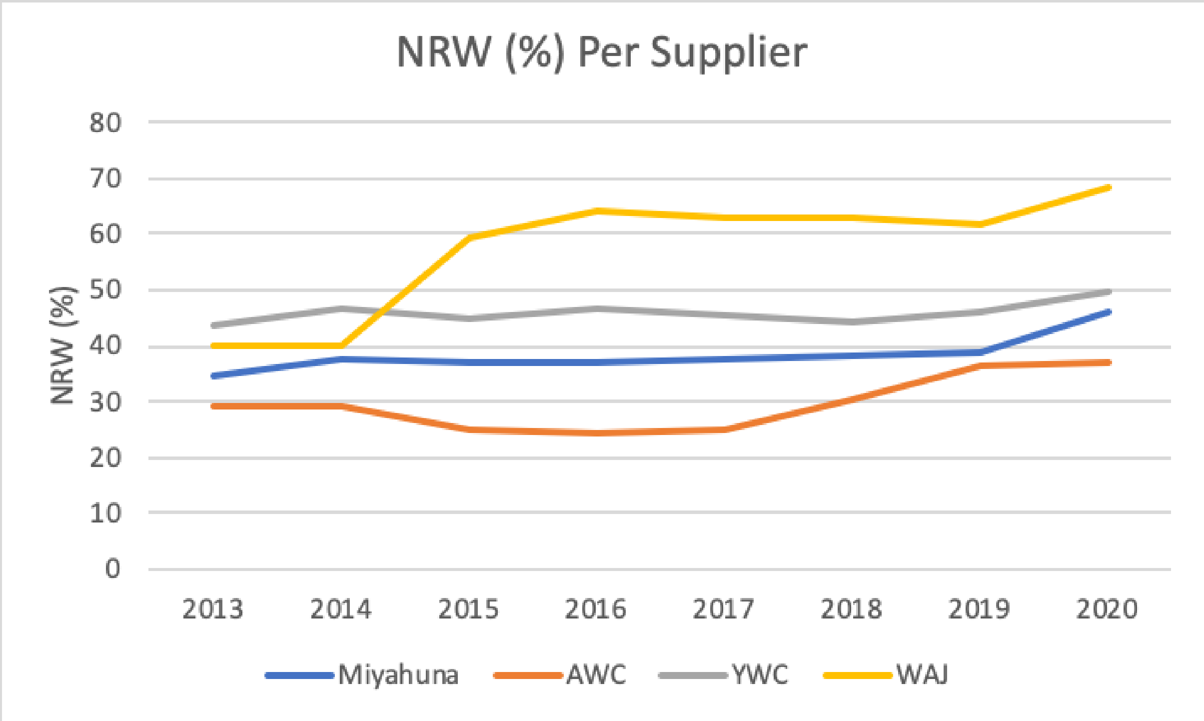
12.4.3 Non-Revenue Water and its Impacts on Customers

After responding verbally to the complaints of their customers, the suppliers are then compelled to act upon them. This section shows how suppliers respond to the complaints of ‘no water.’ The main cause of ‘no water’ complaints is the country’s dilapidated infrastructure, which results in extensive NRW. Thus, the most effective way to tackle the complaints of ‘no water’, and improve customer orientation, is to tackle NRW.

In fact, under current conditions, increasing water supply actually harms customer orientation, as so much water is lost during delivery, creating a vicious cycle. In this cycle, lost water requires re-pumping to replace the water lost, increasing the costs of extraction, purification and distribution. It also increases the amount of energy used, which in addition to being expensive, is harmful to the environment (especially if it is fossil fuel based).

Also, the water lost is not billed; less revenue is compounded by increased costs. Thus, I argue that NRW merits discussion as it directly impacts customer service. Indeed, the more water lost in transit, the less water for the consumer and the less revenue the supplier has for maintenance and upgrading the system. This creates a vicious cycle, which can only be broken if a supplier addresses NRW. Indeed, the more a supplier tackles NRW, the more water it delivers, and therefore the more the customer benefits. This section explores this side of customer orientation.

Figure 32 NRW (%) Per Supplier in Jordan, 2013-2020



Sources: Miyahuna (2018); YWC (2018); UPMU, (2019); (2020); (GBD, 2013-2022); (GBD, 2013-2022)

As Figure 32 above shows, every water supplier in Jordan showed an increase in NRW, between 2013 and 2020, but at varying rates. WAJ showed the biggest jump, from 40% in 2013 to 68.1% in 2020, a jump of 28.1%. AWC and YWC both showed modest jumps during this time period, of roughly 8% and 6% respectively. Miyahuna increased from 34.3% in 2013 to 46.1% in 2020, a jump of 11.8%. Also, it is noteworthy that, while all suppliers witnessed increased NRW, AWC was the only supplier that experienced a (brief) drop. Between 2014 to 2017, NRW actually dropped by 4.3%, before it picked up again after 2017. Having shown the rates of NRW for each supplier, the next section will discuss the reasons for such differences.

It should be noted that Miyahuna actually managed to keep NRW relatively steady from 2013 to 2019; it is in 2020 when a large jump is recorded. As was previously mentioned, this was the start of the COVID-19 epidemic, which exacerbated the already formidable challenges facing the water supply network.

12.4.4 Collection from Customers Efficiency (%)

While the previous section analysed NRW, this section will analyse one of NRW's main causes. Revenue collection is an important component of customer orientation, both on its own and for tackling NRW, which in turn promotes water efficiency. The more revenue collected, the more funds are available for re-investment into, and the repair and renovation of, a dilapidated system.

Table 61 Collection from Customers Efficiency (%)[3]

	2017	2019	2020	2022
Miyahuna	91.3	95.5	86.1	88
AWC	95	94.8	84.2	97
YWC	N/A	73.7	84.4	130.5
WAJ	80.5	N/A	N/A	80.5

Source: UPMU, (2019); (2020); Ogata (2017); Ogata (2022)

As Table 61 above shows, Miyahuna has shown a modest drop in its ability to collect bills from customers, whereas AWC has shown a modest jump. The reason for YWC's figure of 130.5% efficiency in collecting bills from customers is that it counted all the bills it collected in 2022, even though many of those bills were from 2021 (COVID-19 made bill collection difficult for YWC in 2021) (Ogata 2022). WAJ remained constant between 2017 to 2022, at 80.5% efficiency. Thus, AWC showed the most proficiency in collecting bills in 2022, at 97%, followed by Miyahuna at 88% and WAJ at 80.5% (it is not clear how much of YWC's collection is from the previous year).

12.4.5 Metering

One of the reasons that repairing the network is such a struggle, as well as collecting revenues, is the lack of sufficient metering in the water network. The more meters there are installed across the distribution network, the more accurate an understanding of consumption there is.

[3] Due to data limitations, the years 2018 and 2021 are unavailable

There is also a greater chance of pinpointing the location of leaks across the network. This in turn will improve customer service while at the same time reducing NRW and increasing revenue collection.

Table 62 Metering, (%)[4]

	2017	2019	2020	2022
Miyahuna	99.5	91.5	93	99.3
AWC	99	97.5	96	93
YWC	93	87.7	89	N/A
WAJ	98.3	98	97	97.5

Source: GBD (2019d); GBD (2020d); Ogata (2017); Ogata (2022); UPMU, (2019); (2020).

As Table 62 above shows, Miyahuna's network is well covered by metering devices, at least at well and reservoir extraction points. In fact, in 2017, only YWC has a metering percentage below 98%. By 2020, all the suppliers experience a drop (most likely because of COVID-19). By 2022, most have jumped back to near the metering levels they showed in 2017, with the exception of AWC. AWC experienced the biggest drop between 2017 and 2022, at 6% less metering in the intervening years.

12.4.6 Continuity of Supply

Another hindrance to customer orientation in Jordanian water systems is the intermittency of supply. Water is not continually pumped across the network; customers only get a few hours of water supply during certain days of the week. Not only does it mean that customers do not get water on demand, but if there was a continuous supply, it would be easier to find leaks in the mains, using sound to find such leaks. However, with an intermittent supply, as is the case with most Jordanian suppliers, this is not possible, making the location of leaks (and repair) of leaks much harder.

[4] Due to data limitations, the years 2018 and 2021 are unavailable

Table 63 Subscribers Receiving Continuous Supply, (%)[5]

	2017	2019	2020	2022
Miyahuna	4.6	35.8	35.8	38.7
AWC	N/A	168	168	168
YWC	2.1	9.1	9.1	15
WAJ	4.0	14	19	29

Source: Ogata (2017); Ogata (2022); UPMU, (2019); (2020)

As Table 63 above shows, few of the residents of YWC and WAJ receive a continuous supply of water. For many households, this necessitates them supplementing their water from other sources, such as water tankers, unlicensed wells, and so on. As for AWC, most of its customers receive a continuous supply. This is possibly because industrial consumers require a continuous supply of water, and the fact that AWC only has to pump to the population of Aqaba, as opposed to many states. With the exception of AWC, the suppliers showed modest growth in continuous supply between 2017 and 2020.

12.5 Analysis

The previous section discussed the customer orientation of suppliers, finding notable differences in terms of both customer orientation and efficiency. This section will discuss each supplier in turn, examining the different ways in which these suppliers are customer oriented, and how that impacts their efficiency.

[5] Due to data limitations, the years 2018 and 2021 are unavailable

12.5.1 Miyahuna

Table 64 Customer Orientation Indicators, Miyahuna[6]

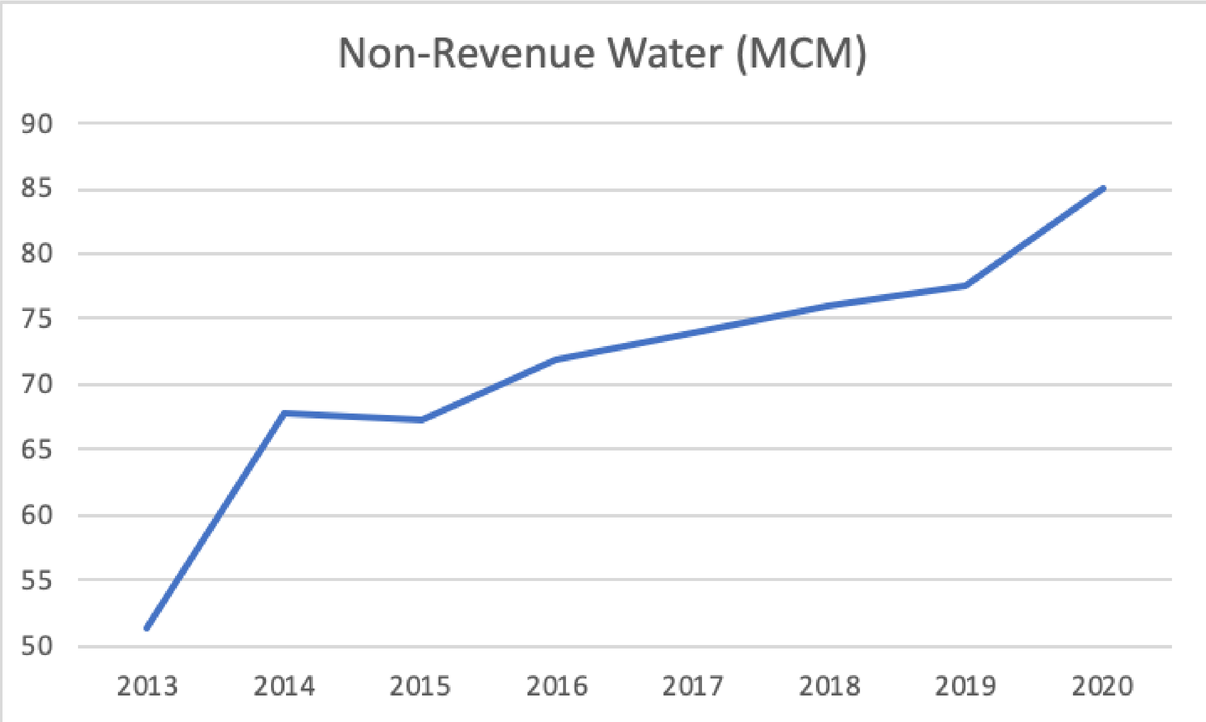
	2017	2019	2020	2022
Complaints per 1000 Subscribers	133	146	191	250
Customer Collection Efficiency (%)	91.3	95.5	86.1	88
Metering (%)	99.5	91.5	93	99.3
Continuity of Supply (hours/week)	4.57	35.784	35.784	38.7
NRW (%)	37.3	38.7	40.6	N/A

Source: Ogata (2017); Ogata (2022); Miyahuna (2021); UPMU (2019); UPMU (2020)

Table 64 above summarises the indicators discussed in the previous section, with a focus on Miyahuna. Before the COVID-19 Pandemic in 2020, Miyahuna showed proficiency at bill collection and metering (both of which increased revenues) and responding to complaints and tackling NRW. The company's progress in reducing NRW is not simply a result of it being the largest of the corporatised suppliers, but a result of crafting and implementing a five-year long strategy in 2017, the "Miyahuna 5-Years NRW Strategic and Investment Plan 2017-2021." As was shown in Figure 32, Miyahuna kept NRW relatively steady between 2013 to 2019, before it shot up in 2020 (possibly due to the COVID Pandemic). Hence, if one were to look at NRW volumes, as opposed to percentages, then a different picture emerges.

[6] Due to data limitations, the years 2018 and 2021 are unavailable

Figure 33 Non-Revenue Water (Millions Cubic Meters), Miyahuna



Source: Miyahuna (2021)

The graph above shows a rapid increase in the volume of Miyahuna's NRW, from 2013 to 2015, and a modest increase from 2015 to 2017. Between 2017 to 2019, there is a much slower growth in the volume of NRW. Indeed, between 2013 to 2017, the volume of NRW increased from 51.3 to 74 million cubic meters, an increase of 44.2%, or an annual average increase of 11.1%. However, between 2017 to 2019, the volume of NRW increased from 74 to 77.4 million cubic meters, an increase of 4.6%, or an annual average increase of 2.3%. It was only in 2020, with the onset of the Pandemic, that NRW shot up again. Thus, it could be argued that the implementation of the "Miyahuna 5-Years NRW Strategic and Investment Plan 2017-2021," had a notable impact on slowing the growth rate of NRW.

The strategy slowed NRW growth rates by using a diagnostic tool kit to continuously gauge its performance. In the areas found lacking, a scoring matrix for such factors as bulk metering, metering accuracy, and data collection is used to analyse and improve performance. Using these KPIs, Miyahuna then implements an incremental action plan to reduce leaks, improve infrastructure and monitoring systems (Khashman, 2016). While the strategy did not achieve its goal of halving Miyahuna's NRW, it did make progress in other areas. Specifically, Miyahuna showed customer orientation in responding to complaints by slowing the growth in NRW volumes, increasing the level of metering and increasing the rate of continuous supply significantly (as shown in the previous section). This customer orientation in turn showed improvements in efficiency, including but not limited to, increasing bill collection, which led to increased cost recovery, which in turn helped increase the revenue to cost ratio (as shown in Table 56) (thus reducing the need for subsidies).

However, there are still areas where Miyahuna can improve. Neither Miyahuna nor any of the suppliers regularly survey customers, and it is still up to customers to complain and make their voices heard.

12.5.2 AWC

Table 65 Customer Orientation Indicators, AWC[7]

	2017	2019	2020	2022
Complaints per 1000 Subscribers	N/A	70.8	57.1	N/A
Customer Collection Efficiency (%)	95	94.8	84.2	97
Metering (%)	99	97.5	96	93
Continuity of Supply (hours/week)	N/A	168	168	168
NRW (%)	25	36.2	37	N/A

Source: Ogata (2017); Ogata (2022); UPMU (2019); UPMU (2020)

As Table 65 above shows, AWC offers a fully continuous water supply throughout the week, which is due to multiple factors. It has a close proximity to the Gulf of Aqaba, it supplies to only one governorate, as opposed to three or four (like the other suppliers) and its customer base is much more industrial and corporate than the other suppliers. This ability to offer continuous supply gave AWC the lowest 'no water' complaints

[7] Due to data limitations, the years 2018 and 2021 are unavailable

amongst suppliers, at 57.1 per 1000 subscribers. It also showed the highest collection efficiency of 2022, at 97% (YWC's figure of 130.5% does not count because it includes collections from the previous year). All these factors allow the company to show a steady stream of positive revenue to cost ratios, between 2012 to 2020 (as shown in Table 57), removing the need for subsidies.

Thus, AWC's success is a result of a combination of its structural advantages (being a port city, having an industrial customer base) and its customer orientation. For example, even if it is able to deliver water continuously, it will not translate to profit unless it is able to collect the bills on that sold water. Thus, its high bill collection ratio (the highest out of the suppliers) is essential to getting that revenue, which is a result of its customer orientation. Another example is the low number of water complaints (compared to the other suppliers). Again, structural advantages are important, but it is because of its customer orientation that it implemented preventive maintenance in 100% of its pipes (that is, maintenance meant to prevent pipe bursts in the future) in 2020. For comparison, YWC implemented preventive maintenance in only 31.9% of its pipes in 2020 (UPMU 2020). In other words, the low number of water complaints is also due to the proactive nature of the supplier, which invests in preventive maintenance so that it has less pipe bursts later, and therefore less complaints.

12.5.3 YWC

Table 66 Customer Orientation Indicators, YWC[8]

	2017	2019	2020	2022
Complaints per 1000 Subscribers	87	80	81	85
Customer Collection Efficiency (%)	N/A	73.7	84.4	130.5
Metering (%)	93	87.7	89	N/A
Continuity of Supply (hours/week)	2.1	9.1	9.1	15
NRW (%)	43.8	46.1	49.5	N/A

Source: Ogata (2017); Ogata (2022); UPMU (2019); UPMU (2020)

Whereas Miyahuna and AWC have both shown consistently that they can make a profit, YWC still struggles to break even. In fact, it only broke even once between 2012 to 2020, as shown in Table 58. This means that it still depends on the MWI for subsidisation. However, even though it is not yet profitable, YWC has shown tremendous strides in profitability. As Table 58 showed, between 2012 to 2016, the supplier's revenue to cost ratio fluctuated between 0.51 to 0.64, and between 2017 to 2020, fluctuated between 0.93 to 1.21. Not only was YWC profitable in 2019, but it is possible that the firm would have continued its upward trajectory of profitability into later years, had it not been for the COVID-19 epidemic.

While there are many reasons for the firm's increase in profitability, I argue that one reason is its increased customer orientation. At first glance, this might not seem likely, from the indicators. It shows the lowest metering out of any of the suppliers, at 89% in 2020, whereas every other supplier showed metering above 90% (UPMU 2020). The only reason it has such a high bill collection ratio in 2022, at 130.5%, is because it was gathering all the bills it could not obtain in 2021. However, there are many ways to show a company's willingness to improve its customer orientation.

One such indication is the launch of YWC's first business plan. The company developed a business plan to address its myriad challenges and meet the challenge of supplying to an ever growing number of customers.

[8] Due to data limitations, the years 2018 and 2021 are unavailable

This plan detailed strategies to minimise NRW and increase cost recovery through increased collections of bills. In addition to restructuring the organisation and streamlining the labour force, the plan introduced incentives for delinquent bill collection. In less than a year, the plan helped the company recover delinquent payments in excess of three million JD (USAIDb, 2017). It should also be noted that threats to cut services to law-breakers were not idle; in June and July 2017, 369 subscribers had their service cut due to alleged wastage of water (Jordan Times, 2017).

12.5.4 WAJ

Table 67 Customer Orientation Indicators, WAJ[9]

	2017	2019	2020	2022
Complaints per 1000 Subscribers	197	195	140	131
Customer Collection Efficiency (%)	80.5	N/A	N/A	80.5
Metering (%)	98.3	98	97	97.5
Continuity of Supply (hours/week)	4	14	19	29
NRW (%)	63	61.9	68.1	65

Source: GBD (2017d); GBD (2019d); GBD (2020d); GBD (2022d); Ogata (2017); Ogata (2022)

As Table 67 above shows, WAJ still has a long way to go, before it shows solid customer orientation. It has shown a gradual drop in the number of complaints per 1000 subscribers, from 197 in 2017 to 131 in 2022. However, in other indicators relating to customer efficiency, it has shown little improvement. The customer collection efficiency remains unchanged between 2017 and 2022, at 80.5%. Also, there was a slight drop in metering, from 98.3% in 2017 to 97.5% in 2022.

Not only does it not show any signs of improving its customer orientation, but the firm struggles financially as well. As Table 59 showed, WAJ did not break even once between 2012 and 2020. Also, the revenue to cost ratio steadily decreased during that time, plummeting to 0.25 in

[9] Due to data limitations, the years 2018 and 2021 are unavailable

2020. Indeed, the three corporatised utilities did manage to increase their revenue to cost ratios between 2012 to 2020; WAJ was the only supplier to show a consistent drop in this metric. This leaves WAJ in position wherein it requires constant funding from the Ministry of Water and Irrigation.

In attempting to explain this phenomenon, one can argue that the governorates WAJ supplies to are poor, arid and remote, thus exacerbating the challenges of water delivery. However, the states supplied by YWC all share these same traits (poor, arid, remote), and it was able to show increased performance. As was argued in Section 12.5.3, this was because YWC adopted a business plan which improved its customer orientation. Indeed, Miyahuna itself adopted a plan to reduce NRW (as was shown in Section 12.5.1). As of the time of this writing, WAJ has not published any long-term strategic document to either improve its financial performance in terms of supplying to its governorates, or in terms of improving its ability to serve customers. Thus, it is clear that this supplier is not customer oriented, it does not seek cost recovery, and it operates on soft budget constraints.

This in itself may be because it is the only supplier to remain non-corporatised. Rather, this supplier is still run on principles of maximising supply to the highest number of people possible, regardless of cost. It does not focus on revenue generation or cost cutting because it is not institutionally bound to. If the firm wishes to improve both its relationship with its customers, as well as its finances, it might consider corporatising the supply of water to the governorates it is responsible for.

It should be noted that previous chapters in this thesis (those using DEA, DID and SFA analyses), were studies of relative efficiency, between suppliers. These studies compared the performance of each supplier relative to the other suppliers (or in the case of the DID analysis, comparing governorates to one another). Such comparisons allow for an understanding of the performance of a supplier or governorate, rooted in its context. If simple, absolute measures of efficiency were used, it would not provide any meaningful context. That is, if it is shown that a certain supplier's output per unit of input is 'X,' by itself such information tell the reader very little. By comparing the results to other suppliers, context is given, benchmarks are established, and it becomes clearer whether a firm's performance is exemplary or sub-par.

However, these comparisons have to be relevant. That is, it makes little sense to compare the efficiency of Jordanian water suppliers (in an arid, developing country) to suppliers in vastly different contexts (for example, in different climates, environments or economic status). Thus, an analysis using relative efficiency allows for meaningful analysis, allowing for meaningful comparisons between Jordanian water suppliers, and therefore more insightful recommendations for the suppliers.

However, the absolute efficiency of a supplier is also important. This chapter studied the efficiency of Jordanian suppliers, using absolute efficiency (for example, using the revenue to cost ratio of each firm). While relative efficiency is important, combining it with a study of absolute efficiency allows for deeper analysis into the workings of the supplier.

Ultimately, studies of both relative and absolute efficiency are needed. Taken together in a study, they can offer the most comprehensive examination of a supplier's performance

12.6 Conclusion

This chapter has discussed the customer orientation and financial performance of each Jordanian supplier. It was shown that customer oriented firms generally showed greater performance levels than firms which were not customer oriented.

However, it might then be argued that firms that were already efficient in the first place, may then go on to show improved customer orientation. That is, the direction of cause and effect is not clear. This chapter has shown that, in fact, each of the corporatised suppliers (in particular Miyahuna and YWC) took conscious efforts to improve their customer orientation, and only afterwards did they show significant improvement in a variety of indicators. This chapter showed that customer oriented suppliers show better results, because they put more effort into such matters as addressing customer complaints, metering and tackling NRW.

13. Conclusion

I have argued throughout this thesis that the corporatisation of water in Jordan has not increased water *supply or supply efficiency* to the extent needed to cover its water deficit. However, it has *increased water supplies in poorer governorates* (compared to state-run governorates), as well as *access to water, by way of home connections*. I also maintain that while corporatisation has improved cost efficiency, the main sources of inefficiency are internal. I have also shown that one possible source of these internal efficiencies is the degree to which suppliers are not customer oriented.

The efficiency of water supply is one of the most pressing issues of our time. With rapid population growth, climate change, and modernising lifestyles, it is imperative that Jordan improves its water supply efficiency. Indeed, Jordan is one of the water poorest countries in the world, and its water challenges will only grow in the coming decades. Thus, a study of Jordan's water supply efficiency may be applicable to other developing, arid countries. The literature on water supply efficiency is diverse, with multiple methods for studying the topic. This thesis makes use of three of those methods: Data Envelopment Analysis; Difference-in-Difference Analysis; and Stochastic Frontier Analysis. By relying on three different methodologies, and avoid biased results that might arise from only one methodology, and explore efficiency from multiple dimensions. This thesis used these techniques to analyse how the corporatisation of water suppliers over the last 20 years has impacted Jordan's water supply efficiency.

The Jordanian water supply system has been studied primarily through the lens of political economy, demand-management, geology, hydrology and technology. It has rarely been studied through the lens of economic efficiency. The study of the Jordanian water supply system and different methods of increasing efficiency is relatively recent, especially using frontier techniques (starting in 2010).

This thesis addressed this gap in the literature, by addressing the impacts of the corporatisation process on the efficiency of Jordanian water provision. Jordan's water provision system was entirely state-run two decades ago; there has been since then a shift towards more corporate principles. This thesis studied how the shift from purely state-run to mostly corporatised water provision has impacted water supply efficiency in Jordan.

The following sections will answer this paper's Research Questions, and confirm or deny the Hypotheses outlined in Section 4.7. The first Research Question asked "How has the corporatisation process impacted the supply efficiency of the Jordanian water sector?". As was shown in the Literature Review Section 3.2, the literature (overall) maintains that corporatisation of water suppliers will improve efficiency, including in developing countries. Corporatisation, theoretically, reduces waste, and therefore costs, avoids political pressures and implements best business practices. Another advantage is that corporatised companies have more incentive to collect water bills than purely state-run utilities, thus increasing cost recovery.

This thesis' results, initially, support this view from the literature. As the 'Difference-in-Difference' Chapter has shown, corporatisation has improved water supply, compared to purely state-run governorates. In fact, it has improved water supply specifically in those governorates that are the least efficient and the poorest. Although, it is possible that these governorates were starting from such a weak position, they had the most potential to progress in terms of supply.

While the corporatisation process did improve Jordan's water supply, it is debatable as to how beneficial it was. Jordan faces a water deficit of 373 million cubic meters, while corporatisation brings 7.9-32 million cubic meters, depending on the governorate. This is not enough to meet the rapidly growing demand for water in the country.

Also, the SFA showed that there was a correlation between the period of corporatisation and total costs, implying that total costs rose during this period. Certainly, as the DEA Chapter showed, there is much room for reductions in capital and operating costs, across each supplier, without the need to reduce supply.

Thus, with supply and costs increasing, efficiency, defined as output per unit of input, has not been significantly impacted by corporatisation. However, this thesis has demonstrated that, as opposed to *supply efficiency*, corporatisation has improved *access* to water in Jordan, including poorer and remote areas. That is, the number of homes with connections to the water supply has increased significantly over the last two decades. There is still room for improvement though, with potential for even more home connections and reduced costs (as shown in the DEA). Also, increasing the number of home connections provides the additional benefit of economies of scale, with more connections reducing the cost/unit.

The second Research Question asked, "Which is the more efficient mode of running a utility, corporatised or completely state-run?". In the DEA, each supplier has its strengths and weaknesses, but some suppliers clearly showed more efficiency than others. Amongst the corporatised companies, both Miyahuna and YWC showed consistent levels of efficiency, and the state-run WAJ also showed high levels of efficiency. In fact, it was the state-run WAJ which showed the steadiest levels of efficiency, compared to the corporatised suppliers.

The DID Analysis examined the different governorates, as opposed to the utilities. When studying Jordan as a whole, this chapter found that corporatisation did not increase the water supply in Jordan (just as the DEA Chapter did). However, when narrowing the analysis to specific governorates, a different story emerges. The governorates of Ajloun, Balqa, Irbid, Karak, Ma'an and Mafraq witnessed increased water supply, with corporatisation. Also, when comparing corporatised Madaba and Irbid to (then) state-run Balqa and Zarqa, water supplies increased by 32-34.9

million cubic meters. Therefore, corporatisation may have been more proficient at increasing water supplies in poorer governorates. However, this trend does not extend to the country's two largest governorates, Amman and Zarqa.

In the SFA, Miyahuna exhibited the highest technical efficiency, followed by WAJ; YWC was the least efficient firm, and the only firm to perform below the average efficiency level.

In comparison, the DEA showed WAJ as the most consistently efficient firm, with Miyahuna and YWC both showing high levels of efficiency, for the corporatised suppliers. On the other hand, the SFA showed that the most cost efficient firms were Miyahuna and WAJ, which supplied Amman, Zarqa and poorer state-run governorates. In the SFA, YWC was the least cost-efficient supplier. In the DID analysis, the corporatised governorates showed greater efficiency than the state-run governorates, and this applies to poorer governorates too. Indeed, the poorer governorates were among those which benefited the most from corporatisation.

In conclusion, the answer as to whether state-run or corporatised firms were more efficient is not straightforward. Depending on the methodology, the answer is different. The DEA showed the state-run operator as the most efficient firm, whereas the SFA showed the corporatised Miyahuna as the most efficient. Thus, in terms of *supply efficiency*, the state-run WAJ is the most efficient, but in terms of *cost efficiency*, the corporatised Miyahuna was the most efficient.

The third Research Question asked "Are the sources of inefficiency internal or external?". By implementing an SFA with a fixed effect model, one can separate the technical efficiency from exogenous shocks. Through correlation analysis, one can determine whether technical efficiency is correlated with the supplier's factors of production. The SFA found that technical efficiency was indeed highly correlated with supplier output.

Therefore, inefficiencies are mostly due to issues found within the utility itself, and not exogenous or external factors.

Having answered the Research Questions, the Hypotheses are now discussed. The first Hypothesis stated: "The corporatisation process has improved the efficiency of Jordanian water supply significantly, but less so the overall supply". The results show that corporatisation improved supply efficiency, but not by the amount needed to reduce water deficits. The second Hypothesis stated: "The corporatised firms will show increased efficiency, over the state-run firm". In actuality, the state-run firm was amongst the most efficient of the water suppliers, with corporatised suppliers showing mixed levels of efficiency. The Third Hypothesis stated: "There are substantial savings to be made, by improving efficiency". In fact, the main saving, in terms of corporatisation, is in terms of expanding the number of homes with water connections, as this benefits from economies of scale. Finally, the fourth Hypothesis stated: "The causes of inefficiencies will be mostly external." This was false, as the inefficiencies of Jordanian water suppliers were mostly internal.

In attempting to explain the underlying causes for the differences in Jordanian water supplier efficiency, this thesis examined the underlying customer orientation of suppliers. It was found that a relationship may exist between customer orientation and supplier performance. Indeed, suppliers who were found to have improved customer orientation noted increased performance and positive developments in many areas.

Despite the progress Jordan has made, it has a long way to go, towards maximising water supply efficiency. There is a case to be made for policy makers to corporatise the remaining governorates. However, this should be done without illusion. This will not solve water shortages in those governorates, or in other parts of Jordan. As most of the supplier inefficiencies are internal, further study can be directed towards analysing the sources of inefficiency, and how to tackle them. As was shown in Chapter 12, one possible factor in these internal causes of inefficiency is customer orientation. Corporatised firms, backed by clear, long-term plans to improve their customer orientation and performance, showed clear progress in terms of a variety of indicators. These include, but are not limited to, metering, continuity of supply, addressing complaints and NRW. The firms which tackled these indicators exhibited the most improvements in financial performance.

13.1 Addressing the Gaps in the Literature

This thesis has made contributions towards the study of parametric and non-parametric frontier analyses, such as SFA and DEA respectively. It has also used a non-frontier methodology in the DID. In addition to using these statistical methods, this paper has contributed to the study of water supply efficiency in an arid, developing country. Indeed, most studies follow only one method, with a few being multi-method approaches. This thesis is in a niche category, using the three quantitative methods just mentioned, and the qualitative method of customer orientation. Certainly, there is a sparse literature on the impacts of customer orientation on water utilities. Thus, this thesis, in the framework of Schwartz (2006), provides further evidence that there might be a relationship between customer orientation and supplier performance. Not only is this the first thesis to bring these disparate techniques together, but it is the first thesis to apply them to a developing, arid country such as Jordan.

Ultimately, this thesis contributes to the theory of the corporatisation of water in developing, water scarce countries. Future researchers wishing to study the impacts of specific governmental policies on water suppliers may find relevant techniques within this thesis. Also, this thesis provides information on how to interpret the results of such techniques.

However, there are limitations to this thesis, which may limit its rigour and applicability, which should be addressed. For the DEA Chapter, the findings may have been more robust if a Tobit Regression or a Malmquist Index were used. Additionally, the DEA may have benefitted from adding more DMUs, either in the form of water suppliers from other

MENA countries, or increasing the number of years of the study. Also, increasing the number of variables used in each of the statistical methods would have allowed for greater exploration of the factors affecting Jordanian water supply efficiency.

The primary source of data for this thesis is the Jordanian government's statistics for the water sector, since they are the primary supplier of water, and are in charge of the country's water statistics. Hence, any errors within these statistics may be reflected in this paper.

Finally, this thesis does not delve into the geo-political causes of Jordan's water challenges. Any geo-political issues with its neighbours are ignored, as the thesis focuses entirely on efficiency issues. This may leave the thesis less comprehensive, as Jordan's relationship with its neighbours may reduce its water supplies significantly.

Ultimately, in order to improve supply and supply efficiency, the process of corporatisation has to be revamped. It must be able to address the coming challenges of the 21st century. These include, but are not limited to, rapid population growth, NRW, infrastructure and climate change. Corporatisation has brought many benefits, but unless it is able to significantly increase supply efficiency, then it will not solve the country's water shortage. Further research is required into the sources of high capital costs amongst suppliers, and methods for reducing these costs. This should be accompanied by research into reducing NRW, and finding water sources other than groundwater. These are among the main challenges facing the water sector today, and that corporatisation has so far not met sufficiently.

13.1.1 Implications of this Study for Development

This thesis provides multiple benefits for the study of development. It provides concrete, actionable advice for the study of water supply and government policies in developing or arid countries. While the thesis does not provide advice on how to increase water supply, it does show how to improve the efficiency of water supply, as well as which policies increase the number of water connections.

It studies the impacts of governmental policies on water supply and water-related issues, such as home connections and NRW. This is important in arid, developing countries, especially in a context of growing climate change. Studies that discuss the nature of efficiency are especially important in countries with little resources to spare (whether financial or physical, such as water). In studying the impacts of policy measures, this thesis shows how to measure efficiency in the water sector, and how to gauge whether the causes of said inefficiency are internal or external.

By offering strategies on how to study supply efficiency, this thesis can offer advice for other researchers interested in the study of water supply. It offers strategies for studying supply efficiency both in relative terms (the chapters on DEA, DID and SFA methods) and in absolute terms (Chapter 13). The thesis also shows some strategies for improving cost-efficiency and performance in water suppliers.

Ultimately, corporatisation by itself cannot directly improve the twin human rights of access to water and water security. However, if corporatisation is combined with proper strategic planning and customer orientation, it can reduce NRW, which results in a virtuous cycle: less water wasted means more water for the consumer, as well as more revenues for the supplier. Thus, the supplier can re-invest those revenues into infrastructure, training, metering, increasing network connections or some other requirement for efficient water supply. This, in turn, may help in increasing access to water. Therefore, corporatisation can be said to indirectly benefit water security and the human right to water. Also, reductions in NRW increases sustainability, as less energy is used to re-pump lost water. Thus, corporatisation can indirectly contribute to sustainability as well.

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