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A Test of the Hotelling Valuation Principle Applies to Water Resources

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A Test of the Hotelling Valuation Principle Applied to Water Resources

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Abstract:

Like oil and gas reserves, ground water can be considered an exhaustible resource in many areas and should be included in tests of the natural resource theories. This paper applies the Hotelling Valuation Principle derived by Miller and Upton to water resources, specifically ground water. Data from 9 publicly traded water companies are used to test if the in situ value of groundwater is equal to its current net price above ground. A sensitivity analysis is performed to determine the effects of varying the initial stock of groundwater reserves on the value of those reserves. This study does not find support for the Hotelling Valuation Principle as applied to water resources and in fact finds the in-situ values to be less than the above ground net price when the initial stock is varied from a 10 year supply to a 40 year supply in the aquifer. Only when there is a very small 5 year supply left in the aquifer do we find support for Hotelling Valuation Principle.

1. **Introduction**

Tests of Hotelling's Natural Resource Theory, in which the net price of a natural resource must rise at the rate of discount, are traditionally applied to exhaustible resources such as hard minerals, oil, and gas reserves. Rarely is it applied to water resources.

Water reserves exist in 2 distinct categories: surface water and ground water. Surface water is a renewable resource which is replenished year after year with varying supplies according to climate changes. Ground water is an exhaustible resource mined by municipal water utilities in the same manner that we mine oil and gas reserves. Although there may be a certain amount of ground water recharge from watershed runoff, the groundwater mining process in large metropolitan areas outstrips total recharge. Furthermore, when considering the time it takes for an aquifer to recharge, we can reasonably think of ground water as an exhaustible resource and subject it to tests of the Hotelling Valuation Principle.

The Hotelling Valuation Principle begins with Miller and Upton (1985) who proposed an alternative testing strategy for Hotelling's principle. By taking the dynamic optimization problem of natural resource extraction and converting it to a static process, they show that the value of reserves will depend mainly on the current prices less extraction costs regardless of when the reserves are extracted. Stated differently, the per unit value of reserves in the ground is the same as the current value above the ground less extraction costs. This is because the expected percentage rise in future product prices exactly offsets the market discount rate over time. It is important to understand that the Hotelling Valuation Principle (HVP) relies on the assumption that, in equilibrium, net prices rise at the rate of interest over time and that the rate of interest is equal to the rate of discount. Miller and Upton specifically tested the following equation:

$$\frac{V_0}{R_0} = \alpha + \beta(p_0 - c_0) \qquad (1)$$

Where V_0 is the discounted present value of profits at time = 0, R is the *in-situ* quantity of reserves available for extraction, p is the market price of the resource unit and c is the unit cost of extracting the resource. Because data on reserve values was limited, Miller and Upton (1985) based the current period "per unit" value of reserves (V/R) on the total market capitalization of publicly traded oil companies. The results indicate that the hotelling value: $\beta(p_0 - c_0)$,"current

price less extraction costs," account for a large portion of the variation in market values ($\beta = 1$). However, results from a later study do not support the HVP.

Watkins (1992) also looked at 27 transactions of petroleum reserves to test Miller and Upton's HVP. The results conflicted with Miller and Upton and do not support the HVP. Bell, Lacombe, Ryan, and May (2000) examine the operations of firms in the oil and gas industry using a panel dataset with 90 observations covering 15 oil companies over the years 1986-1995. In this study, they cannot reject the null hypothesis of HVP and instead find support.

Cairns and Davis (1999) point out "There has been a veritable cottage industry testing and disputing HVP as a valuation tool." Cairns and Davis, using data from Watkins (1992), find that HVP provides an upper bound to petroleum reserve values while the hotelling value provides a lower bound. Specifically, they show that HVP tends to overvalue reserves which implies that net prices rise at *greater than the current rate of interest*.

2. **Objectives**

This study performs a hypothesis test of the Hotelling Valuation Principle, as developed by Miller and Upton (1985), to place a value on ground water reserves. Just as Miller and Upton used stock prices of publicly traded oil and gas companies as a proxy for the market value of the reserves, this study uses stock prices of publicly traded water utilities as a proxy for the market value of groundwater reserves. The Miller and Upton hotelling values, spot price less the marginal costs of extraction, were estimated based on well head prices less extraction costs. For the hotelling values in this study, the current prices of ground water are based on the current revenue per unit of water delivered and the extraction costs are based on the current operating expenses per unit of water delivered. This essentially models average revenue and average costs as opposed to price and marginal cost. Section 3 provides a derivation of the HVP based on work by Miller and Upton. Section 4 describes the data used in this study. Section 5 presents the results and section 6 concludes.

3. **The Model**

Hotelling Valuation Principle

This test involves a basic statement of the Hotelling Valuation Principle: the per unit value of reserves in the ground are the same as the current value above the ground less the marginal extraction cost. This occurs because the expected rate of increase in future water prices exactly offsets the market discount rate. From Miller and Upton (1985), the discounted present value of profits, or the proxy for total reserve value, is given as:

$$V_0 = \sum_{t=0}^{N} \frac{p_t q_t - C(q_t Q_t)}{(1+r)^t} \quad given the constra\text{int} \quad \sum_{t=0}^{N} q_t \le R_0 \qquad (2)$$

Maximization provides the following first order conditions:

$$foc: \frac{dV}{dq} = (p_t - c_t)\left[\frac{1}{1+r}\right]^t = \lambda_t$$

$$foc: (p_t - c_t) = (p_0 - c_0)(1+r)^t$$

$$substitute: \qquad (3)$$

$$V_0 = (p_0 - c_0)\sum_{t=0}^{N} q_t = (p_0 - c_0)R_0$$

$$\frac{V_0}{R_0} = \alpha + \beta(p_0 - c_0)$$

Where:
V is the discounted present value of profits.
R is the total ground water reserves available in the aquifer.
p is the market price of ground water. Since there is not a spot market for water, I use the water revenues per gallon pumped from the company income statement.
q is the rate of extraction
c is the marginal cost of extraction.
r is the interest rate.

Implicit assumptions in this model are 1) all firms are price takers, 2) water is an exhaustible resource, 3) costs are not a function of cumulative extraction, and 4) constant returns to scale exist.

The Hotelling Valuation Principle hypothesis test, under constant returns to scale, expects the value of $\alpha = 0$ and $\beta = 1$. However, if current prices are rising at a rate less than the interest rate, we will expect the value of beta to be less than 1. Miller and Upton consider 2 extensions of HVP. The first extension, which assumes diminishing returns to scale, impacts only the intercept term and has no effect on the slope coefficient. The second extension assumes extraction costs rise over time at the rate of interest. Miller and Upton show that the slope coefficient is still equivalent to one and the intercept will be less than zero.

4. **Data**

Values for ***V*** were obtained from the total value of a publicly traded water utility as indicated by the stock price (value/share) multiplied by the outstanding shares. This data is readily available as "Total Capitalization" in the Balance Sheet for the water utility. Annual data from balance sheet and income statements of these utilities were obtained from the online Mergent database of publicly traded companies, for the years 1992-2002. Values for ***R*** add a complication because the actual volume of most aquifers is unknown. Unlike oil companies which are federally required to estimate “proven reserves”, water utilities are not subject to the same requirement. Since the value of ***R*** is elusive it might be useful to perform a sensitivity analysis based on varying amounts for ***R.*** This study calculates 5 proxies for ***R*** indicating a 40 yr, 30 yr, 20 yr, 10 yr and 5 yr supply of water in the aquifer. The supply is extrapolated forward

from the last 10 years of pumping data. Since there is not a spot market for water, the market price of groundwater, ***p***, is estimated using the water revenues per million gallons (mg) pumped. This data is available on the company income statement. The marginal cost of extraction, ***c***, is calculated from the total water operation expenses per unit of water delivered (mg). Since marginal costs are usually not available it is accepted in the literature to use average cost as a proxy. There is no need to collect data on the interest rate because, as seen above, the interest rate from discounting and the rate of increase in future prices is assumed to cancel out in HVP. The value of Beta will tell us if this assumption holds true.

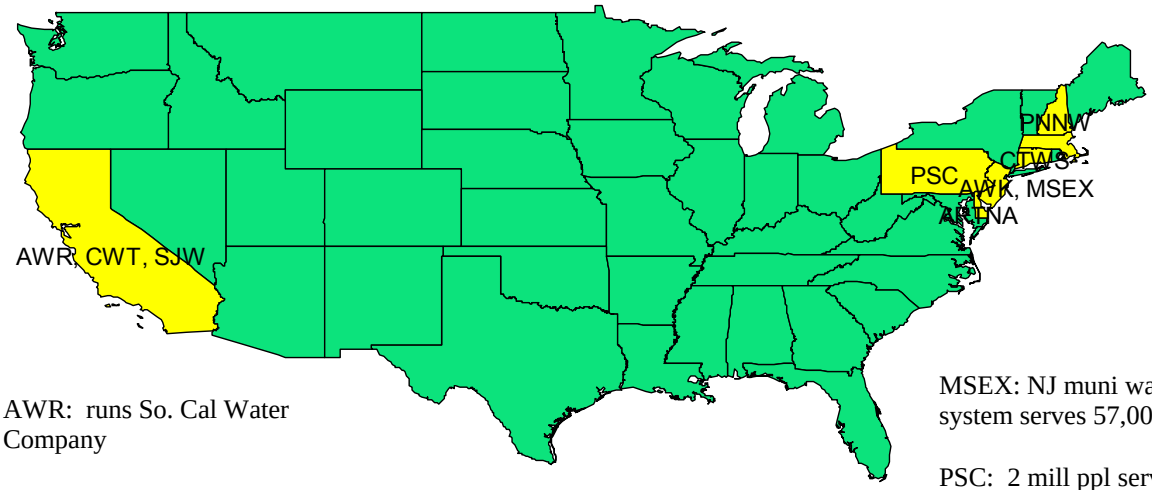
The publicly traded companies used in this study are listed in the Table 1 below:

TABLE 1: PUBLICLY TRADED WATER UTILITIES. STOCK SYMBOLS AND STOCK PRICES

Description	Stock Symbol	Market Cap	P/E	ROE %	Div. Yield %	Debt to Equity
American States Water Co.	AWR	386.40M	18.175	10.74	3.404	1.275
American Water Works Co.	AWK	4.49B	26.361	9.711	2.186	2.184
Artesian Resources Corp.	ARTNA	72.39M	16.882	9.624	4.112	1.188
California Water Service	CWT	366.49M	21.138	8.859	4.64	1.28
Connecticut Water Service	CTWS	197.83M	26.134	10.804	3.176	0.984
Middlesex Water Company	MSEX	173.90M	24.457	9.746	3.733	1.286
Pennichuck Corporation	PNNW	64.08M	30.248	7.181	2.91	0.923
Philadelphia Suburban	PSC	1.31B	22.631	12.412	2.946	1.405
SJW Corp.	SJW	241.19M	16.179	10.034	3.484	0.788

All the above companies are publicly traded water distribution or water utility companies. Of the 9 listed, 6 reside on the East Coast and 3 on the West Coast. Annual data, from 1992 to 2002, were collected for each company with respect to each variable,

FIGURE 1: LOCATION OF PUBLICLY TRADED WATER UTILITIES USED IN STUDY



AWR: runs So. Cal Water Company

CWT: operates in 25 districts in North.
and South Cal. Serves 1.7 mil ppl

SJW: San Jose Water company serves 988,000 ppl

CTWS: 40 towns through CT and MA, delivery only, not actual pumping

ARTNA: Delaware, serves 67,700 ppl

MSEX: NJ muni water system serves 57,000

PSC: 2 mill ppl served across 3 states

PNNW: NH and MA, serves 26,200 ppl

AWK: owns several water util across 3 states

V, R, p, c, and total extraction. The following map displays the location of each publicly traded water company.

10 years of data across 9 publicly traded water companies comprises a panel data set of 90 observations. I estimate both a fixed effects model and a random effects model while varying the initial reserve stock from a 5 year supply of water to a 40 year supply of water (based on previous 10 years of pumping data). The following Table 2 reports summary statistics for all variables used in the panel regressions:

TABLE 2 SUMMARY STATISTICS FOR ALL VARIABLES USED IN HVP

Variable	Obs	Mean	Std Dev	Min	Max
VR40	70	0.2512	0.1603	0.0758	0.6520
VR30	70	0.3349	0.2137	0.1011	0.8693
VR20	70	0.5023	0.3205	0.1517	1.3040
VR10	70	1.0046	0.6410	0.3033	2.6079
VR5	70	2.0093	1.2821	0.6067	5.2159
hotel	66	1.1162	0.6906	0.1470	2.3369

Where VR40 is the equivalent of V/R with a 40 year supply of water reserves left in the aquifer measured in ($/mg). It can be seen in the means of the data that a straight line appreciation of pumping is assumed. This is potentially fallible depending on the growth rate of the population consuming the water supply. If the population growth rate is linear then the assumption is valid. If the population growth rate is exponential, then a new exponential series of pumpage must be created. In fact, population studies are usually described by logistic growth, but for the purposes of this paper, a linear growth function for pumping is assumed.

"hotel" represents the price less extraction costs (p – c).

5. **Results**

The results of this study find the coefficient of the hotelling values (our Beta, β) to be significantly less than one for the 10 year through the 40 year supply estimates. A beta value less than one indicates the in-situ reserve values are undervalued when compared to the valuation of those same reserves "above ground." These results are similar to the Cairns and Davis results which found the expected hotelling value coefficient of 1 to be an upper bound. However, this study *did find support* for HVP at the 5 year supply estimate. The reason is purely mathematical. From equation (3), if you decrease R, eventually V/R will increase to the point where it equals the hotelling value, or net current prices. It is at the 5 year supply level that HVP holds and in-situ reserves are equal to the above ground price less extraction costs.

Both a fixed effects model and a random effects model were estimated. The fixed effects model estimates the "within" panel variation (a panel being the data for 1 company over 10 years time). The random effects model is a weighted average of the fixed effects (within panel) and between effects (across panel) results. Both estimations control for unmeasured heterogeneity that pooled ordinary least squares ignores. Fixed effects estimates consider only the within-panel variation of values and ignore any between-panel variation. When comparing the estimates from

the fixed effects model and the random effects model, we use the Hausman test of orthogonality. The assumption of orthogonality between regressors and the error term is not rejected indicating the random effects specification to be superior.

The following Table 3 lists the regression results from the fixed effects model and the random effects model for the varying supply levels of R.

TABLE 3 REGRESSION RESULTS FOR FIXED EFFECTS AND RANDOM EFFECTS ESTIMATIONS

	fixed effects				***random effects***			
supply	alpha	alpha=0	beta	beta=1	alpha	alpha=0	beta	beta=1
significance	t=(2.01)		t=(2.21)		z=(1.68)		z=(3.31)	
40yr	0.114*	reject	0.111*	reject	0.095	accept	0.123*	reject
30yr	0.152*	reject	0.148*	reject	0.126	accept	0.163*	reject
20yr	0.228*	reject	0.222*	reject	0.19	accept	0.246*	reject
10yr	0.457*	reject	0.443*	reject	0.379	accept	0.492*	reject
5yr	0.913*	reject	0.886*	accept	0.75	accept	0.983*	accept
rsq	0.0773				0.4788			

* significant at the 90% level

t or z statistics are given in parenthesis above the variable column

Only at the 5 year supply level is the test for beta=1 accepted. All other reserve amounts show beta to be significantly less than one. This indicates that water prices may be rising at a rate significantly less than the interest rate. The second test of the constant coefficient equal to zero is rejected at all levels in the fixed effects model but is not rejected at all levels in the random effects model. Figure 2 illustrates the per-unit value of reserves (V/R) vs. the Hotelling value or net current prices for each level of aquifer supply.

The Hausman statistic, which implies that the random effects estimates are more robust than the fixed effects estimates for this model, is consistent with the R squared values which show the random effects model to have a better fit than the fixed effects model.

FIGURE 2. PER-UNIT RESERVE VALUE (V/R) VS. CURRENT NET PRICE (P-C)

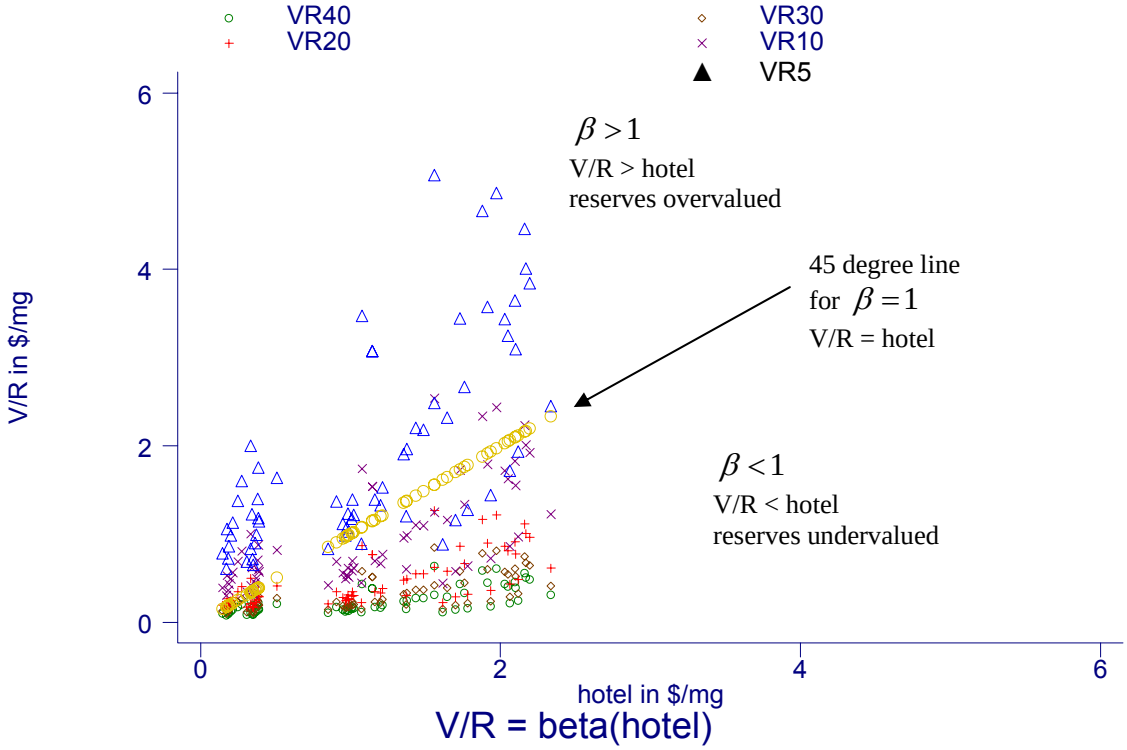


Figure 2 reinforces the Cairns and Davis finding that most of the V/R values will be less than the expected value of 1. Indeed, a 5 year supply of water is an extreme assumption at best. Most analysts assume a 10 to 40 year time horizon when modeling sustainability. Given this timeframe, 88% of the points fall below the 45 degree line which Cairns and Davis label as the upper bound for the Hotelling Valuation Principle. These results indicate the *in-situ* value of ground water reserves are undervalued when compared to their net prices above ground. The present value of future production of ground water is less than the current value of production (net prices).

6. Conclusion

From this study and this specific dataset, we can conclude that the Hotelling Valuation Principle does not hold for water resources, unless you can find an aquifer with only a 5 year supply of water. These results are consistent with the Cairns and Davis studies but contrary to the Miller and Upton study and the Bell et al study. The value of groundwater *in situ* is less than the value of water above the ground less the extraction costs. Or, stated differently, the value of groundwater that has been extracted is worth more than the groundwater *in* situ. Some possible reasons for the difference in these values are: 1) water prices are rising at a rate less than the rate of interest, 2) measurement error may exist in the financial data of the publicly traded water utilities, 3) the use of average cost instead of marginal cost may create a measurement bias and 4) relying on a stock market valuation could be erroneous since it assumes that the stock price is driven only by fundamentals when in fact stock market prices may also be driven by factors such as the economy and the current federal reserve policy.

The control of water utilities in the United States continues to be transferred from the public sector to the private sector. As this trend continues, more data will become available for testing the Hotelling Valuation Principle in water resources. HVP is currently an accepted valuation method for reserves in the gas and oil industry, although it is generally viewed as an upper bound. Other methods of reserve valuation include Discounted Cash Flow (lower bound) and Transaction or Comparable Sales methods in which the reserve values are based on land values from real estate transactions. As the water industry matures, more data will become available to compare the various valuation methods for reserves as is now done in the gas and oil industries.

There are currently 19 water systems publicly traded on the American stock exchanges and many more private operations that exist in rural and urban communities. Water is an exhaustible resource in many areas and should be included in tests of the natural resource theories. Future applications of the HVP to water resources need to find an accurate measure of the groundwater reserves in the aquifer as this study merely performs a sensitivity analysis to determine the effect of varying the initial stock of the resource.

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