Willingness to Pay for Perceived Increased Costs of Water and Wastewater Service in Shrinking US Cities: A Latent Class Approach

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Abstract: Chronic population decline in cities nationwide has resulted in increased per capita costs for continued service of water and wastewater infrastructure. Due to the high fixed costs associated with water and wastewater infrastructures and this chronic population decline, the financial burden to maintain and operate the fixed-grid footprint has become a challenge for those who reside within these shrinking cities. With this in mind, the understanding of public opinion toward the provision of service provided by critical infrastructure sectors is crucial for informed decision making by both utilities and state agencies. Hence, this study seeks to present a new methodological approach to assess the willingness to pay for the provision of water and wastewater services, and to evaluate the drivers of the willingness to pay in shrinking cities. A latent class Tobit regression modeling approach is proposed to identify and understand the influential variables associated with a stated preference survey on the willingness to pay for increased rates in shrinking cities. In addition, the modeling approach can more accurately capture the unobserved heterogeneity across the nationwide shrinking cities. The results illustrated that the latent class Tobit outperformed the more basic Tobit model and accounted for unobserved heterogeneity. Moreover, characteristics determining an increased willingness to pay for improved reliability of water and wastewater service included the responsibility of paying the water bill, homeownership, and income level. Characteristics determining a decreased willingness to pay for improved reliability of water and wastewater service included gender, awareness of chronic population decline, having no income, marital status, and employment status.
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Introduction

A shrinking city is a classification type arising from chronic population decline over multiple decades. Characteristic to these shrinking cities are increased per capita costs to ensure the continued service of water and wastewater infrastructure sectors (Faust et al. 2016a). Due to the high fixed costs associated with water and wastewater infrastructure and the continual decrease in users over multiple decades, the financial burden to maintain and operate the fixed-grid footprint has been passed on to the end users (Rybczynski and Linneman 1999; Butts and Gasteyer 2011; Faust et al. 2016a). The primary driver of urban decline in many US cities is rooted in deindustrialization (e.g., evolution of the automobile and manufacturing industries in the rust belt cities), subsequently resulting in people with the means, skills, and abilities often leaving in pursuit of other employment opportunities (Martinez-Fernandez and Wu 2009; Pallagst 2008). Notably, other causes of this urban decline include drivers such as population transitions, including declining birth rate or aging populations, and climate factors, such as natural disasters and prolonged droughts (Martinez-Fernandez and Wu 2009). This population decline often consequentially results in the city's poverty rate increasing to upward of 40% (e.g., Flint, Michigan = 41.6%; Saginaw, Michigan = 35.5%; Detroit = 39.8%; Baltimore = 39.8%; Gary, Indiana = 38.7%; and Cleveland, Ohio = 35.9%), well above the national poverty rate of 14.8% (Faust et al. 2016a; US Census Bureau 2016), passing on the burden of water and wastewater infrastructure associated costs to communities least equipped to pay the corresponding increased utility rates.

In response to the decreased number of rate payers and in order to mitigate the magnitude of rate increases, utilities in shrinking cities have taken measures such as the continual reduction of personnel and reactive maintenance to operate on reduced funds (Faust et al. 2016a). These consequential decisions made under the present-day financial constraints characteristic to many shrinking cities among water and wastewater utilities is unsustainable to maintain the same level of service (Faust et al. 2016a). However, contrary to many shrinking city utilities' perceptions, a majority of users indicated that they are willing to pay increased rates for water and wastewater service if they understood the benefits or had a perceived increase in reliability (Faust et al. 2016a). Reliability, as defined in Faust et al. (2016a) and this study, is the *perceived* improved quality (e.g., water quality received or reduced combined sewer overflows) or operational characteristics (e.g., fire flows, pressures, and reduced disruption of service) associated with the level of service provided. Although there is often a disconnect between perceived system performance and actual system performance, it is nonetheless important to consider the end users' (i.e., the consumer in the context of water service) views of the service provided. In the context of decision making, there is an intrinsic relationship between policies and public perceptions (Burstein 2003; Soroka and Wlezien 2004; Gray et al. 2004).

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Previous public opinion literature in the context of urban decline has evaluated quality of life and land use in the context of abandonment and vacancies without considering the provision of infrastructure services and impact of urban decline on critical infrastructure services, including underground infrastructure, which is particularly of interest to this study (Greenberg and Schneider 1996; Bright 2000; Hollander 2010, 2011). Understanding the public opinion toward the provision of service provided by critical infrastructure sectors, captured in this study as the willingness to pay (WTP), is crucial for informed decision making by the utility and shaping disseminated information (Hensher et al. 2005; Castro et al. 2016).

Surveys and survey analysis techniques have been used to evaluate consumer stated preference WTP to provide insight into users' perceived valuation of and inclination to pay for services and goods. Previous stated preference WTP surveys have been conducted worldwide (Whittington et al. 1990; Merrett 2002; Raje et al. 2002; Hensher et al. 2005; Willis et al. 2005; Genius et al. 2008; Wang et al. 2010; Abramson et al. 2011). Hensher et al. (2005) used stated choice experiments and mixed logit models to assess the WTP for different water and wastewater service attributes. Hensher et al.'s (2005) stated choice preference survey was deployed in 2002 in Canberra, Australia, for 211 households providing choices between different service options and associated prices. The results from the statistical model indicated that residents associate a monetary value with different levels of service and increased reliability. Willis et al. (2005) evaluated the cost-benefit trade-off for improvement in water and wastewater service to determine whether further investment for improved services was economically efficient in the United Kingdom. Results from stated choice experiments were modeled using random utility theory and various logit models for 1,000 residential customers. Wang et al. (2010) used survey analysis to assess the residential acceptability of increased water prices across 1,500 households in China. A study by Genius et al. (2008) sought to measure the WTP for improved water supply and water quality in Crete using contingent value methods. Data were collected by door-to-door interaction with local residents, yielding 206 total surveys, indicating that residents were willing to pay approximately 18% for improved water and wastewater quality.

Although frequently used, surveys pose the challenge that with the complexity of any decision or opinion, it is impossible to capture every influential variable impacting the WTP, and encompass a subset of the full population targeted. Many factors are unobserved, such as lifestyle characteristics and water and wastewater use patterns, introducing variation across the population, such as, flushing habits for males versus females and variability in the duration of showers (Alcubilla and Lund 2006). This can result in models with specification problems, such as omitted variables, biased or inconsistent parameter estimates, and incorrect estimations (Mannering et al. 2016). Due to this limitation, we propose that employing models that capture unobserved heterogeneity may address the fundamental issues associated with using statistical modeling and survey analyses to understand the factors influencing WTP, namely, a latent class approach. A latent class approach can account for possible unobserved heterogeneity without having to make an assumption about the parameter distribution, which may not always be consistent across all observations. Latent class models can account for possible unobserved heterogeneity by assuming that observations come from distinct classes based on common characteristics (Mannering et al. 2016). In contrast, Willis et al. (2005) captured this unobserved heterogeneity for WTP via random parameters in one of four proposed models; however, a potential drawback of the random parameter approach is that it may lead to incorrect assignment of continuous distributions to the full sample or population, as discussed in Mannering et al. (2016).

This study is twofold: (1) presenting a new methodological approach to assess WTP for the provision of water and wastewater, and (2) evaluating drivers of WTP in shrinking cities. Open-ended contingent valuation methods (CVMs) were employed (Genius et al. 2008), using survey techniques to ask the respondent their WTP for improved reliability. Similar to the study performed by Genius et al. (2008), the WTP response in the survey yielded a high percentage of zeros (22 and 27% for water and wastewater, respectively) for possible reasons such as the inability to afford it due to the high poverty rates in shrinking cities (Faust et al. 2016a) or the justification that improved service should be provided at no additional cost (Genius et al. 2008). Notably, protest zeros in this study were treated as legitimate zero valuations (Halstead et al. 1992) because respondents were valuing a proposed policy versus commodity (McGuirk et al. 1989). Strict valuation of the services cannot be separated from the policy associated with financing infrastructure improvements and methods of payment for such efforts (Randall 1986), which is improved reliability in this study. However, many studies truncate protest zeros from the sample because these responses do not represent a *true* economic valuation (e.g., Jorgensen et al. 1999; Dziegielewska and Mendelsohn 2007). The inclusion of protest zeros may result in sample selection bias (Strazzera et al. 2003) and may significantly reduce the mean WTP (Halstead et al. 1992). We propose a latent class Tobit regression modeling approach to provide more accurate estimates for WTP in the presence of a high percentage of zeros, as well as to more accurately capture the unobserved heterogeneity of these respondents across both the nationwide shrinking cities and those who may have responded with potential protest zeros. Here unobserved heterogeneity refers to unobserved factors (not included in the model) that systematically vary across individuals. In the case of zeros, the latent class Tobit modeling framework accounts for the observed factors related to individuals who are not willing to pay for improved services but, for instance, may desire the benefit. Moreover, using this methodology, this paper seeks to identify and understand the influential demographic variables associated with stated preference WTP for increased rates in shrinking cities; a question driven by interest of shrinking city utilities using data collected via survey in September 2013. Understanding the demographic drivers provides an avenue for utilities to economically plan efficiently and shape information disseminated and communication methods (e.g., radio, newspaper, and social media for different age groups), as well as decide in which areas of their cities to invest in outreach and education using census tract data or community survey block data to identify communities that are most likely to oppose rate increases.

Methodological Approach

There have been a range of studies that have explored an individual's attitudes toward the WTP for improved services using either choice modeling techniques or CVMs (e.g., Jordan and Enlnagheeb 1993; Hensher et al. 2005, 2006; Genius et al. 2008; Tentes and Damigos 2014; Veronesi et al. 2014). The choice of evaluation technique is influenced by the data sources and how the variables of interest are captured. For this study, we deviated from the more popular methodologies as outlined in the preceding references and utilized a special case of the Tobit modeling framework first introduced by Tobin (1958). Specifically, the latent class Tobit modeling framework offers a richer characterization of the zero willingness to pay for improved reliability process (Brown et al. 2015).

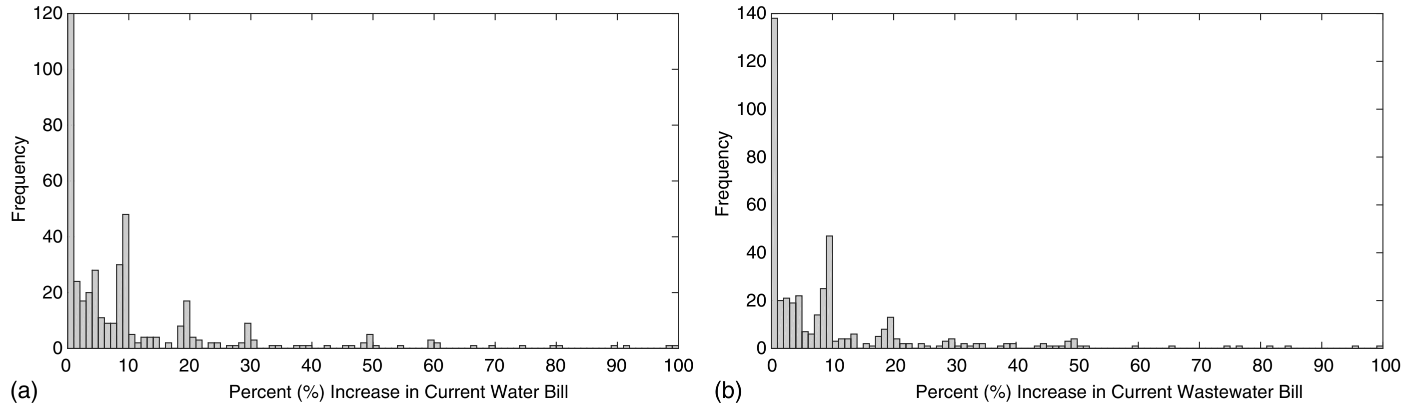

Fig. 1. Histogram of response to (a) "How much MORE would you be willing to pay for improved reliability of your WATER service?" and (b) "How much MORE would you be willing to pay for improved reliability of your WASTEWATER service?".

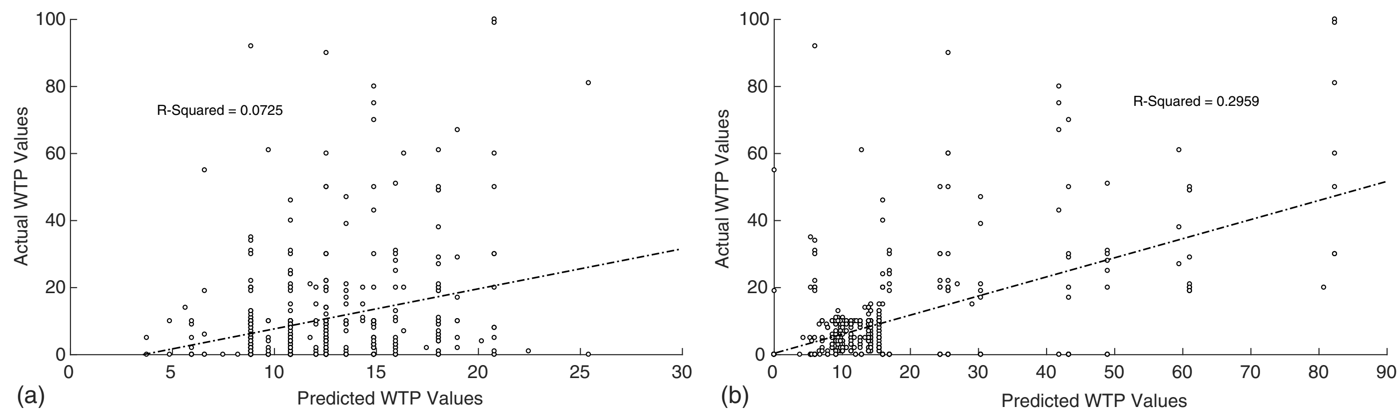

Fig. 2. Actual versus predicted values for WTP for water estimated with the Pearson product moment correlation coefficient R^2: (a) Tobit; and (b) latent class Tobit.

The latent class Tobit modeling approach first (probabilistically) splits the sample into two or more populations (that we predict prior to estimation to represent zero WTP for increased reliability) and then, for each of the sample populations, separate Tobit models are estimated. Therefore, the same explanatory variables in the Tobit (or willingness to pay for improved reliability) model can have differing effects across the different classes (referred to as unobserved heterogeneity).

To formulate the latent class Tobit regression model, we first utilized the standard Tobit regression model to left-censor the data at a value corresponding to the willingness to pay (Figs. 1 and 2) as follows (Tobin 1958; Washington et al. 2010):

$$Y_i^* = \boldsymbol{\beta}\mathbf{X}_i + \varepsilon_i \quad \text{with} \quad \varepsilon_i \sim N[0, \sigma^2] \quad \text{and} \quad i = 1, 2, \ldots, N$$
$$Y_i = Y_i^* \quad \text{if } Y_i^* > 0$$
$$Y_i = 0 \quad \text{if } Y_i^* \leq 0 \tag{1}$$

where N = number of observations; Y_i = willingness to pay (the response variable); $\mathbf{X}_i$ = vector of explanatory variables (e.g., socioeconomic and service characteristics); $\boldsymbol{\beta}$ = vector of estimated parameters; and ε_i = normally and independently distributed error term with a mean of zero and a constant variance, σ^2.

We then extended the standard Tobit regression model and employed the latent class approach. The latent class Tobit regression, as mentioned previously, attempts to capture the unobserved heterogeneity between variables by allowing parameters to vary with a discrete distribution (e.g., not a predefined distribution such as the normal distribution) across a number of classes. This is accomplished by defining a finite number of points and measuring the probability of the interval between points. Applying this to the Tobit regression model results in the following:

$$Y_i^*|(\text{Class} = C) = \boldsymbol{\beta}_C\mathbf{X}_i + \varepsilon_{i|C} \quad \text{with} \quad \varepsilon_{i|C} \sim N[0, \sigma_C^2] \quad \text{and} \quad i = 1, 2, \ldots, N$$
$$Y_i = Y_i^* \quad \text{if } Y_i^* > 0$$
$$Y_i = 0 \quad \text{if } Y_i^* \leq 0 \tag{2}$$

where $\boldsymbol{\beta}_C$ = vector of estimated parameters belonging to Class C; and $Y_i^*|(\text{Class} = C)$ is the willingness to pay for improved reliability of individual i in Class C. The corresponding log-likelihood function can now be written as (Brown et al. 2015)

$$LL = \sum_{i=1}^{N} \log\left[\sum_{C=1}^{C} P_{iC}(\delta_C, \omega_s)[f(Y_i|\text{Class} = C, \mathbf{X}_i, \boldsymbol{\beta}_C, \sigma_C)]\right] \tag{3}$$

where $P_{iC}(\delta_C, \omega_i)$ = prior to model estimation—logit probability of being in Class C and represented by the multinomial logit form (Brown et al. 2015)

$$P_{iC}(\delta_C, \omega_i) = \frac{e(\omega_i \delta_C)}{\sum_{C=1}^{C} e^{(\omega_i \delta_C)}} \quad \text{with} \quad C = 1, 2, \ldots, C \quad \text{and} \quad \delta_C = 0 \text{ for normalization} \tag{4}$$

After the parameters have been estimated, a second estimation was conducted to determine the posterior probabilities of willingness to pay Y_i belonging to Class C (Greene 2012). The posterior probability that an individual belongs to Class C was determined postestimation. In other words, the posterior probability utilizes the estimated parameters to determine a class probability based on the observed willingness to pay and is represented as follows:

$$P(\text{Class} = C|Y_i) = \frac{f(Y_i|\text{Class} = C)P(\text{Class}C)}{\sum_{C=1}^{C} f(Y_i|\text{Class} = C)P(\text{Class}C)} \tag{5}$$

Finally, to assess the impact of significant variables, partial effects were computed. For indicator variables (i.e., the type of variables used in the current study), this is the difference in the expected WTP when indicator variable x_i changes from 0 to 1 (Greene 2012)

$$P_{x_i}^{Y_i^*} = E[y_i|x_i^1] - E[y_i|x_i^0] \tag{6}$$

where $E[y_i|x_i^1]$ = expected WTP when indicator x_i takes on the value 1; and $E[y_i|x_i^0]$ = expected WTP when indicator x_i takes on the value 0.

The latent class Tobit regression model was applied utilizing the NLOGIT 5 software. The following sections illustrate the estimation results of the willingness to pay for water and wastewater improved reliability.

Data

Three to four phone interviews and two to four face-to-face interviews were conducted between 2012 and 2013 with city officials from Flint, Michigan; Saginaw, Michigan; Akron, Ohio; and Gary, Indiana to identify challenges facing water and wastewater utilities in shrinking cities, and to contribute in developing the survey discussed in this study. One common thread found among the city officials interviewed were the drastic measures taken to reduce potential rate increases and operate the water and wastewater utility service under the current financial constraints. A need identified by the shrinking cities involved in this study was to better understand (1) *if* residents were willing to pay more for improved level of services, (2) what *percentage increase* residents were willing to pay for water and wastewater services, and (3) what are the *drivers* of individuals likely to support and oppose rate increases. Following a series of questions regarding perceived changes in the quality of water and wastewater service and attitudes toward infrastructure management alternatives, respondents were asked:

> How much more would you be willing to pay for improved reliability of your water service? (Reliability is defined either as improved water quality or operational characteristics-e.g., fire flows, pressures, reduced disruption of service).
>
> Enter "0" if you would not be willing to pay more for your water service for a more reliable system.
>
> ______ Percent (%) increase in current water bill

Respondents had the option of text entry or moving the slider bar to the desired percentage. Respondents had to *either* enter a value or move the slider, i.e., opting to not respond would not provide a default value of zero. A similarly posed question followed with regard to wastewater services, with examples of improved reliability including reduced combined sewer overflows and reduced disruptions of service. Notably, a limitation is that the questions posed in the survey are general, without quantifying the change in reliability across specific alternatives, potentially causing hypothetical bias in the sample. Hypothetical bias arises from respondents who state a higher willingness to pay than revealed in reality (Loomis 2011). Due to the structure of the questions, and lack of specificity, various alternatives may result in differing (and likely lower) WTP among respondents. Of interest to this study was not the exploration of specific alternatives or attributes, but a WTP for general, improved reliability among the public, in spite of the high poverty rates and high per capita costs for service in shrinking cities [for more information regarding the impacts on levels of service arising from urban decline, see Faust et al. (2016a)]. Exploring this WTP through CVM and statistical modeling enabled interested parties to reach out to potential sources of opposition—or those who are not willing to pay—to explore community-supported solutions to address systemwide challenges faced by this classification of cities. In spite of this limitation, the methodological contributions of using such models to assess more specific scenarios is evident.

Qualtrics, a web-based survey software, was used to gather data in 21 US shrinking cities nationwide (listed in Table 1) in September 2013. Shrinking cities considered in this study are those that have experienced *chronic* urban decline of at least 30% since their peak populations of approximately 100,000 or more. Medium and large cities were chosen for this survey to capture cities that have invested in large infrastructure footprints, originally intended to support a much greater population than currently resides in the cities. Participation in the survey was voluntary, with all respondents 18 years of age or older. The survey underwent validation prior to deployment via content review by 11 subject matter experts with expertise in infrastructure challenges in shrinking cities, water and wastewater utilities and management, or in the development and deployment of public opinion surveys. Post-content validation, the survey underwent an institutional review board review and was predeployed to 25 people in the general public (not included in the final sample pool) to ensure individuals with limited knowledge

Table 1. Targeted cities comprising survey response pool

City	Percent decline from peak population (%)	Peak population (year)	2010 population (US Census Bureau 2016)
Akron, Ohio	>30	290,351 (1960)	199,110
Baltimore	>30	949,708 (1950)	620,961
Birmingham, Alabama	>35	340,887 (1950)	212,237
Buffalo, New York	>50	580,132 (1950)	270,240
Camden, New Jersey	>35	124,555 (1950)	77,344
Canton, Ohio	>35	116,912 (1950)	73,007
Cincinnati	>40	503,998 (1950)	296,943
Cleveland	>55	914,808 (1950)	396,815
Dayton, Ohio	>45	262,332 (1960)	141,527
Detroit	>60	1,849,568 (1950)	713,777
Flint, Michigan	>40	196,940 (1960)	84,465
Gary, Indiana	>55	178,320 (1960)	98,026
Niagara Falls, New York	>50	102,394 (1960)	52,200
Pittsburgh	>50	676,806 (1950)	371,102
Rochester, New York	>35	332,488 (1950)	121,923
Saginaw, Michigan	>45	98,265 (1960)	51,508
Scranton, Pennsylvania	>45	143,333 (1930)	67,244
St. Louis	>60	856,796 (1950)	537,502
Syracuse, New York	>30	220,583 (1950)	75,413
Trenton, New Jersey	>30	128,009 (1950)	43,096
Youngstown, Ohio	>60	170,002 (1930)	103,020

Source: Adapted from Faust et al. (2016b).

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Table 2. Descriptive statistics of survey respondents

Characteristic	Minimum/maximum	Average	Standard deviation
Individual characteristics			
Male (1 if male, otherwise 0)	0/1	0.61	0.49
Marital status			
Single (1 if single, otherwise 0)	0/1	0.36	0.48
Married (1 if married, otherwise 0)	0/1	0.45	0.50
Divorced (1 if divorced, otherwise 0)	0/1	0.12	0.33
Age			
18–25 years old (1 if 18–25 years old, otherwise 0)	0/1	0.09	0.28
26–35 years old (1 if 26–35 years old, otherwise 0)	0/1	0.20	0.40
36–50 years old (1 if 36–50 years old, otherwise 0)	0/1	0.24	0.43
Over 50 years old (1 if over 50 years old, otherwise 0)	0/1	0.47	0.50
Highest level of education			
Some high school (1 if some high school, otherwise 0)	0/1	0.03	0.17
High school diploma (1 if high school diploma, otherwise 0)	0/1	0.34	0.47
Technical college degree (1 if technical college degree, otherwise 0)	0/1	0.16	0.37
College degree (1 if college degree, otherwise 0)	0/1	0.35	0.48
Postgraduate degree (1 if postgraduate degree, otherwise 0)	0/1	0.12	0.33
Approximate income			
No income (1 if respondent has no income, otherwise 0)	0/1	0.09	0.28
Under $19,999 (1 if income is less than $19,999, otherwise 0)	0/1	0.24	0.43
$20,000–$34,999 (1 if income is between $20,000 and $34,999, otherwise 0)	0/1	0.24	0.43
$35,000 – $49,999 (1 if income is between $35,000 and $49,999, otherwise 0)	0/1	0.17	0.38
$50,000–$74,999 (1 if income is between $50,000 and $74,999, otherwise 0)	0/1	0.15	0.36
$75,000–$99,999 (1 if income is between $75,000 and $99,999, otherwise 0)	0/1	0.07	0.25
$100,000 and above (1 if income is greater than $100,000, otherwise 0)	0/1	0.04	0.20
Employment status (respondents chose all that applied)			
Employed for wages or salary (1 if true, otherwise 0)	0/1	0.41	0.49
Self-employed (1 if true, otherwise 0)	0/1	0.09	0.29
Out of work and looking for work (1 if true, otherwise 0)	0/1	0.05	0.22
Out of work and not currently looking for work (1 if true, otherwise 0)	0/1	0.01	0.11
Homemaker (1 if true, otherwise 0)	0/1	0.13	0.33
Student (1 if true, otherwise 0)	0/1	0.06	0.24
Retired (1 if true, otherwise 0)	0/1	0.21	0.41
Unable to work (1 if true, otherwise 0)	0/1	0.10	0.30
Other			
Number of years lived in current city (years)	0.25/80	32.94	20.69
Responsible for water bill (1 if responsible for water bill, otherwise 0)	0/1	0.71	0.45
Household characteristics			
Household approximate income			
Under $19,999 (1 if household income is less than $19,999, otherwise 0)	0/1	0.04	0.18
$20,000–$34,999 (1 if income is between $20,000 and $34,999, otherwise 0)	0/1	0.15	0.36
$35,000–$49,999 (1 if income is between $35,000 and $49,999, otherwise 0)	0/1	0.19	0.39
$50,000–$74,999 (1 if income is between $50,000 and $74,999, otherwise 0)	0/1	0.17	0.38
$75,000–$99,999 (1 if income is between $75,000 and $99,999, otherwise 0)	0/1	0.23	0.42
$100,000 and above (1 if income is greater than $100,000, otherwise 0)	0/1	0.11	0.32
Other			
Number of people living in household (people)	1/9	2.59	1.34
Number of children under the age of 18 living in household (children)	0/5	0.56	0.93
Number of children under the age of 5 living in household (children)	0/3	0.17	0.49

regarding water and wastewater infrastructure services could respond to and understand the survey questions, and the intended data would be gathered.

The final sample pool was 450 completed surveys (providing a level of confidence of 95%). A minimum of 10 responses from each city was sought to (1) reduce the potential that the survey responses reflected specific state, regional, or city policies; and (2) allow for locational variation comparison across cities and states. It should be mentioned, however, that public opinion is dynamic, constantly evolving due to imperfect or changing information and experience; thus, this survey represents a snapshot in time. Table 2 shows select survey respondent statistics used to estimate the latent class Tobit models.

As previously mentioned, in spite of the increased poverty rates and income inequity seen in many shrinking cities, a majority (70–75%) of consumers indicated that they are WTP for improved reliability of water and wastewater services (Faust et al. 2016a). Approximately 50% of the survey respondents indicated this willingness to pay for rate increases between 1 and 10%, with 20–25% willing to pay more than a 10% rate increase (Faust et al. 2016a).

Model Estimation Results

Multiple models were assessed to determine the appropriate technique to capture the WTP of shrinking city residents for the

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improved reliability of water and wastewater service. In particular, two metrics were used to identify the most appropriate technique, namely, model fit using the Madalla R^2 (shown in Tables 3 and 4 for final models) and the rate of prediction versus actual WTP values using the Pearson product moment correlation coefficient R^2 (shown in Figs. 2 and 3 for final models). As can be seen, the latent class Tobit yielded more accurate parameter estimates demonstrated with the better overall model fit. The application of the latent classes attempts to capture unobserved heterogeneity by allowing the estimated parameters to vary across the unobserved groups, i.e., classes, as opposed to fixing the impact of the parameter across the full population. The significant presence of latent class indicates that independent parameters have varying impacts on the willingness to pay. For instance, gender's impact on WTP for water and wastewater service has a positive effect on Class 1 and a negative effect on Class 2 (Tables 3 and 4). The presence of the variability across the classes of this parameter informs the utility and decision makers that this explanatory variable has varying impacts.

Figs. 2 and 3 illustrate the actual versus predicted WTP values for the Tobit and latent class Tobit for water and wastewater, respectively. The latent class Tobit models demonstrate a better overall fit, quantified by the estimated R^2 values. The latent class Tobit yielded a 0.2959 R^2 value, a considerable improvement from the R^2 value of 0.0725 estimated by the Tobit regression model for the WTP for water. The latent class Tobit yielded an R^2 of 0.3655, as compared with the R^2 value of 0.0826 estimated by the Tobit regression model for the WTP for wastewater.

Model Discussion

As previously discussed, the results of the Tobit fixed model as compared with the latent class Tobit model indicate that the data are more accurately modeled into two classes, with an accompanying probability of 46 and 54% membership in Classes 1 and 2, respectively, for both water and wastewater (Tables 3 and 4). The fixed Tobit models consider the average impact across the full population; whereas dividing membership into two classes allows for the estimation of $\boldsymbol{\beta}_i$ for each class, more accurately capturing the impact of the independent variables for different divisions of the population. In the absence of considering latent class memberships, erroneous inferences may be drawn from the data regarding the impact of a sociodemographic variable on individuals' WTP.

Table 3. Latent class Tobit regression model results for willingness to pay for improved reliability of water service

			Latent class Tobit				
	Fixed-parameter Tobit		Latent Class 1		Latent Class 2		Partial
Variable	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	effects
Constant	4.363	1.24	−0.696	−0.07	6.985	4.88	—
Gender (1 if male, 0 otherwise)	−3.319	−1.67	−9.943	−1.83	0.642	0.80	−2.807
Responsibility of paying water bill (1 if yes, 0 otherwise)	7.451	3.33	19.827	2.99	−1.938	−2.17	5.359
City population perception (1 if individual perceived a loss of population over the past four decades, 0 otherwise)	−6.019	−3.07	−15.880	−3.12	0.826	1.03	−4.556
Income level (1 if no income, 0 otherwise)	−11.953	−3.17	−28.389	−2.86	−0.497	−0.31	−8.861
Homeownership (1 if individual has owned their current home between 2 and 5 years, 0 otherwise)	5.277	1.43	9.994	0.96	2.236	1.76	3.868
Sigma	—	—	28.4456	13.95	4.3715	8.82	—
Class probabilities	—	—	0.457	10.14	0.543	12.04	—
Log-likelihood at zero	−1,500.559		−1,390.357				—
Log-likelihood at convergence	−1,484.895		−1,371.469				—
$n = 420$	420		420				—
Madalla R^2	0.071877		0.086017				—

Table 4. Latent class Tobit regression model results for willingness to pay for improved reliability of wastewater service

			Latent class Tobit				
	Fixed-parameter Tobit		Latent Class 1		Latent Class 2		Partial
Variable	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	effects
Constant	3.610	1.08	−2.406	−0.26	6.708	4.00	—
Gender (1 if male, 0 otherwise)	−2.627	−1.33	−7.716	−1.53	0.588	0.59	−2.148
Responsibility of paying water bill (1 if yes, 0 otherwise)	6.538	3.12	17.650	3.01	−1.217	−1.16	4.959
Income level (1 if income is between \$35,000 and \$49,999, 0 otherwise)	6.485	2.64	11.460	1.84	1.1824	0.98	3.919
Marital status (1 if individual is divorced, 0 otherwise)	−6.480	−2.14	−21.294	−2.29	0.508	0.33	−6.323
City population perception (1 if individual perceived a loss of population over the past four decades, 0 otherwise)	−5.484	−2.85	−12.698	−2.51	−0.229	−0.23	−3.959
Employment status (1 if homemaker, 0 otherwise)	−6.915	−2.30	−4.847	−0.54	−4.458	−2.83	−3.062
Sigma	—	—	26.5403	12.6	4.7653	7.39	—
Class probabilities	—	—	0.4625	7.92	0.5375	9.2	—
Log-likelihood at zero	−1,439.462		−1,353.681				—
Log-likelihood at convergence	−1,422.608		−1,332.829				—
$n = 420$	420		420				—
Madalla R^2	0.077121		0.094525				—

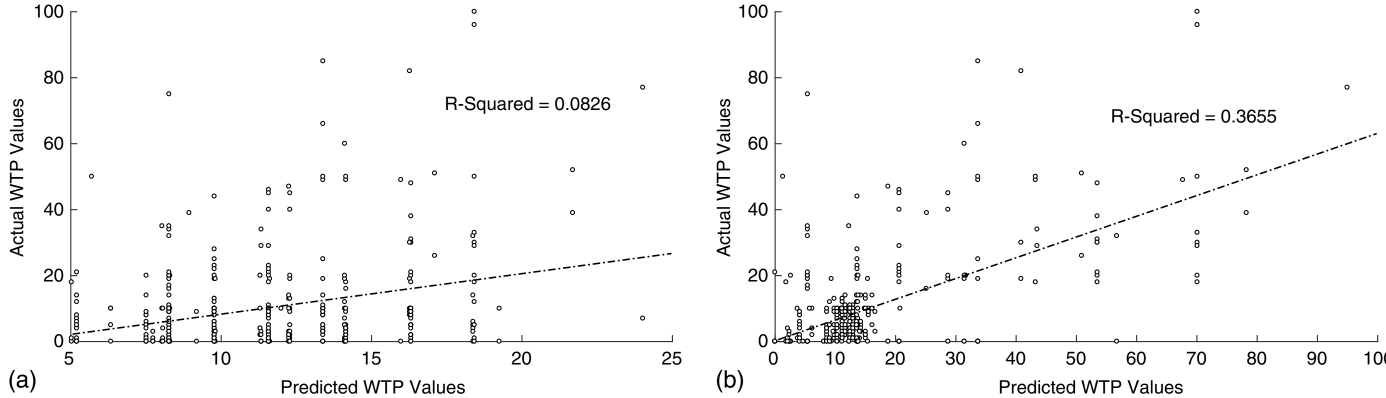

Fig. 3. Actual versus predicted values for WTP for wastewater estimated with the Pearson product moment correlation coefficient R^2: (a) Tobit; and (b) latent class Tobit.

Drawing erroneous conclusions may lead to ineffective or inaccurate decisions in regard to understanding sources of potential opposition and a different population WTP.

Fixed-Parameter Tobit Regression Models

The latent class Tobit models provided an overall better fit for WTP. However, discussing the results of fixed Tobit models in conjunction with the latent class Tobit model provides insight into the different and additional information provided by the latent class Tobit model that incorporates the heterogeneity of the population (as compared with the fixed model that assumes homogeneity in the impact of parameters). Turning to the models, gender, specifically males, had a decreased WTP for both improved reliability of water and wastewater service. However, the impact of responsibility for the water bill payment (which is often coupled with the wastewater bill) had a positive impact on the WTP for both fixed Tobit models. Income level was a significant estimable parameter in the WTP for both water and wastewater. Interestingly, the level of income differed in significance for the models. Individuals with no income, as would be suspected, had a negative impact on the WTP for water service; whereas individuals with incomes between \$35,000 and \$49,999 had a positive impact on the WTP for wastewater service.

Awareness of the occurrence of population decline had an opposite effect on WTP for water service versus wastewater service, with a negative effect on WTP for water service, and a positive effect on WTP for wastewater service. Homeownership was significant only in the WTP for water service, having a positive impact on WTP for individuals living in their homes between 2 and 5 years. Other significant parameters only significant in predicting the WTP for wastewater service included marital status (specifically, divorced individuals) and employment status (homemakers), both having a negative significance.

Latent Class Tobit Regression Models

Posterior class membership shows that individuals willing to pay more for wastewater service belong to Class 1, with a mean WTP of 16%, while the mean WTP in Class 2 is significantly lower at 6%. As for the total number of individuals in each class, posterior probabilities indicate that 30.5% fewer individuals are willing to pay more for wastewater service (178 in Class 1 as compared with 242 in Class 2). Pertaining to water services, individuals willing to pay more belong to Class 1 with a mean WTP of 18%. Tantamount to wastewater service, individuals belonging to Class 2 are willing to pay significantly less for water service with a mean WTP of 6%. In relation to the number of individuals belonging to Class 2, 33.3% fewer individuals are willing to pay more for water service (175 in Class 1 as compared with 245 in Class 2).

Discussed previously, the presence of the classes allows for the estimable parameter to vary across class membership, capturing the unobserved heterogeneity of the variable. Turning to gender, the partial effect indicates a decrease of 0.028 and 0.022% in WTP for improved reliability of water and wastewater service. However, the impact within the classes differs, with a negative significance in Class 1 and a positive significance in Class 2, demonstrating that this variable has varying effects on different groups of the population. The presence of this variable and the heterogeneity across classes associated with male respondents may be attributed to the roles of males as the primary source of income in 60% of homes (Wang et al. 2013). Similar findings on the unobserved heterogeneity having different positive and negative effects or differing in magnitude of effects (e.g., income level) may be seen within each significant parameter identified.

Consistent with Faust et al. (2016b), awareness of population decline was an influential parameter impacting public perception toward the infrastructure systems. Awareness of the chronic population had a negative significance on both models, decreasing WTP by 0.090 and 0.040% for water and wastewater, respectively. Only 54% of people were aware in 2013 that they were residing in shrinking cities, which impacts their perceptions and attitude toward water infrastructure (Faust et al. 2016b).

Income level had a negative significance in the WTP for water, decreasing WTP by 0.089%. This partial effect has the greatest magnitude in this model (Table 3); however, the magnitude of the parameters within each class varied considerably. Individuals with incomes between \$35,000 and \$49,999 had a positive significance in the WTP for wastewater model, increasing WTP by 0.040%. Presumably, these individuals have a reliable income that can afford the increased financial costs associated with improved reliability of wastewater service. Similar to the WTP for water model, the magnitude of this variable's impact differs between classes, further demonstrating the need to account for this unobserved heterogeneity across the population. The partial effect of individuals who are responsible for paying their water bill had a positive significance of increasing WTP by 0.054 and 0.050% for water and wastewater, respectively. However, this variable has considerable heterogeneity across the population, with a negative significance in Class 1 and a positive significance in Class 2. This heterogeneity captured among those responsible for paying the water bill and the differing significance signs (positive versus negative) may be capturing those with the ability to increase payment with minimal financial burden, and those who cannot (demonstrated in the income level parameter). The income parameter is extremely important for utilities to carefully consider when raising rates due to accessibility of the service and ability to pay because the poverty level in many shrinking cities is often two to three times the national average (Faust et al. 2016a).

The homeownership variable, significant only in the WTP for water model (Table 3), has a positive significance of 0.039%. The presence of this variable is unsurprising because it could be expected that individuals would invest in their local infrastructure service when there is a sense of permanency in their living situation, as opposed to the often-transient nature of renting. Marital status and employment status, two parameters solely significant in the WTP for wastewater service, have negative effects of decreasing WTP by 0.063 and 0.031%, respectively (Table 4). Possibly capturing income, wealth, and the ability to pay for service, the employment status of homemakers and the divorced marital status (i.e., single income) was found to be significant, having a negative impact on WTP for wastewater service.

Summary and Conclusions

This study sought to evaluate consumer stated preference WTP in order to understand users' perceived valuation of and inclination to pay for services and goods. Previous work in this domain consisted of using either choice-based modeling techniques or CVMs to explore an individual's attitudes toward the WTP for improved services. In this study, we deviate from the more popular methodologies and utilize a special case of the Tobit modeling framework, namely, the latent class Tobit, which accounts for unobserved heterogeneity across the different classes as explained previously. The advantage of this method is that it accounts for unobservable factors that may be influencing users' preferences on WTP which are not currently addressed in the literature. As seen from the results, the latent class Tobit outperformed the more basic Tobit model and accounted for unobserved heterogeneity as witnessed by the results (Figs. 2 and 3). The statistical significance of the latent classes demonstrates the observed heterogeneity of the populations. Modeling the WTP as latent class models improved the prediction (captured using the Pearson product moment correlation coefficient) for the WTP for improved water service from 0.07 to 0.30 and for improved wastewater service from 0.08 to 0.37.

An acknowledged limitation to this study includes the dynamic, constantly changing nature of public perceptions. Cross-sectional perception studies taken at a snapshot in time (such as presented in this study) are disadvantageous due to the constant change in public opinion in light of new information, events, or experiences. However, this study sought to assess the feasibility of a new methodological approach using latent class Tobit models, effectively demonstrated through the comparison of models. Furthermore, although cross sectional, this study effectively dispelled the common perception by shrinking city utilities that consumers were unwilling to pay increased rates and found which characteristics impacted the stated WTP. A second limitation to this study is that this is a stated preference survey and consumers often reveal their true behavior through actions. However, contingent valuation provides a platform to anticipate opposition and understanding the public prior to revealing such behavior, and thus provides an opportunity for utilities to anticipate and mitigate sources of discontent.

The statistical analysis presented in this study indicated a number of characteristic, socioeconomic, and demographic driving factors that influence the WTP for water and wastewater services. The parameter findings may be used to evaluate the residential willingness to accept increased rates, identify potential opposition from statistically significant groups, and determine the initial viability of such service and rate changes. The latent class Tobit model results show that characteristics determining an increased WTP for improved reliability of water and wastewater service include responsibility of paying the water bill (both water and wastewater), homeownership (water only), and having and income level between $35,000 and $49,999 (wastewater only). Characteristics determining a decreased WTP for improved reliability of water and wastewater service include gender (both water and wastewater), awareness of chronic population decline (both water and wastewater), having no income (water only), marital status (wastewater only), and employment status (wastewater only).

A shrinking city is a classification type that is fiscally strained with high percentages of residents below the poverty rates. Placing further financial burden on these populations to receive utility services should occur in conjunction with communication to the public and an understanding of the public perceptions of the customers served. This study demonstrated that a majority of the aggregate population is not reluctant to pay increased rates in exchange for improved reliability, and which demographic groups are driving the reluctance to pay potential increased rates. Understanding and incorporating public perceptions into the decision-making process allows for sustainable implementation of changes (in this case, increasing rates) that may improve services rendered in these communities.

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