Water Resources Research

COMMENT
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Key Points:
- Contrary to a recent study's claims, there is little statistical relationship between water scarcity and pricing for conservation
- Contrary to a recent study's claims, water for essential use is not more expensive than for nonessential use in water-scarce regions
- Future research should use larger samples and better measurement to investigate the relationships between scarcity and prices

Supporting Information:
- Supporting Information S1

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Comment on "U.S. Urban Water Prices: Cheaper When Drier" by Ian H. Luby, Stephen Polasky, and Deborah L. Swackhamer

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Abstract In a recent article in this journal, Luby, Polasky, and Swackhamer come to the provocative conclusion that urban water prices in the United States are "cheaper when drier." They also argue that utilities fail to provide affordable water and that they charge less for "additional" use compared to "essential" use. We challenge these claims. While the authors correctly point out the many challenges that utilities face in supplying affordable water while meeting conservation and revenue goals, there are serious flaws in their measures of price, scarcity, and affordability. These measurement problems lead the authors to incorrect conclusions about water pricing in the United States. Using improved measures of price and water scarcity, we find little statistical relationship between the marginal price of water/sewer services and scarcity. Our findings cast doubt on Luby et al.'s findings and point to important avenues for future research.

1. Introduction

In a recent article in this journal, Luby et al. (2018) analyze water and sewer utility pricing in 35 major American cities, with an aim of evaluating "the use of pricing in managing physical water scarcity." Luby et al. do an excellent job of describing many of the challenges facing utilities in setting rates; their section 2 provides a solid overview of the multiple values that governments consider when setting rates. The authors correctly observe that, as public agencies, urban water suppliers in the United States must consider efficiency alongside other social goals like equity and affordability when setting prices. They argue that these other goals keep public utilities from setting prices equal to marginal cost. Their discussion of water pricing culminates with what amounts to three generally sensible hypotheses (p.3), which is provided as follows:

1. "To address scarcity, we would expect prices per unit to be higher in water-stressed areas";
2. "To address water scarcity and cover costs, we would expect higher rates on additional water use (increasing block rates)"; and
3. "To address equity concerns we would expect low prices on the first block of essential water use."

The first of these is the main focus of the article, as its title suggests. Their 35-city analysis of water and sewer prices finds that, contrary to both intuition and economic orthodoxy, "cities facing the most water stress have the lowest prices" (1). They also find that prices are lower for "additional" water use than for "essential" water use. These results are provocative, with potentially important policy implications for water-scarce regions.

In this paper we challenge Luby et al.'s analysis and their inferences about water pricing. Significant methodological problems give reason to doubt their principal finding that water is "cheaper when drier" in America. Both of the main variables in their analysis—water prices and water scarcity—are measured inaccurately for purposes of understanding pricing as a means of achieving resource efficiency. These problems lead Luby et al. to the wrong conclusion about the relationship between scarcity and pricing. To demonstrate these problems, we reanalyze the same 35 cities with more appropriate metrics and methods and find no meaningful relationship between price and water scarcity.

2. Recollection of Rates Data

To conduct our reanalysis, we collected new rates data rather than relying upon Luby et al.'s replication data set for three main reasons. First, it is impossible to distinguish between fixed and the variable prices in Luby

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et al.'s replication data set; they simply provided total prices at zero to 30 hundred cubic feet (ccf) for each city. This format makes it impossible to disentangle fixed from variables prices.

Second, Luby et al.'s treatment of sewer rates was ambiguous. Luby et al. include the price of sewer service in their measure of water pricing. That is an important merit of their study, since drinking water and sewer services are provided by the same entity in most of the cities that they analyze, and customers pay for both services with the same bill. But Luby et al.'s depiction of sewer rates is unclear. The authors note that the "negative relationship between water price and water scarcity also persists when we exclude sewer rates for the subset of cities for which we have separate water and sewer rate information" (4), but they do not identify which cities are included or excluded in these tests. In eight of the utilities that they analyze, volumetric sewer rates are charged according to average winter water use, not total use. That is, customers are not charged a volumetric rate for sewer consumption above their winter average use. The rationale for such rate structures is that average winter consumption reflects indoor water use, which typically results in wastewater flowing into the sewer system. Since water beyond winter average use is mostly for outdoor irrigation, these utilities do not bill that use for sewer services. Luby et al. do not explain how they deal with this complication.

Third, Luby et al. are not clear about how they deal with water budgets, which are used by 3 of the 35 drinking water utilities that they analyze (Denver, Los Angeles, and Riverside). Water budgets impose individualized rate structures that vary from one residential customer to another. Water budgets may present customers with very high or very low marginal costs at various consumption levels, depending on characteristics of their homes, land, and households. It is possible that not all of these utilities employed water budgets in 2015 when Luby et al. gathered rate information, but based on the links provided in their appendix, at least one did use a water budget at the time. Luby et al. do not mention how they dealt with these rates. Additionally, some inconsistencies in Luby et al.'s replication data set also made us reluctant to use it. For example, they report that water prices in Tampa drop by almost $80 between 26 and 27 ccf. It also is not always clear whether their calculations include sewer charges. Finally, although most of the 35 utilities' rate schedules set prices by hundred cubic feet, others use thousand gallon units. It was not clear that Luby et al. consistently transformed charges to reflect differences in units.

In light of these data problems, in September 2018, we collected current water and sewer rates each of the cities that Luby et al. analyzed. In cases where drinking water and sewer services are provided by different organizations, we gathered sewer rates from the agency that provides sewer services in the city. For example, Northeast Ohio Regional Sewer District provides sewer services in Cleveland, and so we use the district's rates to calculate sewer costs in that city. For systems that apply volumetric sewer rates to winter average volume, we capped volumetric charges at the equivalent of 8 ccf. For those utilities that used water budgets, we estimated blocks based on either provided estimates of average use or on estimated national averages (DeOreo et al., 2016).

3. Problems With Price Measurement and Reanalysis

Several problems with Luby et al.'s analysis follow from the way that they measure the price of water. These problems lead to incorrect inferences.

3.1. Total Versus Marginal Price

The measures of price that Luby et al. use are not appropriate to the claims they make about the prices of "additional water use" and "price per unit." Specifically, rather than measuring marginal price (the price for the last unit of water consumed), they measure total price at 8, 12, and 16 ccf. These total prices include both fixed and volumetric elements. In addition to volumetric prices, residential customers pay fixed periodic charges for water service in 30 of the 35 utilities that they analyze; 25 of these cities impose fixed charges for sewer service, too. These fixed charges can be quite substantial.

According to basic microeconomic theory and much of the research literature that Luby et al. cite, the crucial price for purposes of resource efficiency is *marginal* price, not total price. For prices to affect consumer behavior, the customer's costs must vary with the volume of water consumed. For Luby et al.'s first and second hypotheses, the relevant metric is the marginal price of the last unit of water consumed, not the total

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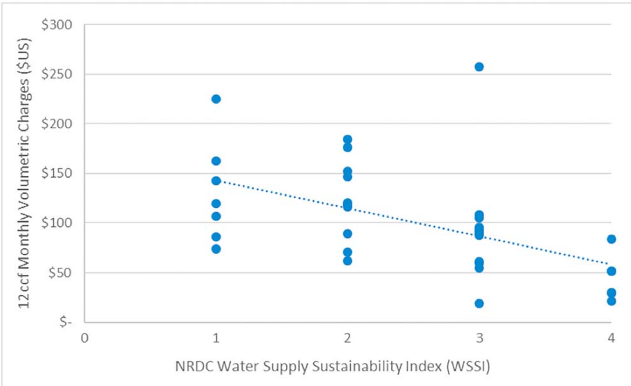

Figure 1. Monthly residential water and sewer volumetric charge for 12 ccf of water as a function of the Water Supply Sustainability Index. A score of 1 is low risk and a score of 4 is extremely high risk of water shortage by 2050. NRDC = Natural Resource Defense Council.

price of water at a given volume. By including fixed costs in their measure of price, Luby et al. understate the efficiency signals that water customers receive with higher marginal use.

In order to see how the use of total price rather than marginal price may have affected Luby et al.'s finding that water prices are "cheaper when drier," we explored the relationship between the volumetric price of 12 ccf of water consumption (i.e., excluding fixed costs) and the Natural Resource Defense Council's (NRDC) Water Supply Sustainability Index (WSSI), Luby et al.'s chosen measure of water scarcity. Figure 1 shows this relationship. Although the ordinal ranking of the cities changes somewhat, the overall picture is remarkably similar to Luby et al.'s Figure 1: As WSSI score increases, 12-ccf price declines. The correlation between WSSI and the total price at 12 ccf is fairly high at −0.471 and therefore is consistent with Luby et al.'s findings. This consistency is important because it establishes that our subsequent differences in analysis are not driven by underlying differences between 2015 and 2018 rates.

3.2. Elasticity

Luby et al. rest their claims about the relationship between scarcity and price on comparative total prices at 12 ccf, a level that approximates average residential water use in the United States (Dieter et al., 2017). Problematically for their analysis, the first 12 ccf of water includes a significant amount of water for essential use; in fact, Luby et al. define "essential use" as 8 ccf monthly for a family of four. The problem is that essential use—water for drinking, cooking, bathing, cleaning, and sanitation—is relatively price inelastic. Although some behavioral changes and increased efficiency of appliances may reduce essential use, major differences in price at lower levels of consumption will likely have little effect on resource conservation. The average U.S. household uses about 5.6 ccf of water a month for indoor use alone (DeOreo et al., 2016), which aligns closely with Chenoweth's (2008) claim that 35.6 gallons per capita per day (a little less than 6 ccf per month for a family of four) is the "minimum water requirement for social and economic development." Water use is unlikely to fall significantly below this level in a modern country, no matter how it is priced.

Thus, about half of the consumption that Luby et al. calculate for their main price metric is mostly inelastic to price signals. In reality, pricing to encourage conservation is sensibly focused on the highest volume users, whose consumption may be more elastic. Even if Luby et al. had considered the volumetric price without including fixed costs, marginal pricing at 12 ccf would not accurately depict the level at which pricing would matter for conservation.

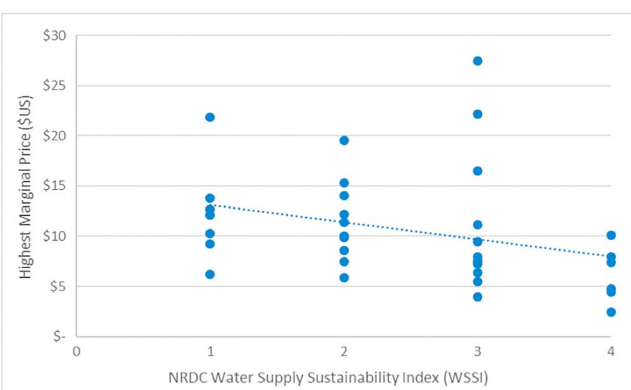

Figure 2. Highest marginal water/sewer price charged for 1 ccf of consumption as a function of the Water Supply Sustainability Index. A score of 1 is low risk and a score of 4 is extremely high risk of water shortage by 2050. NRDC = Natural Resource Defense Council.

As an alternative measure of the conservation price signals of water rates, we instead analyze the highest marginal unit price of water for 1 ccf of consumption in the first 30 ccf charged in each city. Figure 2 shows the relationship between the WSSI and the highest marginal price. Once again, it appears that the marginal price is lower when WSSI is higher, although in this case it the relationship is not as strong, at only −0.221.

4. Problems With Scarcity Measurement and Reanalysis

A number of problems with WSSI make it a poor metric for purposes of analyzing the relationship between water scarcity and prices.

4.1. 2050 Projections

First, the WSSI is an engineering firm's 2010 *projection* of water supply shortage risk in 2050, not a measure of *current* water scarcity. NRDC developed the WSSI with a goal of understanding the impact of climate change on future water risk. The authors do not make this distinction clear and indeed claim that WSSI is "based on current weather patterns."

While WSSI projections are based on current weather patterns, they do not necessary reflect current water scarcity. Repeatedly, Luby et al. indicate that WSSI measures current scarcity with present tense language. They suggest that "the least expensive water in the country is found in the cities with high water scarcity" (p. 1), and that "cities with high water scarcity dominate the ranks of low-price cities" (p. 4). The only point at which the authors mention that WSSI is a projection to 2050 is in the caption to Figure 1. At best, this is an expository failure; at worst, it is misleading since the authors claim repeatedly that the WSSI measures water scarcity.

The WSSI's focus on the future makes it ill-fitting for Luby et al.'s purposes. It seems unreasonable to expect that projected water supply risk 40 years in the future (rather than past or present supply risk) would explain current water rates. There is surely merit in evaluating the utilities' preparedness to deal with potential water risk due to climate change, but that is not Luby et al.'s stated analytical aim.

4.2. Sustainability Versus Scarcity

As its name suggests, WSSI is not a measure of projected climatological water *scarcity* at all; rather, it is a measure of projected *sustainability*, understood as stress for water resources in a region (NRDC 2010). In addition to climatological projections, it includes projections for population growth. Nowhere does the NRDC's report itself refer to the WSSI as a measure of moisture (NRDC 2010). While population growth and climate change may certainly stress water supply conditions in a region, they are not what the authors imply with their title or language: that urban water prices are "Cheaper When Drier." At no point do the authors mention that the measure of water scarcity is really a measure of risk to water supplies from both climatological and demographic stressors; they mention only WSSI's climatological aspects. It is reasonable to consider both the demand side and supply side of water use when it comes to evaluating urban water rates, especially since many definitions of "water scarcity" do consider both supply and demand side factors (Jaeger et al., 2013). Luby et al.'s title and rhetoric, however, suggest only the supply side.

The WSSI lacks even face validity as a measure of moisture. A cursory look at the WSSI ratings for the utilities Luby et al. analyze shows the problem with WSSI as a scarcity metric. Consider Las Vegas, which sits in the middle of the Mojave Desert: WSSI assigns it score of 3—the same rating it gives to Charlotte, Columbus, and Philadelphia. Using the correlation of water prices with such a measure to claim that utilities in drier areas charge less for water is simply incorrect.

4.3. Categorical Versus Continuous Metrics

Finally, WSSI is a categorical variable that is meant to capture a continuous phenomenon. WSSI assigns each U.S. County a value on a 4-point scale based on whether it meets a series of five criteria related to water sustainability (NRDC 2010). It does not specify which criteria are being met or the variation within the categories. A more continuous measure of scarcity for evaluating water prices would more adequately capture the variation across cities.

4.4. The Palmer Index

In order to capture current water scarcity conditions in continuous terms, we employ the Palmer Drought Severity Index (PDSI), the most commonly used measure of regional moisture levels. The PDSI assigns values to the level of water environmental supply/demand in a region (Palmer, 1965). The zero-centered index ranges from dry to moist, with a value of −4 or below suggesting that an area is in extreme drought, while a value of 4 or above means that an area is extremely wet. We calculated the average monthly PDSI for the 10-year period from 2008 to 2017 to create a measure of water moisture levels for each city. Unsurprisingly, this measure does correlate well with the WSSI ($p = -0.52$). Although the PDSI does not fully capture water scarcity as a demand and supply side phenomenon, it is a more appropriate measure of scarcity for present purposes than the WSSI, especially since the language in Luby et al.'s paper suggests they were primarily interested in scarcity as a supply side phenomenon.

As a first look at the relationship between our scarcity measure and price, we examine how the total price for 12 ccf of usage, including fixed costs, is associated with scarcity measured with PDSI.

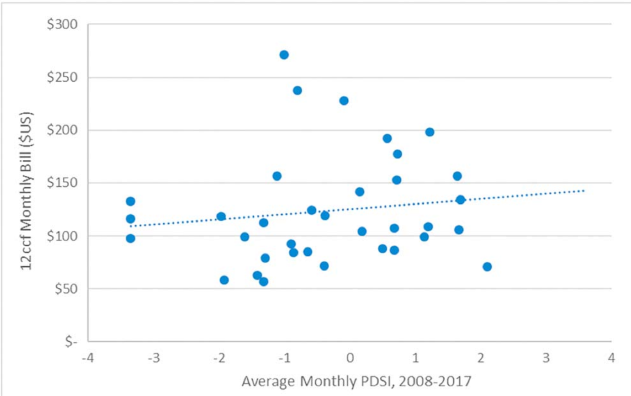

Figure 3. Monthly residential water and sewer utility bill for a household of four using 12 ccf of water as a function of monthly average PDSI from 2008 to 2017. Higher PDSI indicates moister regions. PDSI = Palmer Drought Severity Index.

Figure 3 shows that, while utilities in drier regions charge slightly less for water, the relationship is weak: The correlation between average monthly PDSI and total price for 12 ccf is just 0.13. Even when using total price rather than marginal price, there is only weak support for Luby et al.'s claim.

However, there is essentially no meaningful correlation between highest marginal price and average monthly PDSI, at least among these 35 cities. Figure 4 shows the relationship between highest marginal price and average monthly PDSI, with a correlation approaching zero at just −0.012. This is perhaps evidence that prices do not relate to scarcity in the way that we would expect, but it is not evidence that prices are "cheaper when drier."

5. Increasing Volumetric Prices?

Luby et al.'s second major inquiry deals with the difference in price between essential use and "additional use." They suggest that to "to address water scarcity and cover the cost of provision, prices for water beyond essential use may need to be substantially higher" (5). The authors do not mean to evaluate how well rate structures cover costs, because they do not have data on utilities' capital and operating costs. Rather, their analysis of "prices beyond essential use or additional use" is another way of investigating how conservation-oriented rates are. To do so, they measure the difference between total prices at 8 and 16 ccf. Luby et al. label this interval the price of additional use and then compare it to the price of water at 8 ccf (essential use). Among the 35 cities they analyze, the authors find that "that only 13 cities have higher prices, 20 cities have lower prices, and 2 cities have constant prices" for additional use (p. 5). This result, they argue, shows that utilities are failing to encourage efficiency because the majority of areas have lower prices for additional use than total prices for essential use.

There are at least two significant problems with this analysis. First, Luby et al. once again fail to address sewer rate structures that cap charges at winter average use. Calculating the price from 8 to 16 ccf without considering that some utilities cap sewer charges based on winter use may lead to misleading findings. This is especially true since three of the utilities that Luby et al. estimate as having the largest difference between the prices charged for essential and additional use (Los Angeles, Austin, and Phoenix) employ winter average caps for sewer charges. Second, Luby et al. suggest that they are interested in examining the differences between the prices at the different levels of consumption in part because utilities should be addressing scarcity through increasing block rate pricing. But their analysis once again includes fixed prices for the first 8 ccf of consumption, so their analysis really compares the *total* price of essential use with the *marginal* price of additional use. After correcting these issues, we found that the majority of cities had higher marginal prices from 8 to 16 ccf than for the first 8 ccf: 21 of the areas had higher prices, 5 had the same price, and 9 had lower prices. Further, six of the nine who charged lower marginal prices for the higher consumption block use winter average caps for their volumetric sewer rates.

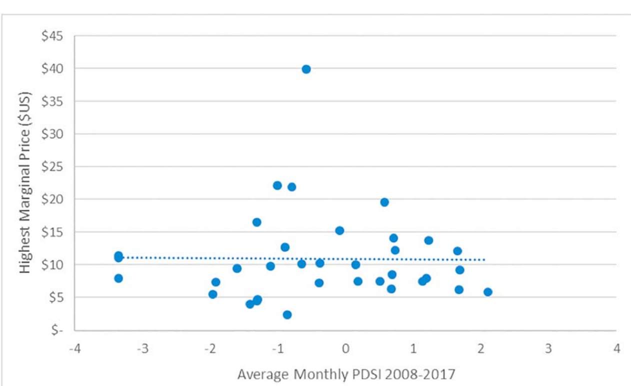

Figure 4. Highest marginal water/sewer price charged for 1 ccf of consumption as a function of monthly average PDSI from 2008 to 2017. Higher PDSI indicates moister regions. PDSI = Palmer Drought Severity Index.

However, the primary difficulty with Luby et al.'s argument about essential versus additional use prices is logical, not methodological. It is difficult to see what they are arguing is wrong with water pricing for additional use. Is it that prices are not high enough for additional use compared to essential use, and so are not sufficient to cover costs? It would be difficult to suggest that these utilities are not meeting their costs without more detailed information on revenues and expenditures. Is the problem affordability? The price of water beyond essential use is not relevant to affordability.

Luby et al. may be arguing that prices are not high enough on additional use compared to essential use and so do not adequately reflect scarcity.

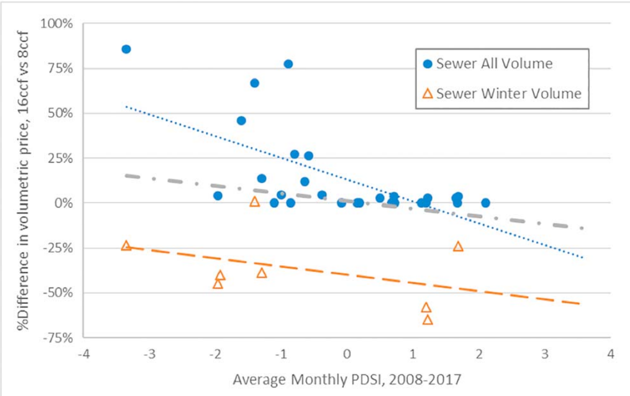

Figure 5. Percent difference in volumetric price between additional and essential use as a function of monthly average PDSI from 2008 to 2017. Higher PDSI indicates moister regions. Triangles represent cities that cap sewer charges at winter average volume. Dotted line shows average for cities that apply sewer volume charges for all water consumption; dashed line shows average for cities that cap sewer volume charges at winter average consumption. Compound line shows overall average. PDSI = Palmer Drought Severity Index.

The authors do not directly test this possibility, as they do not show how the difference in price between the first 8 ccf and second 8 ccf correlates with WSSI. In Figure 5, we show the relationship between PDSI and the percent difference in *volumetric* prices (excluding fixed charges) at 8 and 16 ccf. The heavy compound line in the middle of the graph shows that, similar to the relationship between highest marginal cost and scarcity, there is very little meaningful relationship between scarcity and the percent difference in the marginal price of the first 8 ccf and second 8 ccf. The average difference is slightly higher in utilities in drier regions, but the correlation is weak. The correlation changes markedly, however, when accounting for structural differences in sewer billing. The dashed line in the lower part of Figure 5 depicts the correlation for the eight cities that cap volumetric sewer rates at winter average volume. Notably, volumetric prices at 16 ccf are all lower than at 8 ccf in these cities, because sewer charges do not apply to the second 8 ccf. The higher dotted line shows the correlation for cities that charge volumetric sewer rates for all volume. The result is striking: The difference between 8- and 16-ccf volumetric prices now declines steeply with scarcity ($\rho = -0.64$). Thus, it appears that winter average sewer rates—not water rates—account for much of the difference between 8- and 16-ccf prices that Luby et al. observe.

6. Conclusion

Our examination and reanalysis of water pricing in the 35 largest U.S. metropolitan areas does not support Luby et al.'s main claim that U.S. water prices are “cheaper when drier.” Once improved measures of prices and scarcity are applied, there appears to be no meaningful relationship between scarcity and price. We also find no evidence to support their conclusions about the relative prices of essential and additional use of water.

We wish to emphasize that none of the findings in Luby et al.'s article or this comment should be seen as representative of the United States as a whole. Luby et al. (2018) claim that “As a *general rule* U.S. urban water prices do not satisfy either scarcity or equity pricing principles” (6, italics added). There are thousands of water systems in the United States, and these systems vary widely in demographic, economic, political, and climatological conditions; Luby et al. analyze 35 of them. Inferring a pattern—let alone a “general rule”—based on simple bivariate correlations within a very small, nonrandom sample is inappropriate. While these are important findings, we think our analysis mostly points to opportunities for further research, rather than conclusions about water pricing in the United States. Future research on water pricing should measure pricing appropriately, look beyond the largest utilities, and seek to identify the natural, institutional, and social causes of variation in utility pricing in the United States.

Data

All data used in this analysis are available in the supporting information.

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