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RESEARCH ARTICLE

Demand for piped drinking water and a formal sewer system in Bhutan

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Abstract In this study, we estimate demand for sewage connection and piped drinking water in Bhutan. To estimate household willingness to pay, we use data from a sample of 8968 households surveyed through the Bhutan Living Standard Survey of 2012. A hedonic model is estimated using Heckman two-step procedure to overcome the problem of sample selection bias. On average, households in Thimphu city are willing to pay Nu 452 (USD 7) and Nu 124 (USD 2) per month for piped drinking water connections and sewage, respectively. This translates to 8 and 2% of their monthly household expenditure for water and sewage connection, respectively. The households in Thimphu are willing to pay significantly more than the current joint charge of Nu 78 per month for water and sanitation. There is scope for municipal offices in Bhutan to increase their revenues from public services and to cover potential investment, maintenance and operational costs associated with water and sewage services.

Keywords Hedonic · Bhutan · Sewage · Water · WTP · Heckman

JEL Classification Q25 · Q51 · Q52 · Q53 · Q56

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1 Introduction

In 2012, some 2.5 billion people in the world did not have access to improved sanitation facilities, of which 40% lived in Southern Asia (WHO and UNICEF 2014). Further, 748 million people—mostly the poor—lacked access to improved drinking water source and some 20% of people without access to clean water live in Southern Asia (WHO and UNICEF 2014). The situation in Bhutan is better than rest of the South Asian countries. Yet, there is still much to be done to improve water and sanitation access in order to ensure basic public health and livelihood benefits.

According to the Bhutan Living Standard Survey 2012, about 78% of Bhutanese households have access to piped water inside their dwelling (NSB and ADB 2012). Similarly, some 81% of households have access to improved sanitation facilities and 63% have a flush toilet. However, only 20% of households have flush toilets connected to a piped sewer system (NSB and ADB 2012). Soak pits and septic tanks are used when there is no sewage system and the municipal office provides septic-pumping services. Most residents directly release domestic waste water from the kitchen and washrooms to nearby streams (NSB 2010; RAA 2008; WHO 2006).

Waterborne diseases, such as diarrhea, are among the top five diseases in Bhutan (RGOB 2012). Some 2368 children per 10,000 population below the age of 5 were infected by diarrhea in 2011 (RGOB 2012). These water-borne diseases are generally associated with a lack of sufficient access to clean water and sanitation services (Kolahi et al. 2009; WHO and UNICEF 2014). Clearly, Bhutan has not fully reaped the public health dividends associated with access to improved water and sanitation.

In Bhutan, the office of the mayor, which manages utility services in urban centers, is often criticized for lack of adequate service supply and there are calls for restructuring the service delivery.[1] As Van den Berg and Nauges (2012) argue in the case of Sri Lanka, organizational reform in the management of the utility may be required in order to satisfy health and sanitation demands. One option that Bhutan could explore is partnering with private investors for water and sanitation services to deliver better health outcomes. Municipal offices are legally allowed to enter into contracts with private investors. However, for such contracts to be meaningful, it is important to correctly value the costs and benefits of piped sewage and drinking water connections.

A good understanding of what households are willing to pay for public services would allow policy makers to make informed investment decisions related to water and sanitation infrastructure. It would also allow for accurate determination of tariffs for piped water connections and clarify payment parameters in any contractual agreements with private entrepreneurs (Pattanayak 2006). In addition, municipal offices are currently unable to meet their recurrent expenditures for financing operational and maintenance services for basic urban amenities and rely on government

[1] National newspaper "Kuensel" had covered series of stories relating to this issue in recent years. The story highlighted households demand for better services and also financing initial investment cost, operating and maintenances problems and human resource capacity.

subsidy.[2] With these considerations, this study seeks to estimate household willingness to pay for a piped sewage connections and piped drinking water inside dwelling. Thus, by comparing the current tariff for water and sewage services and household's willingness to pay (WTP) for these two services, we attempt to ascertain if municipal offices have potential to increase revenue from these two services.

We use the hedonic pricing method to estimate willingness to pay.[3] This approach estimates the value of a connection to piped network by comparing the property values or rents between connected and unconnected houses after controlling for other factors. While many studies have estimated willingness to pay for drinking water in other South Asian countries [see Van den Berg and Nauges (2012) for Sri Lanka; Anselin et al. (2008) for India; and, Whittington et al. (2002) for Nepal], there are no such estimates available for Bhutan. Our study also attempts to fill this gap in the literature and offer some robust economic information to the water and sanitation decision-makers in Bhutan. There are also numerous literatures on impact of residential property value from disamenity of landfill [for example, (Hite et al. 2001) in Ohio, and open waste dumps (Wokekoro and Uruesheyi 2014) in Nigeria]. Similarly, Muhammad (2017) had estimated the disamenity from open sewer in Pakistan and Hensher et al. (2005) has estimated the household willingness to pay for avoiding sewage overflows in Australia. However, our study differs significantly from above studies as our study attempts to estimate household's willingness to pay for connecting to central sewage system. As far as the authors are concerned, there is no reliable study on household willingness to pay for connecting to the central sewage system in developing countries and this is our potential contribution to the literature.

2 Brief background of study area

Bhutan is a small country, sandwiched between India and China. A predominantly agricultural economy, the majority of Bhutan's 0.75 million people still depends on subsistence farming (NSB 2014). Bhutan's landscape is dominated by rugged mountain terrain with altitudes ranging from 300 m above sea level in the south to 7300 m in the north. Beyond agriculture, this majestic landscape offers a market for regulated tourism and for trade in hydro-electricity with its larger neighbors.

Politically, Bhutan is administered through 20 districts and 272 sub-districts, which are divided into 205 gewogs (rural sub-districts) and 67 towns (urban sub-districts). Four towns are categorized as A towns and 60 towns fall into category B. Category A towns include Thimphu, Phuntsholing, Gelephu and Samdrup Jongkhar.[4] An elected city mayor administers these towns, with the mayor's

2 Annual reports of respective towns published by Ministry of Works and Human Settlement shows this gap.

3 Other studies have adopted method of contingent valuation (CV) to estimate WTP for water in developing countries. However, in our study, the demand for the water and sewage are observed in market and we adopted hedonic pricing method.

4 Officially four town falls under category of A towns. However, Samdrup Jongkhar town was recently upgraded to A town and differ significantly in terms of urban amenities, economic opportunities and population. Therefore, in our study we consider Samdrup Jongkhar town as B town.

office functioning as an autonomous organization. According to the Population and Housing Census 2005 (RGOB 2005), the only census to date conducted in Bhutan, approximately 17% of the total population lives in these four towns. Same document also reports that about 40% of total urban population lives in capital city, Thimphu.

Wastewater treatment plants are available only in Thimphu, Phuntsholing and Gelephu towns. In Thimphu town, some 52% of households are connected to the existing sewage system (NSB and ADB 2012).[5] Other households and towns resort to septic tanks and soak pits, while some households still use pit latrines.[6] Existing Water and Sanitation Rules allow a house to get connected to the sewage system if the house is within the distance of 70 m from main sewage line and if it is technically feasible to do so. Municipal offices generally offer septic pumping services to un-connected homes for a modest fee.

Available report suggests that about 40% of Thimphu's sewage is currently being treated and its stabilization pond is at maximum capacity (Sabapathy and Rajarathnam 2008). Thus, the Thimphu City Corporation is developing a sequential batch reactor to replace the technology currently being used to treat waste water. Similarly, Phuntsholing City Corporation is conducting a feasibility study for relocating the existing stabilization pond since it cannot cope with demand. The existing sewage system in Gelephu was built in 2008 and meets current needs, but may not be adequate if demand increases.

The overall context in Bhutan is of a growing country that is inadequately served by available water and sanitation infrastructure. As towns grow, the demand for water and sanitation services will only increase. Given this situation, our study seeks to estimate the price households are willing to pay for improved access to these services, with the intention of clarifying for policy makers the kinds of contracts and investments that may be feasible. The municipal offices also have limited financial capacity and rely on government subsidy for financing operational and maintenance services for urban amenities including water and sewage services. The recent coverage by national television BBS has highlighted that Thimphu municipal office is negotiating with government to revisit existing land tax with the objective of doing away with government subsidy and expanding revenue base.[7] Similarly, national newspaper Kuensel covered on the expenditure that Thimphu town is currently incurring on waste collection and has highlighted the huge gap between the revenue and expenditure.[8]

[5] In 1996, Thimphu and Phuntsholing's waste stabilization ponds and central sewage system were connected to 60 and 80% of the houses in each town (WHO 2006). However, with housing growth, by 2012, piped sewage connections have significantly decreased (NSB and ADB 2012).

[6] Personal communication with Mr. Sangay Chedar, Senior Planning Officer under Gross National Happiness Commission (Planning Commission), Royal Government of Bhutan.

[7] BBS stands for Bhutan Broadcasting Service and it is only national television in Bhutan. Article dated Jan 5th, 2017 had covered a story on why Thimphu town is currently negotiating with government to revisit existing land tax. It highlights that the objective of such initiative is to strengthen the financial capacity of Thimphu city and also to do away with existing government subsidy for financing their recurrent expenditure. The story is available at: http://www.bbs.bt/news/?p=65509

[8] Kuensel is Bhutan's national newspaper and story is available at: http://www.kuenselonline.com/strengthening-community-participation-to-keep-the-city-clean/.

3 Data

We use data from the Bhutan Living Standard Survey (BLSS) conducted in 2012. The BLSS 2012 report data on demographic and socio-economic characteristics. These surveys were designed to develop indicators at the district level, and data were collected from households across the country. Information was collected at both household and individual levels.

In the BLSS, household stratification is at the district and at the urban/rural level. Blocks serve as primary sampling units (PSU) for urban areas, while chiwogs (the lowest rural administrative unit of the district) do so for rural areas. Thus, using the probability proportional to size of rural and urban populations in each block or chiwog, 4619 urban households and 4349 rural households were surveyed in BLSS in order to capture detailed socio-economic variability in urban areas (NSB and ADB 2012). This translates to total sample of 8968 households with almost equal proportion of households from both urban and rural areas. From the total of 4619 urban households, 1994 and 2625 households were surveyed from capital city Thimphu and rest of the urban areas, respectively. The unit of analysis of our study is at the household level.

A main variable of interest to us is housing prices and rental. In this dataset, house rent refers to the monthly rent paid by the tenants. If a household owns a house, households were asked how much they would spend to rent a similar house. Several housing attributes are included in our analyses to control for differences in houses that may influence rent. These include the number of rooms, materials used for the floor, roof and external wall, types of toilet facilities and distance to amenities. We measure distance in terms of the number of hours it takes to reach the nearest amenities such as distance to market, road, bus station and district headquarters. We use mean per capita household expenditure within each census tract as proxy for household income since our data set does not contain reliable information about household income. Table 1 shows the details of variable definitions as well as their summary statistics by overall sample, Thimphu subsample, A town, B town and rural subsamples.

BLSS data set is very rich, covering various modules; however, this data set is not without any shortcomings. BLSS have collected information on lots of variables that we would like to control in our analysis; however, some variables such as distance to water source could not be used in our analysis as less than 10% have responded to this question. Similarly, the continuous variables such as expenditure and distance to amenities are not normally distributed and there are some extreme values. To overcome this problem, we did log transformation for these variables. Also, three respondents have reported their monthly expenditure as zero. We replaced zeros with mean expenditure of the respective sub-district that household belong to as our result does not change with or without inclusion of these three respondents.

Table 1 Definition of variables and summary statistics

Variables	Definition	All sample	Thimphu	A town	B town	Rural
Dependent variable						
Rent (*ln*)	Monthly house rent in Nu	2556 (3203)	4918 (4330)	4501 (4025)	2543 (2834)	1365 (1965)
Independent variables for hedonic model						
Sewage	1 if connected to sewage system	–	0.519 (0.499)	0.414 (0.493)	–	–
Water	1 if piped drinking water is inside dwelling	0.802 (0.398)	0.891 (0.311)	0.906 (0.292)	0.826 (0.380)	0.728 (0.445)
Toilet	1 if toilet type is flush toilet	0.709 (0.454)	0.955 (0.206)	0.962 (0.191)	0.871 (0.335)	0.481 (0.500)
Room	Number of rooms excluding balconies	2.987 (1.611)	2.885 (1.350)	2.857 (1.307)	2.885 (1.447)	3.112 (1.826)
Wall	1 if external wall is concrete	0.329 (0.470)	0.503 (0.500)	0.510 (0.500)	0.502 (0.500)	0.139 (0.346)
Roof	1 if roof material is modern	0.940 (0.238)	0.989 (0.099)	0.990 (0.1000)	0.981 (0.137)	0.891 (0.312)
Floor	1 floor material is wood	0.530 (0.499)	0.667 (0.471)	0.509 (0.500)	0.304 (0.460)	0.645 (0.479)
Owner	1 if household owns a dwelling	0.630 (0.483)	0.364 (0.481)	0.342 (0.474)	0.752 (0.432)	0.904 (0.294)
Income	Average per capita expenditure within census tract	1564 (852.5)	1689 (991.0)	1773 (1512)	1525 (146.1)	1454 (204.6)
Market	Distance from nearest food market in hours	1.002 (4.212)	0.218 (0.152)	0.244 (0.310)	0.205 (0.340)	1.824 (5.929)
Road	Distance from tarred road in hours	1.118 (4.418)	0.065 (0.085)	0.059 (0.077)	0.097 (0.284)	2.226 (6.151)
Bus	Distance from bus station in hours	1.602 (4.789)	0.261 (0.174)	0.273 (0.325)	0.635 (2.599)	2.851 (6.415)
District	Distance from district headquarters in hours	2.281 (5.037)	0.432 (2.499)	1.016 (2.692)	0.992 (2.183)	3.635 (6.495)
Agriculture	Distance from agriculture extension office	1.017 (3.830)	0.367 (0.452)	0.363 (0.391)	0.411 (1.233)	1.691 (5.348)
Explanatory variables for Heckman first step						
Male	1 if head of household is male	0.731 (0.443)	0.771 (0.420)	0.796 (0.403)	0.814 (0.389)	0.655 (0.475)
Age	Age of head of household in years	43.69 (14.75)	38.12 (11.64)	38.10 (11.67)	39.22 (12.70)	49.13 (15.33)
Farmer	1 if head household is farmer	0.295 (0.456)	0.009 (0.092)	0.010 (0.100)	0.049 (0.216)	0.580 (0.494)
Primary	1 if head has completed 6 years of education	0.139 (0.346)	0.154 (0.361)	0.150 (0.357)	0.185 (0.388)	0.112 (0.315)
School	1 if head has completed 12 years of education	0.230 (0.421)	0.383 (0.486)	0.393 (0.489)	0.330 (0.470)	0.085 (0.278)
University	1 if head has completed university	0.093 (0.291)	0.171 (0.377)	0.167 (0.373)	0.122 (0.327)	0.035 (0.183)
Wetland	Total irrigation land owned in acres	0.571 (1.890)	0.311 (1.286)	0.253 (1.286)	0.368 (1.713)	0.857 (2.209)
Dryland	Total non-irrigation land owned in acres	1.226 (2.482)	0.675 (2.251)	0.595 (2.089)	0.619 (1.891)	1.885 (2.753)

Table 1 (continued)

Variables	Definition	All sample	Thimphu	A town	B town	Rural
Expenditure	Monthly per capita household expenditure	1565 (5143)	1780 (4359)	1780 (8358)	2155 (3668)	1168 (2282)
Observation		8968	1994	2676	1943	4349

A town includes samples from Thimphu town. Standard deviation in parentheses

4 Model and estimation methods

4.1 The hedonic pricing model

To estimate the value of connection to main sewage line and piped water inside the dwelling of a house, we use the hedonic pricing method developed by Lancaster (1966) and Rosen (1974). The method assumes that households maximize their utility by bidding at the lowest bid curve which is tangent to hedonic price function. On other hand, landlords or house owners offer bundle of housing attributes that provide the maximum profit at the prevailing market price or rent. At this point, bid and offer curves are tangent to hedonic price function. Thus, market is in equilibrium since offered bundle of housing attributes are consumed. The hedonic pricing method is frequently used to measure the value of environmental quality associated with a private good, including an amenity or disamenity (Freeman 2003). In our case, we are interested in examining the value households place on access to a piped sewer system and piped drinking water. The basic idea is to estimate the value of an environmental amenity by examining the difference between the property value of houses with and without the amenity, after controlling for other factors influencing housing values.

In the hedonic model the utility function of a household is:

$$U = U(C, S, N, Q), \tag{1}$$

where C is a composite goods; S denotes structural attributes of a house; N denotes neighborhood characteristics; and Q denotes environmental quality. A household chooses to maximize utility in Eq. (1), subject to the budget constraint

$$M - C - R = 0, \tag{2}$$

where M is the income and R is the monthly rental price of a house. We assume that the housing market is in equilibrium, that is, each household makes a utility-maximizing residential choice given the rental prices and characteristics of alternative housing options and that these rental prices clear the market given the stock of housing and its characteristics. Under these assumptions, the rental price of a house would be a function of the structural, neighborhood and environmental characteristics (Freeman 2003):

$$R = R(S, N, Q), \tag{3}$$

Equation (3) is referred to as hedonic price function. In our study, Q represents environmental characteristics including connection to piped sewer system and piped drinking water inside the house. The value of any particular characteristic can be measured by computing its marginal effect on the rental price using this equation.

Economic theory, generally, suggests that the sales value of a house as a function of its attributes. However, such data are not available in the case of Bhutan. We, therefore, use monthly house rent instead of sales value. Studies by da Morais and de Cruz (2003), Yusuf and Koundouri (2005) and Van den Berg and Nauges (2012) have also used rent as a function of other housing attributes to estimate willingness to pay for different amenities. da Morais and de Cruz (2003) argue that rent can be used as a function of other housing attributes, as rent is directly linked with the market value of a house.

4.2 Econometric model and estimation methods

An important consideration in estimating the hedonic price function in Eq. (3) is the specification of its functional form. Rosen (1974) argues that the function can only be linear when the attributes of a house can be unbundled. Freeman (1979) too agrees that the function can be linear only if the attributes of the product can be repackaged. However, the repackaging of housing attributes is almost impossible; thus, the hedonic price function may need to be specified as a nonlinear function (Freeman 2003; Rosen 1974). Several other scholars also express concern over incorrect functional forms, which can result in inconsistent estimates (Anselin et al. 2008; Kuminoff et al. 2010; Leong 2002). A key finding by Cropper et al. (1988) suggests that a flexible model specification for equilibrium prices generates the most reliable marginal values, only when all variables are included in the model. However, in the presence of omitted variables, simpler functional forms, including log-level and log–log model, tend to perform better. We follow their findings in developing our model specification. We use the natural log of rent as the dependent variable as this transformation also approximates normal distribution. As most explanatory variables have a monotonic (positive or negative) relationship with rent, we consider level and natural log transformations. The econometric model for the hedonic price function we estimate is

$$y_i = X_i\beta + u_i, \tag{4}$$

where subscripts i denote household; y_i is the natural log of monthly rent; X_i is a vector of explanatory variables (in level or natural log) for structural, neighborhood and environmental attributes of a house; β is a vector of coefficients to be estimated; and u_i is the error term.

In the explanatory variables, structural attributes include number of rooms, presence of flush toilet and materials used for wall, roof and floor. Neighborhood characteristics include distance from market, tarred road, bus station, district head quarter and agriculture extension office. Environmental attributes include access to central sewage system and piped water inside the dwelling.

In the econometric model in Eq. (4), we expect that the rent will increase with the increase in the number of rooms, presence of flush toilets and with the use of improved construction materials for wall, floor and roof. Therefore, we expect a positive sign of coefficients on these variables. For neighborhood attributes like distance from market, tarred road, bus station, district head quarter and agriculture extension office, we expect negative coefficient indicating that farther the house is located from these facilities, the value of house will decrease. We also expect that value of house would increase if a house is connected to sewage system and has piped water inside dwelling. Therefore, we expect positive coefficients from our environmental variables for sewage and water amenities.

However, in our data, the variable sewage is observed only if a household (respondent) is living in one of the A towns and not observed if living in rest of the urban or rural areas as they do not have an option to connect to central sewage system. We believe that decision to live in a particular place is self-selected and, therefore, results of Eq. (4) are biased. If households have chosen location and place of residence based on the economic opportunities or location specific amenities, this may result in biased estimation of willingness to pay (Chay and Greenstone 2005). For instance, households may not decide to live in A town if the household's economic return is higher if they live in B towns or rural areas, and thus WTP (for water and sewage) of observed household is biased upward. Following Yusuf and Koundouri (2005), we follow Heckman two-step procedure (Heckman 1979) to overcome this selection bias. Thus, we modify Eq. (4) as

$$y_i = X_i\beta + \lambda\hat{M}_i + v_i, \tag{5}$$

$$\hat{M}_i = \phi_i(.)/\{\Phi(.)\}, \tag{6}$$

where M_i is inverse Mill's ratio, $\phi_i(.)$ and $\Phi(.)$ are values of normal density and cumulative functions predicted from probit model (referred to as first step in Heckman two-step procedure):

$$l_i^* = Z_i\delta + e_i, \tag{7}$$

where $l_i = 1$ if $l_i^* > 0$ and $l_i = 0$ otherwise. Z_i is vector of variables that explain residency location decision and δ is vector of coefficients and it is assumed that there is correlation ρ between e_i and v_i. Similar Heckman two-step estimation was used for correcting bias of observing sale price of a house only when property was sold and fall within the district of school consolidation by Brasington (2004) and Knight (2002) for observing listed sale value only if price change had occurred. For Eq. (5) and Eq. (7) to be estimated, vector Z_i must contain at least a variable that explains residency location decision (Eq. 7), but does not enter into Eq. (5). Therefore, in Eq. (7), following Yusuf and Koundouri (2005) we include gender, age, marital status, occupation and level of education of head of household. In addition, we also include household characteristics such as total land ownership and per capita household expenditure. We assume that if head of household is farmer and owns more land, household may choose not to live in A town and assume that these variables will not explain rent (Eq. 5) directly. Further hedonic theory suggests that buyer's characteristics does not enter the hedonic equation (Freeman 1979).

Hedonic pricing estimation requires addressing empirical issue such as omitted variable bias due to heterogeneity of housing attributes. Recent studies have used spatial fixed effect in hedonic models to hedge against the problem of omitted variable bias (Kuminoff et al. 2010; Anselin et al. 2008; Anselin 2001), allowing for estimation of spatial lag and spatial error models. However, in our case, we do not have geo-referenced data and we have restricted to using fixed effects for towns or sub-districts based on the model we estimate.

Hedonic pricing method makes important assumptions such as existence of perfectly competitive market and household having access to full information on attributes of houses and housing prices. Van den Berg and Nauges (2012) and Yusuf and

Koundouri (2005) highlight that this assumption had been violated in rural areas of developing countries like Sri Lanka and Indonesia. It is also possible that these assumptions may be violated in rural areas of Bhutan too, given that there are very limited stock of houses and its attributes in rural areas. However, in urban areas of Bhutan, specifically in A towns and capital city, given huge stock of housing supply and its attributes along with competitive prices for houses, it is reasonable to assume that these assumptions are not violated. Similarly, housing market in Bhutan differ in terms of stock of houses and its attributes, location amenities such as central sewer system and consumer base among A town, B town and rural areas. Following Freeman (1979), we estimate hedonic equation for each market segment, and we detail this discussion in Sect. 5.2.

Our econometric model (Eq. 5) includes two dummy explanatory variables of interest: connection to sewer system and connection to piped drinking water inside the dwelling. Denote X_j as one of these variables, say connection to sewer system. The willingness to pay (WTP) or the value of connecting to the sewer system can be measured by computing its marginal effect on the house rent. As the explanatory variable is a dummy variable and the dependent variable is the natural log, WTP is measured as follows [Van den Berg and Nauges (2012) and Yusuf and Koundouri (2005)]:

$$\mathrm{WTP}_j = R(e^{\hat{\beta}_j} - 1), \tag{8}$$

where R is monthly rent of a house, and $\hat{\beta}_j$ is an estimated coefficient on the dummy variable for the connection to water or sewage.

5 Results and discussion

5.1 Descriptive statistics

Table 1 presents the definition of the variables and summary statistics of the variables used in the study. The overall mean monthly rent in Bhutan is Nu[9] 2556. The average monthly rent in A town, B town and rural areas is Nu 4501, Nu 2543 and Nu 1365, respectively. Thimphu city has reported the highest mean monthly rent of Nu 4918. It has reported that about 52% of household in Thimphu have connected to central sewage system and about 89% have connected to piped water. In A town, about 91% of households have piped water connection inside dwelling while only about 41% have connected to sewage system. In B town and rural areas, it has been reported that about 83% and 73% have connected to piped water inside dwelling.

We also conducted mean comparison test for rent with and without water and sewage connection. The mean rent of households without connection and with connected sewage is Nu 3789 and Nu 5507, respectively, and mean difference is statistically significant at 1% level in A town sub samples. Similarly, mean monthly rent in

[9] Nu is short hand for Bhutanese currency ngultrum. 1 USD = Nu 67.15 as Jan 2017.

A town without and with water connection is Nu 2408 and Nu 4718, respectively, and the mean difference is also significant at 1% level. The significance of mean difference confirms that water and sewage connection has the potential to explain rent differentials in our hedonic model.

5.2 Estimation results

From Table 1, it is seen that there are different market segments in Bhutan. In order to identify the relevant hedonic markets that may require us to estimate hedonic functions separately or jointly, we conducted Chow test to examine the structural differences between market segments. We conducted chow test for sub-cities of A towns and checked if we can jointly estimate hedonic function for Thimphu and Phuntsholing town. We then estimated similar hedonic function for Thimphu and Gelephu town. For both of the hedonic price functions estimated above, null that the hedonic functions are same is rejected at 1% significance level. On other hand, we failed to reject null for joint estimation of Phuntsholing and Gelephu towns.

Based on above test results, we estimate hedonic models for Thimphu separately. The result of joint estimation of Phuntsholing and Gelephu towns (and as well when estimating separately), coefficient of water and sewage is not significant and we do not discuss results from these two towns[10] (result of joint estimation of three towns are reported in Supplementary appendix, Table A2). Similarly, we estimate hedonic models for B towns and rural area separately. However, as there is possible violation of assumptions of hedonic models in B towns and rural areas and we do not interpret their results (result is reported in Supplementary appendix, Table A1), however, the coefficients are consistent.

Table 2 reports the probit results of first step from Heckman two-step procedure. The dependent variable in this probit model takes 1 if households are residents of Thimphu town and zero otherwise. The marital status of head of household does not seem to have effect on the probability of living in Thimphu town but male headed households are less likely to live Thimphu town. However, as expected, the level of education of head of households has positive effect on the probability that household would live in Thimphu. This confirms our assumption that as education level increases, an individual becomes more employable in competitive job market and more likely to reside in urban areas. On the other hand, variables like age, farmer and land (wet and dry) ownership have negative coefficient. In urban areas there is less farming opportunities and farmers are less likely to reside in urban. Similarly, if a household owns more land, economic opportunities from agriculture activities are more and less likely to reside in urban areas. We did expect positive coefficient

[10] We have sample of 198 and 484 households from Gelephu and Phuntsholing town respectively. It was reported that about 97 and 94% of households have water connected inside dwelling. We suspect that coefficients are not significant due to small sample and less variation. Similarly, in our sample, no households from Phuntsholing have reported as having connected to sewage system and we could not estimate coefficient of sewage for Phuntsholing subsample. About 37% of households have reported of having connected to sewage in Gelephu town but coefficient of sewage was still insignificant.

Table 2 Probit results of Heckman (first step) for Thimphu town

Dependent variable: location of house (1 if house is located in Thimphu, Phuntsholing and Gelephu town and 0 otherwise)	
Variables	Coefficient (SE)
Male	– 0.108** (0.042)
Age	– 0.008*** (0.001)
Married	0.043 (0.045)
Farmer	– 1.761*** (0.090)
Primary	0.239*** (0.051)
School	0.382*** (0.044)
University	0.499*** (0.057)
Wetland	– 0.019* (0.011)
dryland	– 0.013* (0.008)
Expenditure (ln)	– 0.034* (0.018)
Constant	– 0.105 (0.140)
Observations	1994

Standard errors in parentheses

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

from expenditure which we use as proxy for income. However, we got negative coefficient, indicating that as households accumulate more income and wealth, they are less likely to live in Thimphu town.[11] Only possible explanation for this result is that, towns in Bhutan are becoming like any other urban cities with other urban disamenities and we assume that as households accumulate more income and wealth they prefer not to live in more urban areas.

Table 3 reports the estimation results of hedonic models from Heckman two-step procedure (Eq. 5) and OLS, sub-sample result of Heckman two-step procedure of renter (who actually pay monthly rent). The inverse mill's ratio is significant at 1% level indicating the presence of sample selection bias in our hedonic model. However, the consequences of including inverse Mills ratio in model come at the cost of likelihood of introducing heteroscedasticity in the model. We, therefore, conducted Whites test for heteroscedasticity as reported in the bottom part of Table 3. The white's test for null hypothesis of presence of heteroscedasticity in our hedonic model is rejected. In addition, it is shown that the full maximum likelihood model is more consistent than Heckman two-step and we estimate same model and the results of full maximum likelihood are comparable with Heckman two-step result[12] (full

[11] Reviewer pointed out that coefficient of expenditure may be negative because expenditure may not be representing income of households and readers may interpret this result in view of this possibility.

[12] Reviewer also pointed that Heckman two step may be inconsistent with hedonic model, in which inverse Mills ratio for each observation in the hedonic price function is different. In order to make it consistent with hedonic theory, we calculated average inverse Mills ratio within each census tract and estimated with inclusion of "average inverse Mills ratio." The result is comparable in all aspects with Heckman two step model. Since both model yields identical results, we use results from Heckman two step for estimating WTP.

Table 3 Parameter estimates of hedonic model for Thimphu town

Dependent variable: rent (*ln*)

Variables	Heckman		OLS	
	Owner and Renter	Renter	Owner and Renter	Renter
Sewage	0.078*** (0.029)	0.069** (0.035)	0.083*** (0.028)	0.075** (0.034)
Water	0.268*** (0.046)	0.261*** (0.061)	0.270*** (0.046)	0.268*** (0.059)
Toilet	0.228*** (0.067)	0.318*** (0.100)	0.231*** (0.078)	0.326*** (0.106)
Room (ln)	0.855*** (0.030)	0.808*** (0.042)	0.847*** (0.034)	0.808*** (0.045)
Wall	0.128*** (0.028)	0.038 (0.035)	0.134*** (0.029)	0.048 (0.036)
Roof	0.081 (0.134)	− 0.164 (0.207)	0.103 (0.143)	− 0.077 (0.158)
Floor	− 0.131*** (0.028)	− 0.216*** (0.035)	− 0.135*** (0.028)	− 0.216*** (0.033)
Owner	− 0.103*** (0.029)		− 0.123*** (0.029)	
Income (ln)	0.124*** (0.037)	0.188*** (0.044)	0.125*** (0.036)	0.187*** (0.044)
Market (ln)	− 0.046** (0.019)	− 0.076*** (0.023)	− 0.044** (0.019)	− 0.072*** (0.023)
Road (ln)	− 0.027 (0.019)	0.015 (0.024)	− 0.029 (0.020)	0.013 (0.024)
Bus (ln)	− 0.139* (0.082)	− 0.248** (0.111)	− 0.145* (0.085)	− 0.255** (0.128)
District (ln)	− 0.020 (0.022)	− 0.028 (0.027)	− 0.019 (0.023)	− 0.027 (0.026)
Agriculture (ln)	0.085* (0.047)	0.073 (0.053)	0.084 (0.055)	0.069 (0.055)
Mill's ratio	− 0.161*** (0.060)	− 0.324*** (0.105)		
Constant	6.091*** (0.322)	6.184*** (0.421)	5.890*** (0.318)	5.739*** (0.387)
Observations	1994	1268	1994	1268
R^2			0.416	0.377
Diagnostic test				
Wald test (Owner and renter model): 1399.89 [χ^2 (14)-critical: 23.38]				
White's heteroscedasticity test (Owner and renter model): 219.07 [χ^2 (14)-critical: 23.38]				

Standard errors in parentheses. Owner and renter model includes both home owner and renter subsample

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

results reported in Supplementary appendix Table A3). The results of Heckman two-step and full maximum likelihood are identical in terms of signs of coefficient and significance level, except for two variables: the coefficient of owner in maximum likelihood is not significant while it is significant at 1% in two-step model. Similarly, coefficient of distance to bus station become insignificant in maximum likelihood model while it is significant at 10% at in two-step model. However, the coefficient of sewage and water are comparable both in terms of magnitude of coefficient and level of significance. The null hypothesis of all hedonic coefficient (except intercept) is zero and is also rejected by Wald test. The coefficients of most of the variables are significant and are consistent with the existing literature. The hedonic results suggest that, for Thimphu dwellers, monthly house rent increases by about 8% if the house is connected to central sewage system and it increases by about 26% when water is piped inside dwelling, other things remaining constant.

Structural variables like room, toilet, roof and walls are significant and consistent with conventional hedonic results. We expected the coefficient signs of all these structural variables to be positive and their signs are positive as expected except for floor. Results show that the presence of flush toilet, more rooms, concrete external walls and modern roof increases the value of a house. The coefficient of floor is negative indicating that households prefer non-wood floor such as modern concrete floors. The coefficient of variable income is also positive as expected, suggesting that as neighborhood becomes more affluent, other things remaining constant, household are willing to pay more monthly rent. Coefficient of variable owner is negative, indicating that home owners are willing to pay less rent. Similar coefficient on home ownership is also reported by Knight (2002).

The signs of coefficients of neighborhood attributes including distance to market, road, bus-station and district headquarter are negative as expected but only coefficient of market and bus station is significant at the conventional level. This indicates that the value of a house decreases when it is located farther away from these amenities. The distance from agriculture extension is positive and significant indicating that as households move away rural area, the rent increases. This is also reasonable as many of the agriculture extension offices are located in rural areas and it is likely that rent will increase as house is located farther away from rural areas. This result is in contrast with the results of Baranzini and Schaerer (2011) and Jim and Chen (2009) who show that households have a stronger preference for a natural rather than a man-made environments.

We also estimate Heckman two-step and OLS for renter (those who pay rent) subsamples as reported under renter column in Table 3. As mentioned in Sect. 3, rent is the actual value of rent for renter households only, whereas homeowners were asked how much they would spend to rent a similar house. Therefore, it is important to check the sensitivity of results using the renter subsample. This performs the robustness check of the result and our results are still comparable and significant at conventional level, except that variable wall and agriculture became insignificant in Heckman renter subsample model; however, coefficients of water and sewage are still comparable across models. Also, the sign of coefficient, effect size and significance level between Heckman two-step and OLS of renter sub-sample are comparable except for the variable agriculture, which is insignificant in OLS renter sub-sample estimate. The coefficient of sewage and water from OLS, which does not take into account of selection bias, is 8.3 and 27%, respectively, while it is 7.8 and 26.8% from Heckman two-step model. Our results show that the bias from OLS estimates is very minimal.

We also estimated Heckman models with interaction variables and results are reported in Table 4. In the last panel of Table 4, the result of F test for joint significance of interaction variables are reported for each model. The F statistics are greater than critical values in all the models suggesting that interaction variables are jointly significant. In model 1, reference category is houses that do not have connection to both sewage and water. The coefficient of sewage, water and the interaction variable is positive indicating that rent increases when house is connected only to sewage and water and connected to both water and sewage compared to house that is not connected to both sewage and water. Similar results are also reported in model 2

Table 4 Heckman model with interaction variables

Dependent variable: rent (ln)				
Variable	Model 1	Model 2	Model 3	Model 4
Sewage	0.049 (0.115)	0.076*** (0.029)	0.137** (0.064)	0.075*** (0.029)
Water	0.263*** (0.050)	0.101 (0.127)	0.267*** (0.046)	0.120 (0.084)
Sewage × water	0.032 (0.118)			
Water × toilet		0.193 (0.136)		
Sewage × room			− 0.060 (0.059)	
Water × room				0.199** (0.094)
Toilet	0.229*** (0.068)	0.111 (0.106)	0.223*** (0.068)	0.235*** (0.067)
Room (ln)	0.855*** (0.030)	0.854*** (0.030)	0.883*** (0.041)	0.678*** (0.089)
Wall	0.128*** (0.028)	0.124*** (0.028)	0.127*** (0.028)	0.128*** (0.028)
Roof	0.081 (0.134)	0.079 (0.134)	0.075 (0.134)	0.112 (0.135)
Floor	− 0.131*** (0.029)	− 0.130*** (0.029)	− 0.132*** (0.029)	− 0.132*** (0.029)
Owner	− 0.103*** (0.029)	− 0.102*** (0.029)	− 0.103*** (0.029)	− 0.101*** (0.029)
Income (ln)	0.124*** (0.037)	0.123*** (0.037)	0.123*** (0.037)	0.122*** (0.037)
Market (ln)	− 0.046** (0.019)	− 0.046** (0.019)	− 0.046** (0.019)	− 0.047** (0.019)
Road (ln)	− 0.027 (0.019)	− 0.028 (0.019)	− 0.026 (0.019)	− 0.025 (0.019)
Bus (ln)	− 0.139* (0.082)	− 0.140* (0.082)	− 0.137* (0.082)	− 0.142* (0.082)
District (ln)	− 0.019 (0.022)	− 0.020 (0.022)	− 0.020 (0.022)	− 0.018 (0.022)
Agriculture (ln)	0.085* (0.047)	0.082* (0.047)	0.086* (0.047)	0.087* (0.047)
Mills ratio	− 0.162*** (0.060)	− 0.160*** (0.060)	− 0.164*** (0.060)	− 0.156*** (0.060)
Constant	6.093*** (0.323)	6.189*** (0.331)	6.094*** (0.323)	6.196*** (0.327)
Observations	1994	1994	1994	1994
Test for joint significance of interaction variable				
F test (3, 1991) [critical: 2.61]	16.13	17.83	286.28	297.47
R^2	0.418	0.419	0.419	0.420

Standard errors in parentheses. Model with sewage and toilet interaction was estimated, the interaction variable got dropped due to collinearity with sewage variable

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

and model 4, except in model 3. The coefficient of water and room interaction variable is positive (in model 4) suggesting that as house connects to water and number of room increases, the rent increases. Thus, result from model 1 to model 4 suggests that water is one of the most valued attributes of a house.

5.3 WTP for sewage connection and piped drinking water

We now estimate the willingness to pay for a sewage connection and piped drinking water based on the hedonic model presented in Table 3. We estimate WTP for piped drinking water inside dwelling and sewage connection for capital city, Thimphu only. (The WTP for water and sewage from pooled model is reported in Supplementary appendix Table A4). The WTP estimates based on hedonic models are characterized as upper bound estimates (Van den Berg and Nauges 2012) and our

Table 5 WTP for water and sewage (in Nu)

	Heckman	
	Median WTP	% of monthly expenditure
Water	452 [280:623]	8
Sewage	124 [33:214]	2

The percentage of monthly household expenditure is calculated based on the national figure of Nu 5804 in urban as reported in BLSS 2012 report. Confidence interval is calculated from bootstrapped standard errors of median WTP from 500 bootstrap samplings and seed set at 123

Table 6 WTP for water and sewage by household expenditure (in Nu)

Monthly per capita household expenditure	WTP for water	WTP for sewage
First quintile	241	66
Second quintile	301	82
Third quintile	452	124
Fourth quintile	602	165
Fifth quintile	753	206

estimates may be referred to as upper bound WTP too. As mentioned in Sect. 2, this is because overall context in Bhutan is of growing and government is investing in urban amenities such as water supply and sewage networks particularly in A towns. As a result, these amenities are likely to change rapidly and rental premium from such amenities may not be observed in long run when full coverage is achieved. Thus, we cautiously interpret WTP from these amenities as upper bound WTP. Table 5 shows the median WTP for sewage connection and piped water inside dwellings for Thimphu town.

Our results in Table 5 show that households' median WTP for piped water inside dwelling and sewage connection is roughly Nu 452 (USD 7) and Nu 124 (USD 2) per month, respectively, for Thimphu town dwellers. This result suggests that households are willing to pay approximately 8 and 2% of their monthly household income (expenditures) for the piped water inside dwelling and sewage connection, respectively (see Table 5). The 95% confidence interval of WTP for piped water connection is from Nu 280 to Nu 623 per month. Similarly, the 95% confidence interval of WTP for sewage connection is from Nu 33 to Nu 214.

Table 6 also reports the different level of median WTP for water and sewage connection. First quintile is the first 20% who fall under the first category of per capita expenditure group and so on in ascending order of monthly per capita expenditure. The results show how WTP changes with different level of income group. It may be useful from the policy stand to understand how WTP would change with change in income level, should government or relevant agency decides to use such figures for policy purposes.

Other studies have found that the WTP for piped water is about 3.6% of household monthly expenditures in the case of Indonesia (Yusuf and Koundouri 2005), 5–7% of household monthly expenditures in the case of Sri Lanka (Van den Berg and Nauges 2012) and 2.4% of household monthly income in the case of the Philippines (North and Griffin 1993). Thus, our WTP estimates of 8% of expenditures for Thimphu dwellers for piped water are comparable with the WTP estimates of Van den Berg and Nauges (2012) from Sri Lanka.

In addition, we conducted robustness check of the hedonic models by further evaluating WTP for water and sewage based on model 5 through 8 reported in Supplementary appendix Table A5. We re-estimated the Heckman model reported in Table 4 with inclusion of mean values within each census tract for different variables like sewage, water, toilet and room and results are reported in Supplementary appendix Table A5. In model 5, we include both interaction of water and sewage, and also a mean of house connected to piped water and central sewage and similarly in model 6, we include interaction of water and toilet and mean of house with piped water connection and mean of house with flush toilet in each census tract. By including the mean of house connected to sewage and water in each census tract, we are able to allow rent to depend not only on connection status of a particular house but also on overall sewage and water status in each census tract in model 5 and similarly for rest of the models. Based on the hedonics results reported in Supplementary appendix Table A5, WTP for water and sewage is estimated and reported in Supplementary appendix Table A6. The median WTP for water and sewage is still within the confidence interval of median WTP reported in Table 5, except for the median WTP of water for model 6. The median WTP for water based on model 6 is lower than the lower bound of median WTP reported in Table 5. We suspect that this result is due to high correlation between water and interaction variable of water and toilet.

5.4 Financing urban sewage and water infrastructure

We now estimate the potential revenue that Thimphu municipal office can generate if sewage and piped water tariff is charged based on the estimates of WTP. We calculate revenues based on the median WTP reported in Table 5.

Currently, households pay Nu 2.45 per month for consuming less than 20 cubic meters of water, Nu 2.95 per month for consuming between 21 and 40 m^3, and Nu 3.70 per month for consuming more than 40 m^3, including a 50% surcharge for sewerage. However, the BLSS (2012) reports that households pay an average of Nu 78 per month in water charges and 50% of this charge is considered as sewerage charges.[13] We calculate the current revenue generated by Thimphu municipal office based on this charge (Nu 78) and compare with potential revenue if charges were

[13] The Ministry of Works and Human Settlement also reports revenues from water and sanitation charges but we cannot these figures for comparison because they report the total revenue generated as the sum of revenue generated from industries, other institutions and residential houses.

Table 7 Current revenue and potential revenue from water and sewage (Nu in million)

	Number of connected households	Current revenue with current charges for sewage: Nu 39 and water: Nu 39	Potential revenue with WTP for sewage: Nu 124 and water: Nu 452	Potential revenue with minimum WTP for sewage: Nu 66 and water: Nu 241
Sewage	8179	0.32	1.01	0.54
Water	13,998	0.55	6.33	3.37
Total		0.86	7.34	3.91

Number of households connected to water and sewage are estimated based on BLSS 2012. Minimum WTP refers to WTP for sewage and water corresponding to first quintile of expenditure reported in Table 6 based on our study (see Table 7). To compare current and potential revenues we multiply the two different charges by the total number of households connected to sewage and piped water. According to BLSS (2012) 52 and 89% of households were connected to sewage and piped water inside a dwelling, respectively.

The results in Table 7 indicate that Thimphu municipal office has potential to increase its revenue (by almost seven fold) by charging at WTP estimate, relative to what is currently earned. We also estimate the revenue that municipal offices would be able to earn from additional connections to currently unconnected households, based on both the current surcharge and the estimated WTP surcharge. As reported in Table 8, if un-connected households are brought into the system and current services are offered to them, Thimphu municipal office could earn significantly more revenues by charging at the rate estimated in our study. The sewage and water are public goods usually provided by Government and, therefore, it may be necessary for price of such goods to be minimum so that the poorest section of households can also avail these services. For this purposes, we also estimate potential and additional revenue based on the WTP of the lowest (poorest) quintile as reported in the last column of Tables 7 and 8. Our result show that, even if water and sewage is charged based on the WTP of the poorest section of households, Thimphu municipal have potential to generate revenue substantially higher than what is currently being earned.

6 Conclusions and recommendations

In Bhutan, some 73% of rural households and 87% of urban households currently have access to piped water in their homes. Some 40% of A town homes are connected to a formal sewage system, while none in rest part of the Bhutan. By examining differences in the value of rent paid for homes, we are able to establish that house with piped drinking water inside dwelling and those connected to central sewage system are earning higher rental premium compared to those without these amenities after controlling for other attributes. Our results suggest that there is significant demand for such amenities. We exploit this information to estimate household willingness to pay for a formal sewage and piped water connection. Our hedonic results from B town and rural also show positive effect on rental premium from having access to piped drinking water inside dwelling.

Our results show that Thimphu households are, on average, willing to pay Nu 452 per month for access to piped water and Nu 124 per month for access to sewage, while they currently pay a combined charge of Nu 78 per month. Our findings suggest WTP for water and sewage is higher than what is currently paid for water and sanitation services.

Our study suggests that municipalities in Bhutan can increase their current revenues from water and sanitation charges. Thimphu municipality can potentially by about sevenfold increase its gross revenues from municipal charges if it charges the higher rate estimated in our study. The estimates from this research can also be used to justify investments in public infrastructure. If the costs of investments to expand

Table 8 Revenue from additional connection at estimated WTP surcharge (Nu million)

	Number of unconnected households	Additional revenue with current charges for sewage: Nu 39 and water: Nu 39	Additional revenue with WTP for sewage: Nu 124 and water 452	Additional revenue with minimum WTP for sewage: Nu 66 and water: Nu 241
Sewage	7549	0.29	0.94	0.50
Water	1730	0.07	0.78	0.42
Total		0.36	1.72	0.92

Number of unconnected household to water and sewage are estimated based on BLSS 2012. Minimum WTP refers to WTP for sewage and water corresponding to first quintile of expenditure reported in Table 6 connections are lower than what household benefits from access to water and sanitation, such investments should be considered.

Our study provides estimates of demand that can help revise existing tariff for sewage and water infrastructure services in Bhutan. There is a legal provision for privatizing such services in Bhutan and this study may be useful to policy makers to develop contracts with private investors and organizations, if Bhutan decides to partner with private investors for these public services. However, while pricing such services, it may be necessary to keep its price at minimum in order for the poorest section of the population to avail such public services.

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