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Sociodemographic patterns of household water-use costs in Puerto Rico

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Abstract

Variability of household water-use costs across different sociodemographic groups in Puerto Rico is evaluated using census microdata from the Integrated Public Use Microdata Series (IPUMS). Multivariate analyses such as Multiple Linear Regression (MLR) and Factor Analysis (FA) are used to classify, extract and interpret the household water-use costs. The FA results suggest two principal varifactors in explaining the variability of household water-use costs (64% in 2000 and 50% in 2010), which are grouped into a soft coefficient (social, economic and demographic characteristics of household residents, i.e. age, size, income, education) and a hard coefficient (dwelling conditions, i.e. number of rooms, units in the building, building age). The demographic profile of a high water-use household in Puerto Rico tends to be that of renters, people who live in larger or older buildings, people living in metro areas, or those with higher education level and higher income. The findings and discussions from this study will help decision makers to plan holistic and integrated water management to achieve water sustainability.

Keywords

Household water-use costs; IPUMS; sociodemographic; Factor Analysis; Puerto Rico (USA)

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1. Introduction

In addition to protecting water resources, household water conservation is a feasible and important approach to balance between freshwater supply and consumption. Studies on the variability of household water-use include many environmental, engineering, social, economic and cultural factors (Corbella and Pujol, 2009; Inman and Jeffrey, 2006; Jorgensen et al., 2009; Rathnayaka et al., 2014), which are highly characterized with disparate spatial and temporal traits. Understanding the spatial and temporal patterns of household water-use costs within a complex social and demographic context is important for implementing holistic and integrated water-use management.

As a vital resource in sustaining human life, protecting human health, supporting economic development, and maintaining natural and cultural integrity (Gleick et al., 2002), the philosophies of water management change over time. Water has been considered as a natural resource that has utilization value but little economic value. As the pressure and demand for water supply increase, the recognition of the economic value of water resources and hence water pricing procedures attracts more attention to meet the imbalance between water supply and demand (Mitchell, 1984; Arbués et al., 2003; Wodraska, 2006) even for areas with abundant water resources. Water pricing procedures try to adopt the marginal cost pricing strategy to allocate water to the most valuable needs and consequently reduce the ultimate water-use (Agthe and Billings, 1986). However, beyond the consideration of social justice (Renwick and Archibald, 1998), recent studies show that the relationship between water-use cost and water price is weak especially for renters and low income households (Renwick and Archibald, 1998; Hoffmann et al., 2006), and the effects from pricing on water demand vary according to the use, given the basic and essential usages (Dalhuisen et al., 2003). Reynaud (2013) suggested that price policy and non-price policy should be viewed as complementary regulation. Household water-use trends may be further influenced by psychological factors, such as trust between consumers and water authority (Jorgensen et al., 2009), and local water conservation culture such as taking shorter showers, turning off the tap water while brushing teeth, and washing only full loads of laundry or dishwasher (Fielding et al., 2012). Another direction of meeting water demand is domestic conservation, for example using more efficient water consumption devices such as efficient laundry machines, showers and toilets (Rathnayaka et al., 2014). Upgrading water-use devices in a large scale however is a big task that involves both economic (payback period) and social (awareness in water conservation and willingness in spending more on the efficient devices) considerations (Piper and Martin, 1997; Millock and Nauges, 2010).

Beyond studies on the factors driving household water-use costs, it is also imperative to understand their variability across large temporal and spatial scales. There are a few studies addressing this issue (temporal variability: Balling et al., 2008; spatial variability: Chang et al., 2010; temporal and spatial variability: House-Peters et al., 2010; Aggarwal et al., 2012; Yun et al., 2014). However, these studies are either focused on a specific urban or rural areas (Phoenix, Arizona, USA, Balling et al., 2008; Gold Coast, Australia, Willis et al., 2013; rural Puerto Rico, Jain et al., 2014), are not covering the complete demographic structure (single-family, Portland, Oregon, USA, Chang et al., 2010; and the referenced studies on urban residential water consumption summarized in this paper), or are not

considering the whole social and demographic factors in a spatial or temporal scale (social variations in household water-use in Greater Amman, Jordan, Potter and Darmame, 2010). In turn, the temporal household water-use variability can reflect the climatic (Breyer and Chang, 2014), social, population and water supply and management transitions (House-Peters and Chang, 2011; Sauri, 2013). The spatial variability of household water-use reflects the structure of the household, economic status and local water-use culture. Moreover, household water-use is largely linked with its demographic structure, which includes the size of the household, age, and number of children. A large household with more residents is inclined to use more water than a small household, but the per capita water-use may be smaller than the single-person household because of the sharing of utilities and more efficient water usage (Carr et al., 1990).

In this study, we quantify the sociodemographic patterns of household water-use costs in Puerto Rico. We test the hypothesis that household water-use costs differ among different social and demographic groups both temporally and spatially. The findings of the sociodemographic patterns of household water-use costs can be useful for the planning and managing water resources and understanding the residential water-use behaviors and spatial variability in a social and demographic context.

2. Method

2.1. Study Site

Puerto Rico, which consists of one main island and a number of smaller islands, is located between the Caribbean Sea and the North Atlantic Sea. The shape of the main island is roughly described as rectangular with a width of 160 km from east to west, a length of 55 km from north to south, and an area of 8,710 km². Puerto Rico has a typical tropical climate with small seasonal variations in temperatures which range from 19.4 to 29.6°C (Daly et al., 2003). The climate tends to be more moist and colder in the elevated mountainous areas. The average annual precipitation is estimated at 1,700 mm and around 60% of evapotranspiration, with wetter months in May and from August to November (monthly precipitation ranges from 170 to 220 mm) and drier in the other months (ranges from 70 to 120 mm), respectively (Daly et al., 2003).

The topography is divided into three major regions: the middle mountainous areas, the coastal plains and the northern karst region. The mountainous area that divides the main island into northern and southern regions accounts roughly 60% of the land area. Puerto Rico is home of many natural wonders including beautiful beaches and mountains, exuberant vegetation, and abundant water resources (Hunter and Arbona, 1995). The main island is characterized with karst formation which covers around 27.5% of the total island surface area, where the majority of the karst lies in the northern eluviated limestone terrain accounting for about 60% of the total karst area (Ghasemizadeh et al., 2012). However, the groundwater in this area is severely contaminated due to improper waste dumping as a result of industrialization, especially the growth of the pharmaceutical companies since the mid-1950s and also the population expansion (Ramcharan, 2011; Yu et al., 2015). As a result, groundwater use was discontinued as a source of public water supply in many areas of Puerto Rico since 2005 (Molina-Rivera and Gómez-Gómez, 2008).

2.2. Sociodemographic changes

The case of Puerto Rico is of special interest, because (1) it is geographically independent as an island with a very high population density; (2) it went through significant social, economic and population changes over the past several decades; (3) its water resources are severely stressed, especially the groundwater which is threatened by contamination; and (4) there is considerable transition and adjustment in its public water-use management to meet the stringent water demand subject to the socioeconomic, demographic and environmental pressures.

The variation of Puerto Rico populations is a dramatic reflection of social and economic changes over time. The population increased steadily from 2.71 million in 1970 to 3.81 million in 2000, was stagnant for a few years but started to decrease at a slow rate in recent years (Table 1). Puerto Rico is a highly populated island with approximately 420 persons per km², which ranks the fourth highest in America by 2010. Urbanization has occurred rapidly in the past decades, with 98.8% of the population living in urban areas by 2010. The metropolitan area of San Juan, which encompasses 41 of the 78 municipalities in Puerto Rico, has a population density up to 3,192 persons per km² and is among the most populated regions in the U.S. and territories (Martinuzzi et al., 2007). The number of households increased continuously during the population expansion period and also during the population stagnant period and recent declining period, which is consistent with the continued decrease of the household size. The household size decreased from an average of 4.2 persons in 1970 to 2.6 persons in 2010 (38% reduction). Households were predominantly couple with no child households and single-person households (Table 2), emphasizing the family orientation of Puerto Rican municipalities.

The economic status of the population in Puerto Rico showed that the median family income decreased from \$14,300 in 1970 to \$12,400 in 1980, \$12,100 in 1990, then increased to \$14,500 in 2000 and decreased to \$14,000 in 2010. The poverty rate of the population stayed at high rates around 60% from 1970 to 1990, and then it decreased to 49% in 2000 and 45% in 2010. During the time when population increased, the labor force increased and the unemployment rate decreased from 19.5% in 1970 to 10.2% in 2000, then the labor force decreased and the unemployment rate climbed to a rate of 16.4% after 2007. There is a trend that more labor force move to work in government and service related professionals such as managerial, technical, sales and administrative support occupations, and less people tend to work for manufacturing and farm related occupations.

The government-managed Puerto Rico Aqueduct and Sewer Authority (PRASA) is the only authorized entity for water quality, water management, and water supply in Puerto Rico. PRASA withdrawn $2.22 \times 10^6 \text{ m}^3 \text{ d}^{-1}$ from surface water and $0.31 \times 10^6 \text{ m}^3 \text{ d}^{-1}$ from groundwater in 2010, and provided the public water supply to the majority of the population (96.2%). The average domestic per capita water-use on a household basis is $0.21 \text{ m}^3 \text{ d}^{-1}$ in 2010 (Molina-Rivera, 2014). Prior to October 2005 there was a fixed cost rate for up to 10 cubic meters consumption and an additional cost per cubic meter for consumptions over 10 cubic meters. After October 2005, PRASA used block pricing method to tariff water use. The total water use invoice consists four components: base charge, consumption charge (block priced), special charge (fixed value for all accounts), and Environmental, Compliance

and Regulatory Charge (ECRC; block priced). In July 2013, PRASA increased the water price 10% to 30% for different water consumption blocks to cover new costs due to agreements with U.S. Environmental Protection Agency (EPA) and Puerto Rico Department of Health (<http://www.acueductospr.com/TARIFA>).

2.3. Data analysis

We used the U.S. census data from the Integrated Public Use Microdata Series (IPUMS) program at the University of Minnesota Population Center (Ruggles et al., 2010) and the socioeconomic data from U.S. Bureau of Labor Statistics. The IPUMS-USA dataset consist of integrated and harmonized individual-level samples from the U.S. censuses, i.e. microdata. The microdata are structured by household-level samples that can be directly linked to family members within the household. The high quality and the extent of the microdata makes the IPUMS the most popular demographic dataset for studies across temporal and spatial scales (Sobek et al., 2011). We examined the following variables to explain the variability of household water-use costs and their geographic clustering patterns: number of rooms in the household (Rooms), number of units in the building (Units), building age, number of residents in the household (Size), householder age (Age), householder education level or the maximum education level of the couple (Education), annual household income (Income), annual household electricity cost (Electricity), household demographic profile (PF), PUMA, population density in each PUMA (density), and central coordinates of PUMA (Latitude and Longitude). The economic status is reflected by poverty index (PI), whereas $PI \leq 50$ as very poor, $50 < PI \leq 100$ as poor, $100 < PI \leq 150$ as normal, $150 < PI \leq 200$ as good, and $PI > 200$ as rich. We consider the demographic effects through factors related to persons within the household. In order to examine the historical transitions of the sociodemographic profiles, we focus on the decennial census years of 1970, 1980, 1990, 2000 and 2010 in our analysis.

The census microdata which contain extensive sociodemographic information are ideal for clustering and multilevel analyses. Following the household size and structure classification methods by a household income study in Germany (Peichl et al. 2010) and a residential water consumption study in the city of Gold Coast, Australia (Willis et al., 2013), the households are divided into 14 demographic groups according to the number of adults and children (Table 2). A person with an age below 18 years (<18) is considered as child, above 18 years as adult, and above 60 years as an older adult. In order to compare the economic variables with monetary values across years, they were adjusted with inflation rates to constant 1999 dollars, which corresponds to the dollar amounts in the 2000 census. Though water price growth rate is an important factor influencing household water-use (Pint, 1999), it was not considered in this study because of lack of data and for simplicity of analysis. The census microdata are weighted both at household and personal level based on similar demographic conditions, i.e. 1% for 1970 data and 5% for 1980, 1990, 2000 and 2010 data. Though the weights were generally in agreement, there were some variations in years 1990, 2000 and 2010 with standard deviations from 2% to 17%. Therefore, to accurately reflect the population in Puerto Rico, we use a global weighting method for the associated variables using Equation 1:

$$f'_i = \frac{f_i w_i}{1/n \sum_1^n w_i} \quad (1)$$

Where f stands for a sociodemographic variable from the IPUMS-USA dataset, f' is the weighted variable for f , i stands for the sampled household or person, w stands for the household or person weight, and n stands for the total number of sampled households or persons.

The quantitative statistics analyses were conducted using Statistical Analysis System software (SAS 9.4, SAS Institute Inc., Cary, NC). The statistical significance level is 0.05. The group means were compared using ANOVA analysis with Tukey's method. Multivariate analysis is pertinently useful because of the intrinsic characteristics of the dataset, which incorporate multilevel data such as demography, economy, society, and environment. Indeed, multivariate analysis is considered a routine method for large multilevel datasets because it allows for dimension reduction and information extraction to facilitate classification, modeling and interpretation (Dominick et al., 2012). We used PROC REG to perform Multiple Linear Regression (MLR) to evaluate the combined effects of multiple factors on household water-use cost. We examined the Variance Inflation Factor (VIF) for each variable to assure that the issue of multicollinearity among the variables was acceptable for MLR computation. We used Factor Analysis (FA) to classify the most relevant variables based on MLR and to explore the source of variability. The magnitudes of the absolute varifactor (VF) values represent the loadings or scores of the variables, with larger values representing greater contribution to the variability. We rotated the VFs for better representation and interpretation, and explored the loadings of the variables on the first two VFs. Though some variables (such as rooms, education level, building units, etc.) are not continuous, we used them to create contour maps to show the trend of their influence on household water-use costs.

The geographic patterns of the census data were analyzed using the Geographic Information System (ESRI ArcGIS 10.2) software. The smallest geographic unit for the census data that include the household level data is Public Use Microdata Area (PUMA), which includes at least 100,000 people to protect the confidentiality of the surveyed individuals and households. The delineation of PUMAs is carried out by each state and may be subject to variations when there are significant changes in population. In the case of Puerto Rico, we mainly used those of 2000, which contains 30 PUMAs and did not change throughout the years to 2010 (Figure 1).

3. Results

3.1. Household water-use cost

The median annual household water-use costs shows an increasing trend to a peak value of \$322 in 1990, then a declining in recent years to \$252 in 2010 and \$218 in 2012. The percentage of annual household income spent on water-use decreased continuously from 3.56% in 1980 to 1.32% in 2010 (Table 1). Spatially, the average household water-use costs

are higher at the more populated and urbanized areas such as the San Juan Metropolitan Area and lower in the less dense areas (Figure 1).

The household water-use costs differ among households from various demographic groups, with an expected general trend of higher costs in large households than small households (Figure 2a). For the large household category (Groups 9–14), there is no clear increasing trend of water-use cost with increasing household size. However, single-person households (Group 1) have the highest per capita water consumption, and more than three adults with more than three children households (Group 12) have the lowest per capita water consumption (Figure 2b). For households of the same size, generally the per capita water-use costs are higher in household with no or less children than households with children.

For single-person households, water-use cost is correlated with house value ($r=0.12$, $p<0.0001$), number of rooms ($r=0.07$, $p=0.004$), building age ($r=0.03$, $p=0.16$), and with the socioeconomic factors such as poverty index ($r=0.08$, $p=0.002$) and education level ($r=0.08$, $p=0.002$). For the single-person families who live in rented houses and pay rent and water-use costs, water-use cost is correlated with monthly rent ($r=0.07$, $p<0.0001$), number of rooms ($r=0.11$, $p<0.0001$), poverty ($r=0.10$, $p<0.0001$) and education ($r=0.09$, $p=0.0001$). The single-person households are mostly occupied by older adults, whereas in 2010 there are 127,390 (13.7% of total single-person household) male single-person households with an average age of 59.7 years and 211,815 (22.7% of total single-person household) female single-person households with an average age of 66.6 years. There are no significant differences in the water-use costs between females and males, or between adults and older adults for the single-person households. Generally there is no correlation between the annual household income and water-use cost for the whole population. However, there is a minor correlation between household income and water-use cost in households with multiple children (Groups 4, 7, and 8). Figure 3 shows annual household water-use costs in correlation with house property and socioeconomic factors for single-person household and couple household with no child based on 2010 data. Some patterns can be observed between household water-use costs and the building properties and also the resident socioeconomic status (Figure 3). House owners (mean: \$232, $n=2,427$) used slightly less water than the renters (mean: 244\$, $n=418$, $p=0.29$). Households with more rooms in the unit tend to use more water (Figure 3). Single-person households use more water than households from all the other demographic groups on a per capita basis (Figure 2).

3.2. Multivariate analyses

For the whole population, household water-use cost is somewhat correlated with the population density of PUMA (year 2000: $r=0.08$, $p<0.0001$; year 2010: $r=0.02$, $p=0.02$). Based on 2010 data, results from MLR give a modest predicting ability of household water-use costs ($r=0.40$, $p<0.00001$, $n=12,382$) for the whole population. The significant variables left from MLR are electricity cost ($p<0.0001$), age ($p=0.05$), number of rooms ($p=0.04$), and number of residents in the household ($p<0.0001$), while variables such as household income, education, poverty, housing units, and PUMA fail to pass the significance level of 0.05. However, the MLR results differ among different demographic groups. For example, annual household income is found correlate with water-use cost for the single-parent with more

than three children households (Group 4), and couple with more than two children households (Groups 7 and 8).

The FA clustering patterns of PUMAs based on sociodemographic and geographic factors are shown in Figure 4 a&b. Despite small differences between 2000 and 2010, variables such as household size, income, education, and poverty have greater loadings on PC1, and variables such as rooms in the household unit, water-use costs, age, units in the building structure, and population density have greater loadings on PC2. The PUMAs can be primarily categorized into three groups based on their PC scores: metro area (San Juan), urban area with high population density, and less populated suburban and rural area. Two PCs are identified for distinguishing the geographic unit PUMA as a soft coefficient (PC1, variables related to the socioeconomic status of the residents) and a hard coefficient (PC2, variables related to the dwelling conditions).

The FA results on the variability of factors influencing household water-use costs are shown in Figure 4 c&d. In 2000, variables with higher loadings on PC1 include number of rooms, housing units, education, and poverty, and variables with higher loadings on PC2 include household size and electricity. In 2010, variables with higher loadings on PC1 include income, and electricity cost; and variables with higher loadings on PC2 include household size, education, poverty, rooms, units and PUMA. The distribution of the household water-use costs can be generally clustered into low, medium and high levels according to the PC scores, while the variables differ in their weights to explain the variability of water-use costs of different levels. Though the PC loading patterns are slightly different between the two years due to complexity and changes of the sociodemographic patterns and also variations of the sampling households, the variables can still be roughly grouped into the soft and hard coefficients corresponding to the resident socioeconomic status and dwelling conditions, respectively.

The variable loading patterns to the PCs for the 14 demographic household groups are presented in Figure 5. The PC loading patterns are similar for some of the household demographic groups. For example, the single household (Group 1) and couple with one child household (Group 6) are similar in PC loading patterns, because age, electricity, income, education, and poverty are significant contributors to PC1 while the rest are contributing to PC2 in both groups. Other groups that show similar PC loading patterns include: single-parent with two children households (Group 3) and single-parent with more than two children households (Group 4); couple with two children households (Group 7) and large household with more than two children (Group 12); three adult household with no child (Group 9), large household with two children (Group 11) and four adult household with no child (Group 13); large household with one child (Group 10) and large childless household (Group 14). Variation of PC loading patterns suggests that the weights of the variables differ among different household demographic groups.

4. Discussions

The analyses identified sociodemographic factors that may impact household water-use costs, such as dwelling properties (building years, number of rooms, number of household

units in the building structure), household residential factors (number of household members, education level), and economic factors (annual income, poverty index). The correlations between household water-use costs and these factors are significant (p values within the statistical significance level) but not strong (very small correlation coefficients, r values).

In Puerto Rico, buildings with more units noticeably use more water per household, and home owners usually use less water than the renters on a per capita basis, a finding that is consistent with Troy et al. (2005) who studied water-use in Sydney, New South Wales, Australia. Troy et al. (2005) concluded that houses with higher land value use more water, but strongly suggested that there is no direct relationship between house type and water-use. Our study, however, reveals that households with more rooms tend slightly to use more water. While it was suggested that families with higher education levels often have stronger intentions to conserve water (Gilg and Barr, 2006; Lam, 2006), studies have demonstrated that households with lower education levels are more likely to engage in water conservation behaviors and actually consume less water (De Oliver, 1999; Gregory and Di Leo, 2003) or that education level does not have any significant effect on water-use behavior (Fielding et al, 2012). Pintar et al. (2009) observed that more educated residents in Waterloo Region (Ontario, Canada) consumed more drinking water during the day. In Puerto Rico, however, comparison of households with different education levels strongly indicates higher water-use costs for more educated families. Similar to the study by Fielding et al. (2012), age is slightly positively correlated with water-use cost, in Puerto Rico, which is in contrast with Gregory and Di Leo (2003) who estimated that households with older residents use less water. Gregory and Di Leo (2003) suggested that life stage determines per capita residential water-use rather than age itself. Although life stage was not assessed in our study, two possible causes are hypothesized to contribute to more water-use in older adults: (1) presence of teenagers in older householders who may consume more water (Lyman, 1992; Mayer et al., 1999; Stewart et al., 2012), and (2) employment status of older householders who are usually either retired or working less, therefore they spend more time and use more water at home (Mayer et al., 1999). The reasons for the slightly higher water-use costs from renters than single-person households maybe because in Puerto Rico many of the renters are old people, in addition to the hypothesis that renters have less intention to save water compared to house owners because water price is often included in the rent.

The couple-households with no child often use more water (less water on a per capita basis) than single households, regardless of their living house conditions, education level or economic status. Our results suggest children use considerably less water than adults. There is a slight positive correlation between building age and household water-use cost which is consistent with many studies (Kim et al., 2007; Kenny et al., 2008) but is different to Chang et al. (2010) who found single-families living in older buildings use less water than those in newer buildings in Portland (Oregon, US). This is because older buildings in Puerto Rico often contain more rooms ($r=0.43$, $p<0.0001$) and hence households living in older buildings are inclined to consume more water. Our finding of that there is a positive correlation between household resident size and household water-use cost agrees with Willis et al. (2013), who reported that single-families use more water than families with more than one resident on a daily per capita basis. We found that households in the San Juan metropolitan

area tend to use more water. This spatial trend does not agree with previous findings that households in areas with low density use more water (Allen 1999; US EPA, 2006) because low density means more leakage through water transport, newer and bigger houses, larger house acreage, and larger lawns than inner city old houses.

In our case, there are no noticeable spatial differences due to the house building age and the conditions of water infrastructure are generally spatially similar. Differences in on household water-use cost do not appear to be related to population density, but are more likely affected by sociodemographic and cultural factors. For example, we find that the household size appears to be smaller in the more densely San Juan area. In summary, the demographic profile of a high water-use household in Puerto Rico tends to be that of renters, people who live in larger or older buildings, people living in metro areas, or those with higher education level and higher income.

The FA results suggest two coefficients incorporating the various factors influencing household water-use cost: the soft coefficient (socioeconomic factors) and the hard coefficient (dwelling factors). The FA results indicate that the most influential factors on household water-use cost may vary among different demographic groups. For example, the hard coefficient is more dominant in affecting water-use for single-person households. This finding implicates the significance of studies on sociodemographic patterns of household water-use cost because more individualized methods could be proposed to reduce household water-use cost by identifying the most relevant factors. The weak predicting ability of household water-use cost from our analysis suggests the limitations of this study. We propose further studies on surveying the detailed household water-use cost patterns and related factors for households from various demographic groups in a temporal and spatial scale as a case study to supplement the micro information on household water-use. Findings and analyses in the study can be extended to other populations with IPUMS in order to achieve national sustainability and water resources management objectives.

5. Conclusion

Household water-use costs in Puerto Rico increased from 1970 to 1990, then remained stable but slightly decreased more recently. Despite the complex patterns of water-use costs among different household demographic groups, we identified several trends of household water-use as well as sociodemographic factors important in residential water demand management in Puerto Rico. Smaller households, rented households, households with higher education and higher income, household living in larger and older buildings, or households in metropolitan area are likely to consume more water on a per capita basis. The FA results on the multiple variables influencing household water-use costs indicate two PCs, soft and hard coefficients, which are the socioeconomic status of the household residents and the correlation with the household dwelling conditions, respectively. The weak ability to predict household water-use cost using these variables necessitates further studies, especially multidisciplinary research of the social and psychological aspects as well as micro case studies of household water-use.

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Highlights

Household water use varies among different sociodemographic groups

PCA identified the soft and hard coefficients relating to household water use

The soft coefficient refers to household socioeconomic factors

The hard coefficient refers to infrastructure factors

The variables affecting household water uses differ among various demographic groups

Figure 1. Spatial distribution of the Public Use Microdata Areas (PUMAs) in Puerto Rico (plot a; 30 PUMAs), the average household water-use cost of each PUMA in year 2000 (plot b) and year 2010 (year 2010). Note that due to the high population densities, the municipal of Bayamón is divided into 2 PUMAs (00801, 00802) and San Juan into 4 PUMAs (01001–01004).

Figure 2.

Annual household water-use costs (plot a) and per capita water-use costs (plot b) for households from different demographic groups in years 1970, 1980, 1990, 2000 and 2010. In 1970, only data above zero are presented. The bars in each box plot represent 5% and 95% confidence values, the black and the red lines inside the boxes represent median and mean values respectively.

Figure 3. Contour plots of annual household water-use costs with respects to the house properties (number of housing units in the building and number of rooms of the housing unit; upper panels) and socioeconomic factors (household economic status and education level; lower panels) for two demographic household groups, i.e. single-person household and couple household with no child based on 2010 data.

Figure 4. Factor analysis (FA) results for the variables classifying PUMAs (plots a&b) and variables influencing household water-use costs (plots c&d) in years of 2000 and 2010. The size of the arrows represents the loadings of the variables to the PCs.

Figure 5.

FA results of the loadings of the variables to the variability of water-use costs in 2010 for the 14 demographic household groups.

Table 1

Descriptive statistics (mean and median) for sample attributes.

	1970	1980	1990	2000	2010
Demographic information					
Population	2,706,800	3,204,380	3,519,350	3,807,950	3,722,100
Total number of households	658,600	888,780	1,056,190	1,260,890	1,356,830
Average household size	4.2	3.7	3.4	3.0	2.6
Presence of children under 12 years%	32%	28%	23%	21%	17%
Presence of children 12–18 years%	14%	13%	11%	10%	9%
Presence of people above 60 years%	10%	11%	13%	15%	21%
Percentage of people received at least one year college education	82%	79%	76%	74%	73%
Median values for the socioeconomic variable*					
Median water cost	0**	220	322	240	252
Median electricity cost	440	410	400	500	840
Median gas cost	20	410	240	150	190
Median fuel cost	120	230	16	150	190
Median household income	ND	12,730	12,520	15,000	15,540
Median family income	14,300	12,400	12,100	14,500	14,000
Median house value	ND	77,500	63,850	95,000	116,550
Poverty rate	66%	62%	59%	49%	45%
Unemployment rate	19.5%***	17.1%	14.4%	10.2%	16.4%
Labor force	858,272	915,651	1,137,343	1,290,983	1,269,017
Water-use cost, (million \$)					
Total household water-use costs	17	235	372	381	406
Total household income	ND	6,599	13,626	23,881	30,706
Ratios of household incomes for water costs	ND	3.56%	2.73%	1.60%	1.32%

Note:

* : The units for the costs and incomes are nominal dollars, and are adjusted to 1999 dollars using CPI99 values.

** : 75% of the water-use costs data in 1970 are zeros.

*** : The 1976 data from U.S. Bureau of Labor Statistics were used, because the 1970 data were not available. ND means no data.

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Table 2

Household demographic groups, and ratios of household numbers in each group to the total household numbers in the years from 1970 to 2010.

Group	Adults	Children	Category	1970 (%)	1980 (%)	1990 (%)	2000 (%)	2010 (%)
1	1	0	Single-person household	14	14	15	18	25
2	1	1	Single-parent household	2	2	2	3	3
3	1	2	Single-parent household	2	2	3	3	3
4	1	3	Single-parent household	3	2	2	2	2
5	2	0	Childless couple	13	17	20	23	26
6	2	1	Couple with children	9	9	9	9	8
7	2	2	Couple with children	10	12	11	10	7
8	2	3	Couple with children	17	15	10	7	4
9	3	0	Large childless household	5	7	8	9	9
10	3	1	Large household with children	7	6	7	6	5
11	3	2	Large household with children	5	4	4	3	3
12	3	3	Large household with children	9	6	4	2	1
13	4	0	Large childless household	3	3	3	4	3
14	5	0	Large childless household	1	1	2	1	1
Total	-	-	All	100	100	100	100	100