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Border Metropolitan Water Forecast Accuracy

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The University of Texas at El Paso

UTEP Border Region Modeling Project

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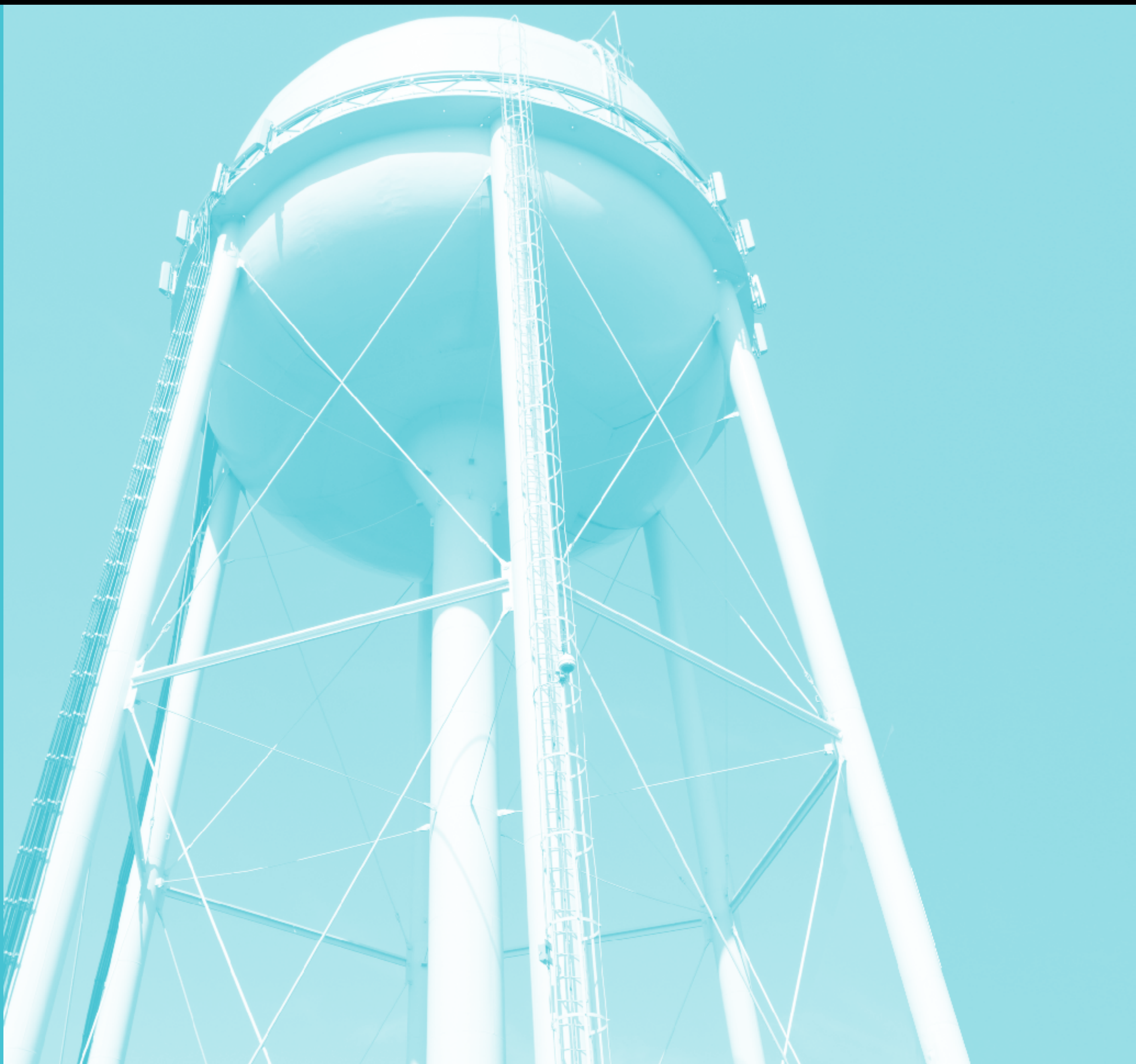

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Border Metropolitan Water Forecast Accuracy*

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Abstract

Municipal water consumption planning is an active area of research due to infrastructure construction and maintenance costs, supply constraints, and water quality assurance. In spite of that, relatively few water forecast accuracy assessments have been completed to date, although some internal documentation may exist as part of the proprietary "grey literature." This study utilizes a data set of previously published municipal consumption forecasts to partially fill that gap in the empirical water economics literature. Previously published municipal water econometric forecasts for three public utilities are examined for predictive accuracy against two random walk benchmarks commonly used in regional analyses. Descriptive metrics used to quantify forecast accuracy include root mean square error and Theil inequality statistics. Formal statistical assessments are completed using 4-pronged error differential regression F-tests. Similar to studies for other metropolitan econometric forecasts in areas with similar demographic and labor market characteristics, model predictive performances for the municipal water aggregates in this effort are mixed for each of the municipalities included in the sample. Given the competitiveness of the benchmarks, analysts should employ care when utilizing econometric forecasts of municipal water consumption for planning purposes, comparing them to recent historical observations and trends to insure reliability. Comparative results using data from other markets, including regions facing differing labor and demographic conditions, would also be helpful.

Introduction

Municipal water consumption research receives substantial attention for several reasons. Among them are infrastructure construction and maintenance costs, supply constraints, and water quality assurance. All of those concerns make accurate planning an important issue for most metropolitan areas throughout the world.

In spite of that, relatively few water forecast accuracy assessments have been completed to date and published. While some internal proprietary analyses of projection accuracy may form part of the "grey literature," these efforts are not publicly available. This study utilizes a data set of water aggregate projections for three separate municipal utilities to partially fill that gap in the academic water economics literature.

Several recent studies have examined the short-term predictive accuracies of monthly time series models of municipal water usage (Fullerton and Elías, 2004; Fullerton, Tinajero, and Mendoza, 2007). Less attention has been directed toward the annual frequency forecasts that are often developed utilizing structural econometric models. Data employed in this exercise are from a regional model that includes blocks of equations for three separate municipal water systems located in two different countries (Fullerton and Schauer, 2001). Water forecasts for those metropolitan economies are published every year, but have not previously been examined for predictive accuracy.

Subsequent sections of the paper are as follows. A brief overview of related studies is presented in the next section. Data and methodology are discussed in the third section. Empirical results are summarized in the fourth section. Concluding remarks and suggestions for future research are in the final section.

Previous Studies

Many of the municipal water consumption modeling efforts to date have involved time series analyses conducted using monthly frequency data (Hansen and Narayanan, 1981; Franklin and Maidment, 1986; Martínez-Espiñeira, R., 2002). These types of models are frequently utilized for annual planning efforts, not only by municipal water utilities, but by electric and natural gas utilities, as well. Predictive accuracy tests using monthly data from several water utilities in recent years indicate that the numbers of users can be forecast fairly reliably. Forecasts of usage per customer generally prove more challenging (Fullerton and Elías, 2004; Fullerton, Tinajero, and Mendoza, 2007).

While monthly forecasts are critical elements for budget year planning exercises associated with annual utility administrative requirements, capacity planning efforts generally require longer range demand simulations and outlooks. The latter forecasts historically have been obtained from either judgmental constructs or from annual frequency data econometric models (Carver and Boland, 1980; Foster and Beattie, 1981; Williams and Suh, 1986). When developing econometric models, much attention is typically directed toward in-sample estimation diagnostics and elasticity magnitudes (Dalhuisen et al, 2003; Worthington and Hoffman, 2008).

To date, comparatively little attention has been directed toward the out-of-sample forecasting track records of econometric models for urban water systems. This probably reflects the difficulty in assembling historical data for these types of annual frequency models. Nevertheless, this is one area in the water economics literature where additional research is required due to the expenses associated with system planning efforts (Billings and Jones, 1996). This study takes advantage of previously published water consumption and customer forecasts data for three separate metropolitan economies. The water consumption and water meter hook-up equations for the three cities are part of a system of simultaneous equations for regional economic activity along the border between Mexico and the United States (Fullerton and Schauer, 2001). The regional econometric model encompasses four urban economies and has been utilized to generate annual frequency econometric forecasts from 1998 forward (Fullerton, 2001a).

For the three municipal water systems for which forecasts are published every year, three additional observations are relevant to out-of-sample predictive accuracy prospects. As noted by Charney and Taylor (1984), population variable estimate revisions frequently lead to notable levels of predictive inaccuracy in regional econometric forecasts. Beyond that, regions with high rates of unemployment also tend to exhibit greater levels of forecast inaccuracy (West, 2003). Finally, weather and business cycles vagaries can directly impact on water usage patterns in unanticipated manners (Billings and Jones, 1996). El Paso, Ciudad Juárez, and Chihuahua City are subject to all of those conditions. Given that, econometric water variable forecasts for these three metropolitan economies likely face uphill battles in the context of accuracy metrics. By emphasizing structural factors that influence water demand, the model forecasts examined herein do, however, meet the guidelines for predictive usefulness proposed by Osborn, Schefter, and Shabman (1986).

Data and Methodology

The forecast data utilized in this effort are taken from the short-term regional forecasts published annually by the Border Region Modeling Project (BRMP) at The University of Texas at El Paso from 1998 through 2007 (for example, see Fullerton and Tinajero, 2005). This includes eighteen categories of water consumption forecasts for El Paso, Texas; Ciudad Juárez, Chihuahua; and Chihuahua City, Chihuahua. Each report contains three-year econometric forecasts for regional employment, income, water, and other important economic barometers. The basic specifications for the per capita water consumption equations are similar to those utilized for other public utility services such as electricity, albeit without cross price variables for substitute goods (Thoma, 2004; Zachariadis and Pashourtidou, 2007; Bianco, Manca, and Nardini, 2009). Summary statistics for water consumption, water meters, population, and employment in all three urban economies are shown in Table 1.

As shown in Table 1, the maximum population in El Paso during the period in question is 729.97 thousand. At one point, it had been anticipated that the El Paso economy would have many more people than that by 2007, but the 2000 census resulted in a large scale downward revision to its population estimate. The initial estimate for 2000 was 716.32 thousand, a figure that was subsequently reduced to 679.62 thousand. That represents more than a 5.1 percent reduction in the number of persons estimated to reside in El Paso, a very large change that then affected historical net migration estimates by proportionally larger amounts in both percentage and absolute terms (see Fullerton, 2001b).

Similar abrupt demographic data adjustments also occur for Ciudad Juárez and Chihuahua City. One example is the 2000 population estimate for Ciudad Juárez. In 2004, that number was 1.219 million. Twelve months later, the population estimate for 2000 was revised upwards by 37 thousand persons to 1.256 million. That 2.9 percent revision also caused proportionally larger changes to the net migration estimates for that city (see Fullerton and Tinajero, 2005).

Because historical customer accounts data for all three municipal utilities are subject to much smaller revisions, it is possible to partially insulate the water system forecasts from the potential errors generally associated with demographic data adjustments. That is achieved by including one period lags of the water meters in the specifications for water customers. Per customer usage forecasts, however, cannot be shielded from the reverberation error impacts of population data revisions and high rates of unemployment and/or underemployment (Charney and Taylor, 1984; West, 2003).

To carry out the accuracy assessments, comparisons are made between the forecasts generated by the BRMP structural econometric model (SEM) with random walk (RW) and random walk with drift (RWD) benchmarks. The RW forecasts are developed by extending the last observed data point forward by three years. The RWD forecasts are generated using the last observed historical percentage change for a particular variable. Both categories of the random walk forecasts have historically provided competitive benchmarks against regional econometric forecasts in other contexts such as transportation and housing (Fullerton, 2004; Fullerton and Kelley, 2008).

There is no reason to anticipate that the data for El Paso, Ciudad Juárez, and Chihuahua City are necessarily representative of municipal water systems at large. The prediction data for these cities are assembled from previously published reports, thus meeting the Klein (1984) and Granger (1996) criteria for accuracy evaluation. Given that, plus the paucity of widely disseminated municipal water forecast assessments, the BRMP data offer a starting point from which to begin to examine questions regarding this general topic. How closely the results and patterns uncovered match those for other regional public utilities is an empirical question that cannot be answered at present.

Theil (1975) inequality coefficients provide the first measure employed to compare the relative accuracy of the SEM, random walk, and random walk with drift predictions. The equation for the Theil inequality coefficient, also known as the U-statistic, is shown below:

$$(1)\quad \boldsymbol{U} = \frac{\sqrt{\frac{1}{n}\sum (Y_t^s - Y_t^a)^2}}{\sqrt{\frac{1}{n}\sum (Y_t^s)^2} + \sqrt{\frac{1}{n}\sum (Y_t^a)^2}}$$

where Y^s are forecast values for the variable of interest during period t, Y^a are actual values, and n is equal to the number of forecast observations. The Theil U-coefficient scales the root mean square error (RMSE) such that it will always lie between zero and one. That is useful because RMSE coefficients, while unit free, are unbounded from above. A U-statistic of one indicates the worst possible degree of forecast inaccuracy, while zero represents the highest feasible level of predictive accuracy.

The RMSE and U-coefficient measures are estimated for each market in the sample. They are intended only for comparison with the same measures for the benchmark extrapolations developed for each market included in the sample and not for accuracy comparisons among the three metropolitan economies. In fact, consumption in El Paso is measured in billions of gallons. In Ciudad Juárez and Chihuahua City, as in many municipal water utilities around the world, consumption is recorded in millions of cubic meters.

In order to further uncover the potential sources of predictive error, proportional second moment components of the forecast are also calculated. The first component, U^M, reveals the error due to bias. The second component, U^S, measures the ability of the forecast to replicate the degree of variability in the series of interest. Lastly, U^C, gauges the degree of unsystematic error within the various forecasts. The equations for these three components are shown below:

$$(2)\quad \boldsymbol{U^M} = \frac{(\overline{Y^s} - \overline{Y^a})^2}{(1/T)\sum (Y_t^s - Y_t^a)^2}$$

bias proportion

$$(3)\quad \boldsymbol{U^S} = \frac{(\sigma_s - \sigma_a)^2}{(1/T)\sum (Y_t^s - Y_t^a)^2}$$

variance proportion

$$(4)\quad \boldsymbol{U^C} = \frac{2(1-\rho)\sigma_s\sigma_a}{(1/T)\sum (Y_t^s - Y_t^a)^2}$$

covariance proportion

where $\overline{Y^s}, \overline{Y^a}$ and s_s, s_a are the means and standard deviations of the Y_t^s, Y_t^a series, respectively, and r is their correlation coefficient. The sum of these components is one; the optimal distribution for U^M, U^S and U^C is 0, 0, 1, respectively. That indicates that bias and variance in forecasts will, ideally, be minimal, and any remaining error will be due to unsystematic variations in the data (Theil 1975).

The second accuracy metric is an error differential regression test (AGS) developed by Ashley, Granger, and Schmalensee (1980). This formal test of predictive accuracy compares the error differentials taken from two competing forecasts. Two separate sets of AGS tests are conducted; one set comparing the SEM predictions with a RW benchmark and the second set comparing the SEM predictions against a RWD benchmark. The null hypothesis tested is shown in Equation 5,

(5) H_0: MSE(e_1) = MSE(e_2),

where MSE stands for mean-squared error, while e_1 and e_2 are competing forecast errors.

For the research at hand, MSE(e_1) represents the mean square error for either random walk benchmark and MSE(e_2) represents the mean square error of the SEM municipal water system forecasts. By defining

(6) $\Delta_t = e_{1t} - e_{2t}$ and $\Sigma_t = e_{1t} + e_{2t}$,

Equation 5 may be re-expressed in the following form,

(7) MSE(e_1) – MSE(e_2) = [cov (Δ,Σ)] + [$m(e_1)^2$ - $m(e_2)^2$],

where *cov* denotes sample covariance for the forecast period and *m* denotes sample mean. SEM forecasts will be judged as superior if the joint null hypothesis that $\mu(\Delta) = 0$ and $cov\ (\Delta,\Sigma) = 0$ can be rejected in favor of the alternative hypotheses described below. Equation 7 yields two regression equations that may be utilized to formally test whether the MSEs are significantly different. In order to determine the structure of the regression equation employed, the signs of the error means must be taken into account.

When the error means are of the same sign, the regression equation used to test the joint null hypothesis is given by

$$(8)\ \Delta_t = \beta_1 + \beta_2[\Sigma_t - m(\Sigma_t)] + u_t,$$

where u_t is a randomly distributed error term. The test for $\mu(\Delta) = 0$ is dependant upon the interpretation of the parameter estimate for β_1. The test for cov $(\Delta,\Sigma) = 0$ relies on the estimated coefficient for β_2. When a positive value for β_2 results, the variance of the corresponding RW, or RWD, forecast errors (e_1) is greater than the variance of the SEM prediction errors (e_2). Given that, a significantly positive β_2 will indicate SEM forecast superiority.

The sign of the error means dictates the interpretation of β_1. When both error means are positive, SEM forecast superiority occurs when the joint null hypothesis that $\beta_1 = \beta_2 = 0$ is rejected in favor of the alternative hypothesis that both are non-negative and at least one is positive. However, SEM predictions cannot be considered more precise than their RW, or RWD, counterparts if either β_1 or β_2 is significantly negative. In addition, if one coefficient is insignificantly negative and the other is positive, a one tailed t-test can be performed to test for significance. When both parameter estimates are positive, a four-pronged F-test can be used to test whether both are statistically different from zero. In this case, the likelihood that both estimates are positive will not be more than one half of the probability obtained from the F-distribution (Ashley, Granger, and Schmalensee, 1980).

While Equation 8 may still be used to test the null hypothesis in cases where both error means are negative, the interpretation of β_1 changes. Under those circumstances, the SEM forecasts are superior if β_1 is found to be significantly negative, and β_2 is either insignificant or significantly positive. The corresponding RW, or RWD, predictions display greater predictive accuracy when a significantly positive β_1 is reported.

When the signs of the forecast error means are opposite, a different regression equation must be employed to test the null hypothesis in Equation 5. Under this circumstance, the dependent variable becomes the sum of the forecast errors:

$$(9)\ \Sigma_t = \beta_1 + \beta_2[\Delta_t - m(\Delta_t)] + u_t.$$

Once again, if $\beta_1 = \beta_2 = 0$, the test fails to reject the null hypothesis in Equation 5. The interpretation of the β_2 coefficient remains unchanged. However, the interpretation of the β_1 estimate now depends on the sign of each error mean. When the RW, or RWD, error mean is negative and the SEM forecast error mean is positive, SEM forecast superiority results when a significantly negative β_1 is accompanied by an insignificant β_2 or by a significantly positive β_2. Furthermore, the SEM forecasts are more accurate if an insignificant β_1 is exhibited along with a significantly positive β_2. When β_1 is significantly positive or β_2 is significantly negative, the RW, or RWD, forecasts are deemed superior.

It is also possible that the RW, or RWD, benchmark error mean may be positive while the SEM forecast error mean is negative. In this case, if either β_1 or β_2 are significantly negative, the RW, or RWD, predictions display greater forecast accuracy. SEM predictions display greater accuracy than the RW, or RWD, benchmark when a significantly positive β_1 is reported along with either a significantly positive or an insignificant β_2 (Ashley, Granger, and Schmalensee 1980; Kolb and Stekler 1993).

Empirical Results

Descriptive measures of predictive accuracy for the SEM forecasts and the RW and RWD counterparts are reported in Table 2. Column 1 of the table lists the variable examined plus the projection technique employed. Column 2 lists the RMSE statistics for each method, while Column 3 lists their respective U-coefficients. Entries that are shown in boldface type are most accurate, while those that are italicized are least accurate. Second moment proportion coefficients help distinguish the nature of the errors within the structural model simulations. Those estimates are reported in Columns 4 through 6 of Table 2.

The previously published SEM forecasts obtain lower inequality statistics than both the RW and RWD benchmarks for seven of the eighteen municipal water variables: El Paso total water meters; El Paso single family meters, El Paso total business meters, El Paso other meter connections, El Paso commercial gallons consumed, Chihuahua City water meters, and Chihuahua City total water consumption. Systematic error generally does not represent a problem for most of the SEM forecasts in the model. Results in Table 2 indicate that bias is associated with the structural model forecasts for El Paso industrial meters, El Paso total gallons consumed, El Paso commercial sector gallons, and Ciudad Juárez total consumption. Some problems are noted within the SEM forecasts with respect to replicating the variability of Chihuahua City water meters. In 9 of the 18 variable categories, more than 50 percent of the out-of-sample simulation errors are random in nature.

Similar to other categories of econometric forecasts developed for the Borderplex regional economies of Las Cruces, El Paso, Ciudad Juárez, and Chihuahua City, the Table 2 SEM comparative forecast performance is mixed (Fullerton, 2004; Fullerton and Kelley, 2006; Fullerton and Kelley, 2008). There are seven water variables where the SEM econometric projections display more accuracy than both of the two benchmark forecasts: El Paso single family meters, El Paso total business meters, El Paso other meters, El Paso commercial gallons consumed, Chihuahua City water meters, and Chihuahua City total water consumption. The RW benchmark outperforms the previously published SEM forecasts for ten variables: El Paso multi family meters, El Paso commercial business meters, El Paso industrial business meters, El Paso total water consumed, El Paso multi family connections, El Paso total business gallons, El Paso industrial gallons consumed, El Paso other water consumption, and Ciudad Juárez total water consumption. The only variable for which the random walk with drift (RWD) forecasts are most accurate is Ciudad Juárez water meters.

While Theil inequality coefficients and their components offer valuable insight into the relative accuracy of each simulation technique along with the potential sources of predictive error, the information provided by them is descriptive in nature. Given that, a statistical test of forecast accuracy is also employed to further examine model reliability. The test utilized is the error differential regression test (AGS) developed by Ashley, Granger, and Schmalensee (1980). Results from this approach are summarized in Tables 2 and 3.

Error differential regression results for the SEM forecasts and the RW random walk benchmark are reported in Table 3. In six cases (El Paso total water customers, El Paso single family meters, El Paso other meter connections, Ciudad Juárez water meters, Chihuahua City water meters, Chihuahua City total water consumption), the results indicate that the SEM forecasts are statistically more accurate than the RW forecasts. Conversely, the outcomes for five variables (El Paso multi family meters, El Paso commercial business meters, El Paso industrial business meters, El Paso other water consumption, Ciudad Juárez total water consumption) suggest that the SEM forecasts are significantly less accurate than the RW benchmarks. In five cases, error differential regression tests yield statistically inconclusive results (El Paso total water consumed, El Paso single family gallons, El Paso multi family gallons, El Paso commercial gallons consumed, El Paso industrial gallons consumed). The results in Table 3 largely confirm the U-statistic tabulations in Table 2.

Table 4 summarizes the error differential regression results for the SEM and the RWD (random walk with drift) forecasts. SEM predictive superiority is indicated for nine of the sixteen variables (El Paso multi family meters, El Paso commercial business meters, El Paso other meter connections, El Paso multi family gallons, El Paso commercial gallons consumed, El Paso industrial gallons consumed, Ciudad Juárez total water consumption, Chihuahua City water meters, and Chihuahua City total water consumption). For the remaining equations, the results favor the RWD technique in five cases (El Paso single family meters, industrial business meters, total water consumed, and other water consumption along with Ciudad Juárez water meters). Statistically inconclusive results are obtained in the error differential regressions estimated for El Paso total water customers and El Paso single family gallons. In the case of El Paso total water customers, the SEM and random walk with drift predictions obtain identical U-statistics (Table 2). The U-statistic reported for El Paso single family gallons favors the SEM forecasts by a seemingly large margin.

Results for the three sets of municipal water system forecasts indicate that the regional econometric approach faces difficulties in terms of overall predictive accuracy.

This is perhaps not surprising. As discussed in Charney and Taylor (1984), econometric forecast errors tend to be large for regions where demographic aggregates are subject to substantial revision. Evidence in West (2003) further indicates that forecast accuracy is difficult to obtain in regions characterized by relatively high rates of unemployment (or underemployment). The metropolitan economies in the sample for this study meet both conditions, making the results obtained empirically plausible.

Internationally, there are a large number of municipal water utilities where these types of obstacles will undoubtedly confront analysts. Econometric models, nevertheless, offer information that still makes them useful. An important lesson can potentially be drawn from the results obtained in this study. Specifically, the random walk results reported in this study may be instructive for other urban water systems. From a planning perspective, they imply that out-of-sample econometric model simulations should be checked carefully against recent historical consumption data. Generation of alternative forecasts under different growth scenarios may also be helpful as a means for allowing analysts to gauge the potential range of conditions that may reasonably be observed in future periods.

Beyond that, the results also contain two further important implications. On balance, the track record to date for the three markets indicates that econometric forecasts do a relatively good job in predicting overall customer base growth. That is similar to what has been previously documented using monthly frequency data (Fullerton and Elías, 2004; Fullerton, Tinajero, and Mendoza, 2007). From a grid capacity perspective, this is helpful because water system infrastructure investments are expensive undertakings and have to rely on annual frequency forecast data such as those analyzed in this study. The ability to plan in advance for future growth can help make that process more manageable. Anticipating future per capita consumption trends is more difficult, implying that accurate projection of regional water supply constraints will continue to be an elusive objective.

Conclusion

Regional econometric models and forecasts are widely used in a number of public utility applications. To date, there have been few documented attempts to assess the out-of-sample predictive accuracy of such models for municipal water systems. This study completes such an exercise for three metropolitan water systems for which previously published forecast data are available. Descriptive and formal inferential metrics are used to gauge econometric forecast accuracy relative to random walk benchmarks.

Empirical results are mixed and indicate that care should be employed when econometric water forecasts are utilized in planning exercises. This is likely to be especially true for municipal water systems located in regions where population data estimates are subject to high degrees of uncertainty and whose labor markets exhibit high levels of unemployment (or underemployment). In such cases, urban water forecasts should be compared to recent historical data, plus model simulations under different growth paths might be useful. If a customer base exhibits a strong trend, comparison to the most recent percentage growth rate will potentially be required. The same holds true for aggregate and/or per capita consumption.

Because forecast assessments for only three urban water systems are employed in this study, it is not known whether these results are representative of municipal water utilities in general. Given that, analysis of metropolitan water consumption for other regions would be helpful. In particular, it would be interesting to conduct similar assessments for areas where population data are subject to smaller revisions and whose labor markets exhibit relatively low rates of excess capacity. It may also prove instructive to carry out such analyses for both larger and smaller water utilities than those included in this effort.

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Table 1.
Summary Statistics for Key Variables

Variable	Mean	Standard Deviation	Maximum	Minimum
El Paso Population	561.942	116.008	729.969	360.462
El Paso Unemployment Rate	8.2	2.8	12.3	3.2
El Paso Total Water Customers	110.257	45.435	193.980	21.560
El Paso Single Family Meters	92.555	36.935	156.248	16.617
El Paso Multi Family Meters	4.432	0.569	4.960	2.226
El Paso Total Business Meters	6.812	1.826	9.409	2.561
El Paso Commercial Meters	6.690	1.762	9.215	2.561
El Paso Industrial Business Meters	0.153	0.040	0.209	0.088
El Paso Other Meter Connections	6.458	7.204	24.064	0.156
El Paso Total Water Consumed	27.123	7.972	36.022	6.129
El Paso Single Family Gallons	15.183	4.287	20.338	3.985
El Paso Multi Family Gallons	2.626	1.041	4.304	0.533
El Paso Total Business Gallons	5.014	1.659	7.997	1.474
El Paso Commercial Gallons	4.171	1.174	7.004	1.474
El Paso Industrial Gallons	1.059	0.774	3.150	0.307
El Paso Other Water Consumption	4.261	1.790	7.296	0.136
Ciudad Juárez Population	727.794	340.159	1359.787	278.995
Ciudad Juárez Total Employment	318.868	71.132	411.485	213.482
Ciudad Juárez Water Meters	133.721	105.349	378.198	16.710
Ciudad Juárez Water Consumption	85.864	52.075	167.014	18.930
Chihuahua City Population	457.225	181.802	787.479	186.100
Chihuahua City Total Employment	159.315	22.536	187.925	130.500
Chihuahua City Water Meters	145.275	66.492	254.611	46.046
Chihuahua City Water Consumption	56.941	7.049	67.816	44.330

Notes:
El Paso population data are reported in thousands.
El Paso water customer meter connections are reported in thousands.
El Paso water consumption data are reported in billion gallons.
Ciudad Juárez population, water meter, and employment data are reported in thousands.
Ciudad Juárez water consumption is reported in million cubic meters.
Chihuahua City population, water meter, and employment data are reported in thousands.
Chihuahua City water consumption data are reported in million cubic meters.
Ciudad Juárez and Chihuahua City employment data are total formal sector jobs covered by the social security system in Mexico.

Table 2.
RMSE and Theil Inequality Statistics for Regional Water Consumption Forecasts

Series	RMSE	U-stat	U-bias	U-var	U-cov
El Paso total water customers					
Structural model	**2.696**	**0.008**	0.369	0.114	0.517
Random walk	*8.974*	*0.026*	0.814	0.000	0.186
Random walk w/ drift	2.965	0.008	0.022	0.288	0.689
El Paso single family meters					
Structural model	**2.368**	**0.008**	0.475	0.191	0.334
Random walk	*6.747*	*0.024*	0.830	0.001	0.169
Random walk w/ drift	2.733	0.009	0.002	0.457	0.541
El Paso multi family meters					
Structural model	0.080	0.008	0.369	0.411	0.220
Random walk	**0.047**	**0.005**	0.114	0.503	0.383
Random walk w/ drift	*0.168*	*0.018*	0.103	0.809	0.088
El Paso total business meters					
Structural model	**0.335**	**0.025**	0.347	0.144	0.510
Random walk	0.402	0.030	0.808	0.001	0.190
Random walk w/drift	*0.484*	*0.036*	0.639	0.010	0.035
El Paso commercial business meters					
Structural model	0.450	0.025	0.414	0.000	0.586
Random walk	**0.362**	**0.021**	0.174	0.005	0.822
Random walk w/drift	*0.734*	*0.042*	0.015	0.478	0.507
El Paso Industrial business meters					
Structural model	*0.011*	*0.028*	0.569	0.079	0.352
Random walk	**0.009**	**0.023**	0.696	0.024	0.280
Random walk w/drift	0.010	0.026	0.000	0.315	0.685
El Paso other meter connections					
Structural model	**1.093**	**0.027**	0.119	0.217	0.664
Random walk	*2.571*	*0.068*	0.692	0.026	0.281
Random walk w/drift	1.546	0.039	0.029	0.287	0.684
El Paso total water consumed					
Structural model	3.221	0.046	0.423	0.354	0.224
Random walk	**2.842**	**0.041**	0.366	0.285	0.349
Random walk w/drift	*3.296*	*0.048*	0.113	0.632	0.255
El Paso single family gallons					
Structural model	0.888	0.023	0.315	0.023	0.661
Random walk	**0.871**	**0.023**	0.201	0.015	0.784
Random walk w/drift	*1.185*	*0.031*	0.004	0.323	0.673

El Paso multi family gallons					
Structural model	0.212	0.031	0.240	0.233	0.527
Random walk	**0.193**	**0.028**	0.384	0.005	0.612
Random walk w/drift	*0.268*	*0.040*	0.049	0.570	0.381
El Paso total business gallons					
Structural model	0.795	0.096	0.772	0.045	0.183
Random walk	**0.635**	**0.077**	0.861	0.011	0.129
Random walk w/drift	0.976	0.118	0.504	0.236	0.260
El Paso commercial gallons consumed					
Structural model	**0.237**	**0.030**	0.676	0.017	0.308
Random walk	0.243	0.031	0.741	0.052	0.207
Random walk w/drift	*0.415*	*0.055*	0.266	0.488	0.247
El Paso industrial gallons consumed					
Structural model	0.112	0.135	0.000	0.003	0.997
Random walk	**0.106**	**0.126**	0.027	0.021	0.953
Random walk w/drift	*0.183*	*0.224*	0.033	0.195	0.773
El Paso other water consumption					
Structural model	*2.335*	*0.152*	0.241	0.456	0.303
Random walk	**2.015**	**0.134**	0.176	0.448	0.376
Random walk w/drift	2.111	0.140	0.171	0.455	0.373
Ciudad Juárez water meters					
Structural model	28.762	0.046	0.118	0.302	0.580
Random walk	*35.150*	*0.058*	0.673	0.110	0.218
Random walk w/drift	**23.110**	**0.037**	0.008	0.722	0.270
Ciudad Juárez total water consumption					
Structural model	15.269	0.046	0.500	0.064	0.436
Random walk	**8.285**	**0.026**	0.001	0.007	0.992
Random walk w/drift	*34.146*	*0.099*	0.226	0.528	0.246
Chihuahua City water meters					
Structural model	**15.987**	**0.037**	0.316	0.335	0.349
Random walk	24.285	0.058	0.808	0.019	0.173
Random walk w/drift	*34.141*	*0.075*	0.181	0.074	0.745
Chihuahua City total water consumption					
Structural model	**4.556**	**0.033**	0.039	0.055	0.906
Random walk	6.336	0.048	0.591	0.001	0.407
Random walk w/drift	*9.388*	*0.070*	0.170	0.214	0.616

Notes:
Boldface type indicates greatest predictive accuracy.
Italicized type indicates least predictive accuracy.

Table 3.
Structural Equation Model and Random Walk Mean Square Error Differential Regression Results

Variable	β_1 (*t*-statistic)	β_2 (*t*-statistic)	*F* (*p*-statistic)	Most accurate
El Paso total water customers (*Both error means negative*)	-6.366 (-8.785)	0.491 (6.641)	19.246 (0.000)	SEM
El Paso single family meters (*Both error means negative*)	-4.464 (-7.226)	0.492 (5.917)	11.491 (0.000)	SEM
El Paso multi family meters (*Both error means positive*)	-0.034 (-2.268)	-0.238 (-2.763)	7.525 (0.001)	RW
El Paso commercial business meters *(Both error means positive)*	-0.145 (-2.885)	-0.042 (-0.724)	1.378 (0.146)	RW
El Paso industrial business meters (*Both error means positive*)	-0.001 (-1.260)	-0.210 (-3.355)	11.257 (0.003)	RW
El Paso other meter connections (*Both error means negative*)	-1.761 (-10.842)	0.181 (2.592)	6.721 (0.008)	SEM
El Paso total water consumed (*Both error means positive*)	-0.369 (-0.675)	-0.067 (-1.134)	6.706 (0.003)	Inconclusive
El Paso single family gallons (*Both error means positive*)	-0.344 (-0.513	-0.141 (-1.820)	9.044 (0.001)	Inconclusive
El Paso multi family gallons (*Both error means positive*)	0.022 (0.296)	-0.129 (-1.613)	11.188 (0.000)	Inconclusive
El Paso commercial gallons consumed (*Both error means positive*)	0.012 (0.130)	-0.066 (-0.653)	4.838 (0.016)	Inconclusive
El Paso industrial gallons consumed (*Both error means positive*)	0.015 (3.339)	-0.031 (-1.486)	2.209 (0.081)	Inconclusive

El Paso other water consumption (*Both error means positive*)	-0.300 (-2.419)	-0.043 (-1.525)	5.113 (0.008)	RW
Ciudad Juárez water meters (*Both error means negative*)	-18.971 (-3.326)	-0.206 (-1.436)	2.061 (0.084)	SEM
Ciudad Juárez total water consumption (*RW error mean negative; LTF error mean positive*)	11.428 (1.615)	-0.497 (-0.888)	3.870 (0.021)	RW
Chihuahua City water meters (*Both error means negative*)	-14.804 (-2.887)	0.158 (1.466)	1.297 (0.152)	SEM
Chihuahua City total water consumption (*Both error means negative*)	-3.978 (-8.038)	-0.052 -(0.866)	0.751 (0.200)	SEM

Table 4.
Structural Equation Model & Random Walk with Drift Mean Square Error Differential Regression Results

Variable	β_1 (*t*-statistic)	β_2 (*t*-statistic)	*F* (*p*-statistic)	Most accurate
El Paso total water customers (*Both error means negative*)	1.196 (1.833)	0.079 (1.127)	5.769 (0.005)	Inconclusive
El Paso single family meters (*Both error means negative*)	1.510 (5.135)	0.254 (3.641)	13.253 (.001)	RW w/drift
El Paso multi family meters (*Both error means positive*)	0.015 (0.356)	0.662 (7.207)	34.162 (0.000)	SEM
El Paso commercial business meters (*Both error means positive)*	-0.243 (-1.075)	0.456 (2.936)	10.397 (0.001)	SEM
El Paso industrial business meters (*Both error means positive*)	-0.00 (-4.539)	0.187 (1.641)	2.692 (0.062)	RW w/drift
El Paso other meter connections (*Both error means negative*)	0.013 (0.045)	0.190 (4.257)	16.968 (0.000)	SEM
El Paso total water consumed (*Both error means positive*)	-0.968 (-1.941)	0.095 (1.138)	4.444 (.012)	RW w/drift
El Paso single family gallons (*Both error means positive*)	-0.441 (-1.475)	-0.222 (1.420)	5.313 (.007)	Inconclusive
El Paso multi family gallons (*Both error means positive*)	-0.042 (-0.845)	0.198 (2.084)	6.307 (.004)	SEM
El Paso commercial gallons consumed (*RW w/ drift error mean negative; LTF error mean positive*)	-0.019 (-0.334)	0.597 (4.394)	19.309 (.000)	SEM
El Paso industrial gallons consumed (*RW w/ drift error mean negative; LTF error mean positive*)	-0.027 (-0.164)	1.490 (2.374)	5.685 (.010)	SEM

El Paso other water consumption (*Both error means positive*)	-0.286 (-3.132)	-0.017 (-0.451)	8.886 (.001)	RW w/drift
Ciudad Juárez water meters (*Both error means negative*)	7.839 (1.473)	-0.102 (-0.848)	0.720 (0.203)	RW w/drift
Ciudad Juárez total water consumption (*Both error means positive*)	4.685 (0.671)	0.532 (9.092)	63.293 (0.000)	SEM
Chihuahua City water meters (*RW w/ drift error mean positive; LTF error mean negative*)	9.692 (0.955)	0.617 (6.447)	28.440 (0.000)	SEM
Chihuahua City total water consumption (*Both error means negative*)	-2.786 (-1.308)	0.342 (2.692)	9.710 (0.001)	SEM

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The authors of this publication are UTEP JP Morgan Chase Bank Professor Tom Fullerton and UTEP Associate Economist Angel Molina. Dr. Fullerton holds degrees from UTEP, Iowa State University, Wharton School of Finance at the University of Pennsylvania, and University of Florida. Prior experience includes positions as Economist in the Executive Office of the Governor of Idaho, International Economist in the Latin America Service of Wharton Econometrics, and Senior Economist at the Bureau of Economic and Business Research at the University of Florida. Angel Molina holds an M.S. in Economics from UTEP and has published research on cross-border regional growth patterns.

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The UTEP Border Region Modeling Project & UACJ Press

Announce the Publication of

Basic Border Econometrics

The University of Texas at El Paso Border Region Modeling Project is pleased to announce Basic Border Econometrics, a publication from Universidad Autónoma de Ciudad Juárez. Editors of this new collection are Martha Patricia Barraza de Anda of the Department of Economics at Universidad Autónoma de Ciudad Juárez and Tom Fullerton of the Department of Economics & Finance at The University of Texas at El Paso.

Professor Barraza is an award winning economist who has taught at several universities in Mexico and has published in academic research journals in Mexico, Europe, and the United States. Dr. Barraza currently serves as Research Provost at UACJ. Professor Fullerton has authored econometric studies published in academic research journals of North America, Europe, South America, Asia, Africa, and Australia. Dr. Fullerton has delivered economics lectures in Canada, Colombia, Ecuador, Finland, Germany, Japan, Korea, Mexico, the United Kingdom, the United States, and Venezuela.

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Contributors to the book include economic researchers from Tthe University of Texas at El Paso, New Mexico State University, University of Texas Pan American, Texas A&M International University, El Colegio de la Frontera Norte, and the Federal Reserve Bank of Dallas. Their research interests cover a wide range of fields and provide multi-faceted angles from which to examine border economic trends and issues.

A limited number of **Basic Border Econometrics** can be purchased for $10 per copy. Please contact Professor Servando Pineda of Universidad Autónoma de Ciudad Juárez at spineda@uacj.mx to order copies of the book. Additional information for placing orders is also available from Professor Martha Patricia Barraza de Anda at mbarraza@uacj.mx.

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Professor Calderón is an award winning economist who has taught and published in Mexico, France, and the United States. Dr. Calderón spent a year as a Fulbright Scholar at The University of Texas at El Paso. Professor Fullerton has published research articles in North America, Europe, Africa, South America, and Asia. The author of several econometric forecasts regarding impacts of the Brady Initiative for Debt Relief in Latin America, Dr. Fullerton has delivered economics lectures in Canada, Colombia, Ecuador, Finland, Germany, Japan, Korea, Mexico, the United States, and Venezuela.

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