

The availability/use of water resources and the relationship to the behavior of the capital market

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Declarations

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Abstract

This paper is intrigued by the following question: while the relationship between water resources and economic growth is well documented, what might have a stronger significant relationship - the availability of water resources or the actual use of these resources. An interesting thirty-year experiment regarding the Sea of Galilee in Israel indicates that the mere availability of water rather than the actual use is a key factor that affects the capital markets. This paper found a significant relationship between the moving averages, seasonally adjusted elevation levels of the sea and the capital market, while the actual use was hardly a significant factor. Given the low quantity of actual use of the water, the findings suggest that there is likely to be another variable that indirectly and differently affects the two variables.

I. Introduction

The relationship between economic growth and water resources has become an essential issue in recent years, given the rise in world awareness of the existence of a climate crisis. Wang et al. (2016) present a list of 53 studies published in the short time period of 2015-2016. The importance of the water reservoir available to an economy and the relationship to the growth capacity in certain industries have been unequivocally proven, as argued by Nagie (2019). Real estate development, for

example, may be delayed due to the lack of viable water sources. Water input in the agriculture industry is critical as this industry currently accounts for about 2.5% of Israeli GDP (7% in the 1970s)¹. Liu et.al. (2019) and Chen et al. (2018) show similar findings for the Chinese economy, although according to the former the relationship weakens with the passage of time.

The academic literature refers mostly to the optimal management of water resources while emphasizing a variable defined as "economic security" that involves knowing about the existence of adequate water reserves. Nagie (2019) discusses the consumption side and presents "a schematic idea of water tax as a possible financial solution to a water crisis". Burhanudin et. al. (2020) also believe that the existence of water sources is of economic, social, and political importance. Water, therefore, can be treated as a financial commodity with an economic value that is not necessarily equal to the market prevailing price. They propose a mechanism for optimal management of water resources by charging consumers the true economic value of water. Scott et al. (2012) demonstrate how water shortages are a barrier to economic growth in the US state of Arizona.

Studies conducted before the world has become aware of the climate crisis presented a similar picture. Howe (1963), Barnett and Morse (1963) Potter and Christy (1962) present evidence for the link between water reserves and US economic growth. The Environmental Status Report (2017)², published in Israel, presents a concise description of the importance of water sources in Israel and the quality of water from each source. The report emphasizes the inverse relationship between the elevation level of the water of the Sea of Galilee and the amount of pumping through the National

¹ Source: Ministry of Agriculture

² Published by the Office of Chief Scientist, State of Israel

Carrier³. Mekorot⁴ announces that in 2021 Israel's water resources were as indicated in Table 1:

[Insert Table 1 about here]

The Environmental Status Report also reports that the Sea of Galilee, the only natural freshwater lake in Israel, is also the only surface reservoir of freshwater. The average depth is 25 meters. The volume of water stored in the lake at the maximum level is about 412.4 million cubic meters and the water level is a good indication of the amount of water stored in it. The Sea of Galilee supplies only about 11% of the water in Israel when pumping was increased in 2021, but historically the pumping from the Sea of Galilee reflects a lower percentage of the water sources. In 2018, for example, the Sea of Galilee accounted for less than one percent of the water sources. (See Table 2)⁵:

[Insert Table 2 about here]

Given that the Sea of Galilee has **not** been the main source of water in the State of Israel in recent years, any significant relationship between the elevation level of the Sea of Galilee and the behavior of the stock market may raise the intriguing question: what is the more significant factor affecting economic growth – the availability of water resources or the actual use of these resources? We need to keep in mind that a significant relationship, where the elevation level of the reservoir may explain the behavior of the stock market, may raise some doubt about the validity of the efficient financial market hypothesis.

³ The project through which the water was transferred from the sea to the dry southern areas.

⁴ A government-owned company that serves as the main water supplier in Israel.

⁵ Source: The Central Bureau of Statistics

The effect of the level of the Sea of Galilee on the capital market, if any, can be in two opposing directions in their influence: reserve versus use. A high elevation level of the sea indicates a high water reserve, while a low level may indicate an amplified use of water from the sea. Let us clarify this point:

- A negative relationship accompanied by an increase in pumping may indicate the effect of the usage variable.
- A positive relationship accompanied by a change in pumping may indicate the effect of the reserve variable.
- A positive relationship accompanied by a decrease in pumping does not allow for an unequivocal conclusion.
- A negative relationship accompanied by a decrease in pumping will require an explanation based on another variable.

If there is a relationship between the amount of water in the Sea of Galilee reservoir, measured by the elevation level of the sea, and the behavior of the financial market, then the relationship can be simultaneous or a leading/lagging relationship. Since the direction of causality is not in doubt, since there is no economic logic in the effect of the financial market on the level of the Sea of Galilee, it is likely that the leading/lagging relationship is characterized by an elevation level at any point in time prior to that of the financial markets data. This leading/lagging relationship can be between one point in time and a later point, or a cumulative relationship (such as a moving average) over time.

While the simultaneous relationship does not contradict the paradigm of weak financial market efficiency, a leading relationship between two specific points

in time may trigger an excess financial return, using the sea level variable as a leading source of information.

What are the different hypotheses and what do they mean?

The absence of a simultaneous or a leading/lagging relationship between two specific time points will contradict the hypothesis of a direct relationship between the level of the Sea of Galilee and the behavior of the financial market. Yet, the existence of a cumulative leading relationship over time may raise the hypothesis, on the one hand, that the relationship between the level and the financial market stems from a third influencing variable that directly or indirectly affects the two variables here, or on the other hand, that this third variable is an intermediary variable. In both cases, a non-zero correlation between the variables will be detected.

We will clarify the difference between the two alternatives, mentioned above. Let $F(.)$ be the level of the Sea of Galilee and $S(.)$ the stock market index. Let $MS(.)$ and $MF(.)$ be the cumulative variables, reflecting the level of the Sea of Galilee and the stock index, respectively. The existence of a third variable, denoted by X , means:

$$\frac{\partial MF_t(X)}{\partial X} = \alpha(.) \text{ and } \frac{\partial MS(X)_{t+n}}{\partial X} = \beta(.) \text{ and } \rho(\alpha(.), \beta(.)) \neq 0 \quad (1)$$

$\alpha(.)$ and $\beta(.)$ are non-zero functions and ρ is the correlation coefficient.

The existence of an intermediary variable X means:

$$\frac{\partial MS(X)_{t+n}}{\partial X(MF_t)} \frac{\partial X}{\partial MF_t} = \gamma(.) \neq 0 \quad (2)$$

The fact that the Sea of Galilee reservoir is **not** the main source of water in the State of Israel, and the empirical fact that the amount of water pumped from the Sea of

Galilee has been declining until recent years, reinforces the hypothesis that a direct relationship between research variables is unlikely to be identified. However, if a leading relationship between the study variables is indeed found, the hypothesis regarding the existence of the additional variable X will be further investigated.

X as a triggering or influencing variable may be explained in several ways. In a year with a high level of precipitations, which also raises the level of the water in the Sea of Galilee, a number of seemingly unrelated processes take place. On the one hand, budgetary cost savings such as compensation for drought damage, a significant increase in agricultural yields accompanied by relative declines in agricultural prices, and relatively low political tension with neighboring countries. For example, lower tension with the state of Jordan regarding the use of water from the Yarmouk river which feeds the Jordan River. Additionally, as a behavioral factor, there exists a sense of optimism that affects the atmosphere in the capital market.

On the other hand, the hypothesis that X is an intermediary variable is a less plausible explanation. In this case, a direct effect of the level of the Sea of Galilee on variable X , which affects the atmosphere in the capital market, must be identified. For example, it can be argued that tourism in the vicinity of the Sea of Galilee, flourishes when the Sea of Galilee fills up.

Whatever the explanation, it remains only to verify empirically the existence of any relationship among the variables.

II. Methodology

The raw database includes two series: The elevation water level of the Sea of Galilei. This study uses daily observations for a 30-years period, from 1992 to 2022⁶.

⁶ Source: The Water Authorities

The 125 stocks Index as defined by the Israel Stock Exchange, TSE, from 1992 to 2022⁷.

The data was processed as follows: we calculated the rates of change in the monthly average of the level of the Sea of Galilee at time t divided by the monthly average one year earlier (seasonal adjustments):

$$F_t = AF_t/AF_{t-12}$$

(3)

The rates of change in the stock index accordingly,

$$S_t = AS_t/AS_{t-12}$$

(4)

Lagging 12 months rates of change in the level of the sea,

$$F_t = AF_{t-n}/AF_{t-12-n} \quad (5)$$

12 months Moving averages of the stock market index,

$$MS_t = \frac{\sum_{i=1}^{12} S_{t-i}}{\sum_{i=1}^{12} S_{t-i-12}} \quad (6)$$

and similarly, 12 months moving averages of the water level,

$$MF_t = \frac{\sum_{i=1}^{12} S_{t-i}}{\sum_{i=1}^{12} S_{t-i-12}} \quad (7)$$

The amount of annual pumping of water, denoted as D_t . There is no publicly available information about the monthly quantities, so the monthly figure is $D_t/12$, seasonally adjusted.

Three linear relationships will be examined:

⁷ Source: TSE

The simultaneous relationship,

$$S_t = \mu_1 + \mu_2 F_t + D_t + \epsilon_t \quad (8.1)$$

The lagging relationship,

$$S_t = \mu_3 + \mu_4 F_{t'} + D_{t'} + \epsilon_t \quad (8.2)$$

The moving averages relationship,

$$MS_t = \mu_5 + \mu_6 MF_t + D_t + \epsilon_t \quad (8.3)$$

III. The results

No significant relationships were found for the simultaneous or the leading/lagging variables. In contrast, significant relationships were found between the moving averages. Table 3 presents the findings over the entire sample period 1992-2022:

[Insert Table 3 about here]

The following graph 1 describes the relationship of moving average over the entire 1992-2022 sample period:

[Insert Graph 1 about here]

Although the finding over the entire sample period 1992-2022 is significant, the graph presents a possibility for several non-conforming periods. Thus, we will examine the relationship behavior in sub-periods (Table 4) and indeed two periods stand out in indicating non-conforming findings.

[Insert Table 4 about here]

IV. Discussion and conclusion

The data demonstrates that there exists a significant relationship between the availability of water in the Sea of Galilee reservoir and the behavior of the capital market. Yet, it is likely that the relationship is not a direct one, that is, there is another variable that simultaneously affects, both the amount of water and the capital market. The explanation for this seems to involve several factors on several levels, but not only, that can also be hypothesized: from an economic point of view, a year blessed with precipitation or a year with insufficient precipitations, must be associated with budgetary impacts. For example, food subsidies and compensations to farmers for damages. There is also an effect on the supply of agricultural products, whether it originates in Israel or whether it originates from the neighboring states. This supply directly affects the price level of agricultural products and products derived from agricultural produce. In the political arena, tensions with Israel's neighbors are directly affected by access to water sources and therefore a blessed or deficient year here has a direct impact on political tensions with neighboring countries. At the social level, a blessed or deficient year has a social impact. The latter factor has been demonstrated in the academic literature that there is a positive correlation between the amount of precipitation and the social atmosphere, which in turn affects the capital market.

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VI. Appendices

Wells	Desalination	Above surface water	Springs	Sea of Galilee
723 43%	550 33%	130 8%	70 4%	190 11%

Table 1

Sources of water in Israel in 2021
In millions cubic meters

period	1969-70	1979-80	1990	2000	2010	2016	2017	2018	2019
Total	997	1042	1939	2020	2263	2307	2307	2271	2318
By Mekorot Ltd.			1232	1102	760	776	776	666	704
Well:			733	544	531	535	535	451	463
Above surface			247	160	53	50	50	53	39
Recycled			87	231	152	156	156	144	160
By other sources	714	701	707	918	951	946	946	960	1005
Well:			393	292	337	327	327	318	317
Above surface			354	177	254	266	266	272	303
Recycled			69	185	360	364	364	370	385
Desalination				264	543	586	588	645	609
Sea of Galilee			153	167	24	34	34	15	42
% of sources			79.0%	8.30%	1.10%	1.50%	1.80%	0.80%	1.80%

Table 2

Sources of water in Israel in 1969-2019
In millions cubic meters

T STAT	SE	VALUE	
8.2496	0.001	0.0068	Intercept
** -2.761	0.0205	-0.03663	Elevation
7.6563	Significance	0.00596	F

T STAT	SE	VALUE	
8.1160	0.001	0.006	Intercept
** -3.056	0.02	-0.062	Elevation
** 3.561	0.0002	0.00055	Pumping
10.302	Significance	0.001	F

Number of observations: 329

(**) Significance < 0.01

TABLE 3

The relationship between the sea elevation
and the stock index 1992-2022

OBSERVATIONS	F	T STAT	SE	VALUE	PERIOD	
27	23.48	6.7151	0.003040504	0.020417306	Intercept	2020-2022
		** 4.8451	0.034437099	0.166868395	Elevation	
	11.88	3.599	0.003	0.01	Intercept	
		0.94	0.093	0.087	Elevation	
		0.839	0.000150600	0.00012640	Pumping	

OBSERVATIONS	F	T STAT	SE	VALUE	PERIOD	
96	4.0964	5.13576	0.000806917	0.004144133	Intercept	2012-2019
		* -2.0239	0.018236729	-0.036910551	Elevation	
	2.022	4.99	0.0008279000	0.004	Intercept	
		* -1.976	0.025	-0.05	Elevation	
		-0.934	0.000029690	-0.000027720	Pumping	

OBSERVATIONS	F	T STAT	SE	VALUE	PERIOD	
60	3.744	1.31585	0.004648311	0.00611648	Intercept	2007-2011
		* -1.9349	0.117399472	-0.227159725	Elevation	
	2.441	0.408	0.004	0.002	Intercept	
		* -2.149	0.158	-0.3432	Elevation	
		1.064	0.000435800	0.0004637	Pumping	

OBSERVATIONS	F	T STAT	SE	VALUE	PERIOD	
48	13.851	8.417	0.003	0.021	Intercept	2003-2006
		-3.722	0.035	-0.131	Elevation	
	13.431	8.417	0.003	0.021	Intercept	
		** -5.161	0.037	-0.19	Elevation	
		** -3.088	0.000435000	-0.001	Pumping	

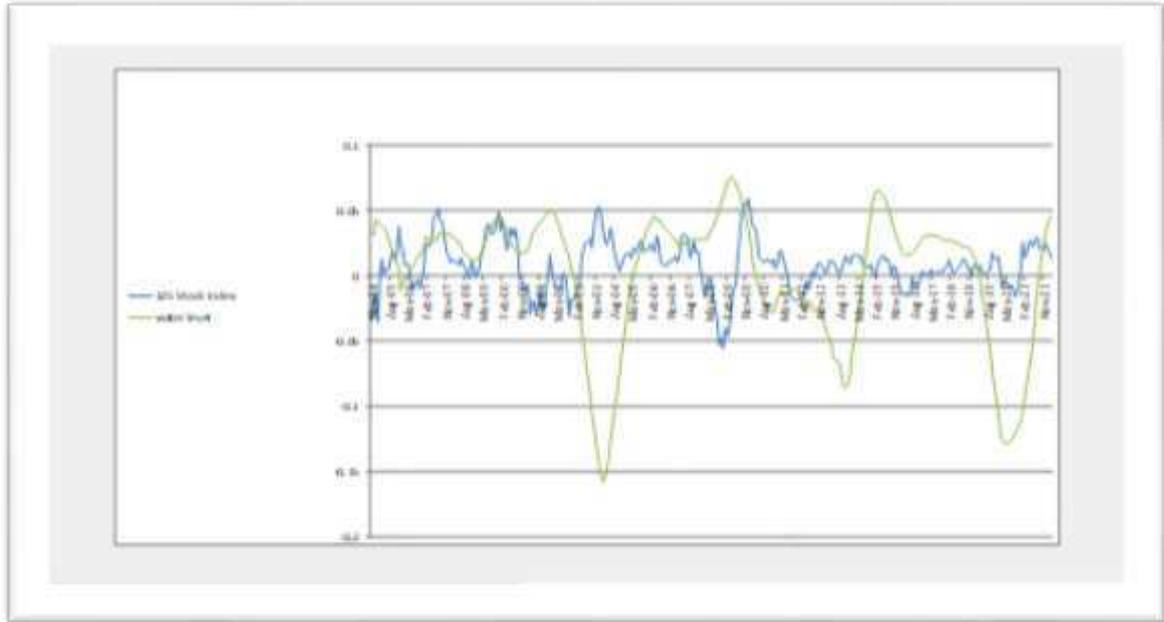
OBSERVATIONS	F	T STAT	SE	VALUE	PERIOD	
98	13.909	9.14186	0.001489906	0.01362052	Intercept	1992-2002
		** -3.7294	0.030751981	-0.114689409	Elevation	
	10.302	8.118	0.001	0.008	Intercept	
		** -3.058	0.02	-0.062	Elevation	
		** 3.56	0.00001558	0.00006	Pumping	

(**) Significance < 0.01

(*) Significance < 0.05

TABLES 4

The relationship between the sea elevation and the stock index in various periods



Graph 1

The behavior of the Sea elevation and the stock index

during the period 1992-2022