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Equity impacts of informal private water markets: case of Kathmandu Valley

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Abstract

South Asia is a hotspot for populations and economies adversely impacted by poor water security. This is evident in the case of Nepal where it has been estimated that 20% of households have no access to a domestic water source and two-thirds of the urban households live with inadequate water supply. Therefore, many depend on private solutions, such as private wells and purchasing water from informal water markets, to meet household water needs. Within this context, this paper examines whether private water vendors provide equitable access to both poor and wealthy households, whether they practice discriminatory pricing and whether poor households face a greater financial burden in meeting their household water needs. The analysis uses primary data collected from a 1,500-household survey conducted in 2014 and uses regression analyses to derive the results. The results reveal patterns of inequity in the private water market, but seemingly not purely due to an inherent bias against poorer households. Regardless, the market does not serve the poor adequately and given the lack of alternatives that poor households have, it points to an urgent need for the government to step in to counterbalance the deficiencies of the market.

Keywords: Equity; Informal water market; Kathmandu valley; Nepal; Water vendor

1. Introduction

Water supply is an essential service which, at the most basic level, requires that every resident receives safe, adequate and affordable water. It is imperative that the disadvantaged are not excluded from these services (Bird & Busse, 2006). Yet, in South Asia, no country has universal coverage for its urban population and inequity is estimated to be the highest within the Asia and Pacific region

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(AWDO, 2013). The gap between urban services that are delivered and those that are needed has for a long time been met by the informal sector (Portes & Haller, 2010). Empirical studies have shown that private water vendors serve a significant percentage of urban residents in Africa, Asia and South America (Conan, 2004). However, the question has remained whether these informal service providers ameliorate the situation by filling the void or whether they instead exacerbate the inequity already existing in the public delivery system by taking advantage of the desperate situation, especially for those who lack alternative ways of obtaining the essential resource of water.

In the urban water supply sector, the formal providers are typically the government utilities or private companies that are officially contracted by the government to distribute networked water (Allen *et al*., 2006). Informal providers include the diverse range of water vendors who sell water to households, outside the formal piped network system, through various means, such as tanker trucks, push carts, donkey carts, or their own piped network (Snell, 1998; Sansom, 2006; Bakker *et al*., 2008; Kjellén & McGranahan, 2009). Most of these private players operate in the informal system because they do not fall under government purview or are not subject to any regulatory frameworks or environmental/quality standards (UN Habitat, 2010; Allouche, 2011).

Private water vendors present a critical policy challenge. On the one hand, they are greatly beneficial to society as they reach customers in some of the world's most difficult to reach areas. They also provide them access to an essential service that the government is unable to provide. Even though not all customers who utilize the services of water vendors are poor (Komives *et al*., 2001), in many cities, it is the low-income households that are worst served by the utility and most dependent on the private water vendors (Pangare & Pangare, 2008; Banerjee & Morella, 2011). On the other hand, anecdotal evidence suggests that these vendors exploit the urban poor and make large profits (Whittington *et al*., 1989; Cairncross & Kinnear, 1991). In fact, households without piped water often pay more per unit price of water than those connected to the piped network, because alternative sources of water tend to be costlier than the subsidized government water supply (Whittington, *et al*., 1991; Cairncross & Kinnear, 1992; McPhail, 1994). Further, being an unregulated market, the potential risk of over-exploitation of the resource is larger since the volume of water extracted is not monitored. Gerlach & Franceys (2012), in their analysis of regulatory experience of the water service sector in 11 metropolitan cities, found that any form of oversight over the operations of water vendors was limited and not enforced, especially in terms of price monitoring. In addition, specifically in India, Jordan and Indonesia, they found that these informal businesses were associated with over-extraction of groundwater and intrusion of seawater into freshwater aquifers.

While reports and studies recognizing the significant role played by small private water vendors in urban water supply have grown over the last few years, they remain largely based on anecdotal evidence and case studies, rather than on rigorously collected large-scale primary data (Kariuki & Schwartz, 2005; Opryszko *et al*., 2009). Further, hardly any aim to empirically assess equity impacts on the market, such as whether vendors provide equal access or charge the same price to households irrespective of their socio-economic status. It is essential to examine whether the private water vendors perform better than the public utility from an equity perspective because, most often, the urban poor are unable to afford their own private solutions to water scarcity. Therefore, their dependence on vendors should not translate into lower-income households being further exploited.

Nepal is one of the fastest urbanizing nations, with an average urban population growth rate per year of 6% since the 1970s (UNDESA, 2012). However, this growth has been taking place in the context of a decade-long Maoist insurgency (1996–2006) which caused an influx of migrants from rural areas to the

capital city of Kathmandu, a trend that the government has been unable to cope with. Extreme unplanned developed has seen Kathmandu grow to an urban sprawl of 2.7 million people (Central Bureau of Statistics, 2012) with high levels of air and water pollution, a looming energy crisis, increasing traffic congestion, inadequate water supply, solid waste disposal and sewerage systems. The rapid increase in the valley's population during the last decade and a lack of investment in water supply provision and system maintenance have resulted in less than 20% of the population receiving a reliable supply of piped drinking water (ADB, 2010). The daily demand for water in the Valley is around 360 million litres, but the supply is much less – approximately 76 million litres a day in the dry season and 123 million litres a day in the rainy season (KUKL, 2014). In light of this, unregulated private vendors have stepped in to fill the water demand–supply gap and therefore, an extensive and vibrant private water market exists.

Using primary data based on a 1,500-household survey conducted in Kathmandu, Nepal, in 2014, the broad purpose of this paper is to examine the equity impacts of the informal water markets, i.e. the manner in which water is made available, allocated and priced in the private market. Many cosmopolitan cities increasingly show a similar reliance on water vending activities to meet the water demand of their residents. Hence, lessons learned from this analysis could help further policy planning in other developing cities.

Specifically, this paper looks at three key issues:

1. Does the private water market provide equitable access to households across different socio-economic indicators?
2. Do the private water vendors practice discriminatory pricing and charge the poor a higher price for the same water?
3. Do poorer households bear a greater financial burden in meeting their household water needs?

The paper is structured as follows. The second section reviews the literature and explains the theoretical perspective on equity that is used in this paper and the way it is applied in the private water markets. The third section describes the data collection methods as well as the methodology employed in the study. The fourth section explains the results of the regression analysis, and the last section consists of the discussion of the results as well as the overall conclusion about the equity impacts of the private water market.

2. Operationalizing equity in the context of water markets

From a review of literature, it is evident that the poor, who are not connected to the public water systems, have to purchase water at prices higher than the utility from private players (Brookshire & Whittington, 1993; Crane, 1994; Banerjee *et al.*, 2010). In fact, in one of the earliest studies to examine water vending, Zaroff & Okun (1984) found that households spent a median of over 20% of their income on buying vended water, and that the prices charged by vendors were typically more than 10 times (up to 50 times) the tariff charged by the public utility. Fass (1988) estimated that in Port-au-Prince, the poor were paying some of the highest water prices in the world, ranging from US$1.1 to US$5.5 per cubic metre. Crane (1994) found that in Jakarta, vendors' prices were approximately 30 times more than the public utility price of water per cubic metre. The high price of privately delivered water was assumed to be the result of vendors' abusive pricing practices (Kjellen & McGranahan, 2009). Later studies, which closely examined vendors' initial investments and operating costs,

concluded that many vendors made only a relatively modest profit (Whittington *et al.*, 1991; Solo, 1999; Collignon & Vezina, 2001; Gulyani *et al.*, 2005; Kariuki & Schwartz, 2005; Opryszko *et al.*, 2009).

Private water vendors do not possess the same economies of scale as the government water supply network, and, also, do not benefit from any subsidies. Therefore, the mere fact that vended water is more expensive than public utility water does not imply that the water vendors in the private water market follow inequitable pricing strategies. While the studies reported earlier find that the unit price of water charged by water vendors is generally higher than other options (Brookshire & Whittington, 1993; Banerjee *et al.*, 2010; UNDP, 2011), they did not go further to see whether there is any discrimination (on factors such as income, race, gender) in the way vendors price water for different households.

Only three studies have empirically looked at equity issues in the context of informal urban water markets. First, a study by Ayalew *et al.* (2014), based in Kenya and Ethiopia, reported that even though low income households spent a significantly greater amount of income on water, it was not due to profiteering amongst water vendors, even though they earned large profits in their business. Second, a study by Sima *et al.* (2013) found that vendors in Kisumu, Kenya, do not try to extract the highest price from high demand areas. Instead the prices reflected the ability of consumers to pay in each neighbourhood, where the highest price was charged to businesses in the central market area and in the wealthier neighbourhoods. Lastly, a recent study by Wutich *et al.* (2016) examining the role of vendors in squatter settlements of Cochabamba, Bolivia, found that vendors are concerned about distributive justice and perform better when unionized. Therefore, this study aims to contribute to knowledge on the equity impacts of the private water vending market, which is currently an under-studied area, because it has important implications for managing urban water resources and ensuring that every citizen receives their basic right to safe, affordable and adequate water.

An empirical estimation of equity can only take place if the term ‘equity’ itself is clearly defined. In the literature, there is no standard way of operationalizing equity. In the context of water distribution by the private water market, this paper uses the concept of distributional justice that refers to the socially just allocation of goods in a society. Fair allocation takes into account the total amounts of goods that are distributed, the procedure of distribution as well as the pattern of distribution that results.

The principles of distributive justice used here are based on the works of the Greek philosopher Aristotle, who distinguished between horizontal and vertical equity (Roemer, 1998). *Horizontal equity* refers to the idea that people who are equal with respect to certain relevant characteristics should be treated equally. Therefore, horizontal equity occurs when all similar individuals are treated the same, implying an absence of discrimination (Wagstaff & van Doorslaer, 2000) on the grounds of gender, race, profession, etc. When applied to the case of private water markets, horizontal equity in water service provision by private vendors would mean equal physical access to the service across different communities and varying income levels. For horizontal equity to exist all households should have an equal chance to purchase water, should they need to, and there should be no difference in access based on household characteristics. This is crucial in developing countries, where service coverage by public utilities is typically low, usually ranging from 15% to 75% of the population (Fauconnier, 1999).

According to the idea of *vertical equity*, people who are unequal in relation to specific and relevant characteristics should be treated unequally, and in proportion to those inequalities. This principle recognizes that not all households are the same and that their starting points relative to other households should be considered in an analysis of equity. In this context, it relates particularly to cost and affordability. This is an essential equity impact to explore in the context of private water markets, where prices can differ across households and, therefore, place financial burdens in differing ways.

Vertical equity typically requires that as an individual's capability to pay increases, so should the net fiscal burden (which can be negative) (Wagstaff & van Doorslaer, 2000). Since many people are unequal with respect to income and wealth (ability to pay), for a water market system to be vertically equitable, those with greater income and wealth should pay a greater proportion of their income to meet their household needs, since water is an essential and non-substitutable good.

In general, the most economically efficient or socially optimal way to price is said to be marginal cost pricing. This refers to setting the price of a product at or slightly above the variable cost to produce it. However, this does not always happen as it depends on the market power of the sellers. It is possible that vendors base their price according to how dependent the consumers are on the water, i.e. which lack access to alternative sources of water. Therefore, if the market is vertically inequitable, then low-income households will pay more per cubic meter because the tanker drivers will respond to the differential willingness-to-pay (and elasticity of demand) by charging the low-income households more to enhance their profits.

An overview of the equity principles and how they are applied in this paper is displayed in Table 1. The two equity principles and their associated guiding questions, indicators and measures are included.

In large metropolitan cities, a significant number of people continue to lack access to the public water utility system (UNDP, 2006). In fact, many slums and other informal settlements are excluded from municipal water infrastructure and are likely to remain so in the foreseeable future (Njiru, 2004; Fox, 2014; Mehta *et al*., 2014). Therefore, assessing whether the main alternative system for them, i.e. the private water market, is equitable or not is of crucial importance.

3. Data collection and methodology

The data used in this paper was drawn from a household survey conducted in the Kathmandu Valley. The household survey was conducted for 1,500 households across the five municipalities of Kathmandu Valley – Kathmandu, Lalitpur, Madhyapur, Kirtipur and Bhaktapur. It was a part of a re-survey conducted of 1,500 households selected in 2001 based on a multi-stage clustered random sampling

Table 1. Equity principles and their application in the study.

Type of equity	Guiding question	Outcome variable	Equity measure
Horizontal equity	A. Do factors such as income, ethnicity or location of residence mediate household access to tanker water?	Whether the household can be accessed by tanker trucks	Equal access to vended water for those in equal need of vended water
Vertical equity	A. Do the tanker water operators practice discriminatory pricing?	Unit cost per metre cube of water purchased by household	Equal price of water for those in equal situations
	B. Do poorer households spend a greater proportion of their income on purchasing water than wealthier homes?	The proportion of household income spent on purchase of water	Equal (or less) proportion of income spent on purchasing water by low income households when compared to higher income households

procedure (Pattanayak *et al.*, 2005). Clusters were located using aerial maps provided by the Central Bureau of Statistics for the 1996/97 World Bank Living Standard Measurement Survey for Kathmandu. In three of the five municipalities in the Kathmandu Valley (Kathmandu, Lalitpur and Bhaktapur), a previously conducted complete enumeration of all households was used as the sample frame (SILT Consultants and Development Research & Training Centre, 1999). In Kirtipur and Madhyapur, the 1991 population census was used as the sampling frame. Further details on the sampling strategy, data collection and replacement process can be found in Appendix 1.

From the equity framework developed above, three outcome variables are relevant: (i) a dummy for whether tanker trucks can access the household's water storage reservoir/overground tank (i.e. the truck can come close enough for water to be delivered by pipes which are usually 30–60 metres long), (ii) the unit cost of water (cost per cubic metre) households pay to purchase water from tankers and (iii) proportion of income spent on meeting household water needs, including both public and private sources. In the study, all these variables were analysed using regression models.

The independent variable consists of the wealth group and the control variables include ethnicity (six major categories as reported in the UNDP Nepal Human Development Report, 2014), location of residence (ward level) and the type of road that is closest to the household (dirt road, narrow brick road or paved road). The household wealth was estimated using a wealth index based on key asset ownership and housing characteristics, following the principal component analysis method of Filmer & Pritchett (1999). It included aspects such as house characteristics (e.g. lot size of the house, number of rooms and ownership of home), construction materials used (e.g. materials for roofs, walls and floors), access to utilities and infrastructure (e.g. type of sanitation facility, electricity and sources of water), and ownership of selected durable assets (e.g. TVs, radios, computers, Internet access, telephones, mobile phones, VCD/DVD players, refrigerators, washing machines, motorbikes and cars). Using the wealth index values, three wealth groups were created – richest 20%, middle 40% and the poorest 40%. An asset-based indicator was chosen for the analysis because, firstly, asset ownership rather than consumption expenditure is considered to be a better estimate of long-run economic status of the poor (Filmer & Pritchett, 2001). Secondly, information collected on assets is believed to be more accurate than that on consumption, thereby reducing the likelihood of measurement error (Labonne *et al.*, 2007). Appendix 2 details the analytical and empirical strategy and explains the choice of regression models as well as other control variables used in the study. Further, Appendix 3 provides the descriptive statistics for all the variables used in the regression analyses. For robustness check, all three regressions were also run with a log of household income (except for the third because income forms a part of the dependent variable) and wealth as a continuous variable.

4. Results

This section is divided into three sub-sections, each looking at the results related to the three key research questions.

4.1. Does the private water market provide equitable access to households across different socio-economic indicators?

Table 2 presents the marginal effects for the regression results of the probit model that looks at whether tanker trucks can access the household's yard. Column 1 includes only a measure of wealth and indicates

Table 2. Factors mediating access to tanker truck water.

Dependent variable – access to tanker trucks (access = 1, no access = 0)							
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Wealth group: middle	0.095***	0.084***	0.067**	0.065*	0.063*		
	(0.029)	(0.03)	(0.032)	(0.035)	(0.035)		
Wealth group: rich	0.128***	0.107***	0.101**	0.085**	0.082**		
	(0.035)	(0.036)	(0.039)	(0.041)	(0.042)		
Wealth index						0.003	
						(0.003)	
Log of household income							0.020
							(0.022)
Road 2: pitch				0.244***	0.243***	0.242***	0.259***
				(0.045)	(0.045)	(0.045)	(0.045)
Road 3: stone/brick				−0.331***	−0.331***	−0.329***	−0.331***
				(0.043)	(0.043)	(0.043)	(0.043)
Storage					0.010	0.026	0.022
					(0.033)	−0.032	(0.032)
Ethnicity FE		Yes	Yes	Yes	Yes	Yes	Yes
Ward FE			Yes	Yes	Yes	Yes	Yes
N	1,394	1,380	1,335	1,335	1,335	1,335	1,355
Pseudo R-sq	0.009	0.013	0.119	0.236	0.236	0.234	0.243

Notes: Base group for wealth is poor and for road is dirt road. Standard errors in parentheses $*P < 0.1$, $**P < 0.05$, $***P < 0.01$. FE: fixed effect.

that being in the middle or rich wealth bracket significantly enhances the household's access as compared to poor households. A middle wealth household is likely to have 9.5% greater likelihood of being accessible to tanker trucks, while rich households are 12.8% more likely. Columns 2 and 3 show that this general pattern is repeated even when ethnicity of the household and location of residence are controlled for. Column 4 shows that the type of road closest to the household plays a significant role in access, with living near narrow brick roads leading to a 33.1% decrease in access. The explanatory power of the model with the inclusion of type of road near the household increases drastically, while at the same time, dramatically lowering the predicted effect of wealth on access. Despite this, it is important to note that, being rich enhances access by 6.5% and being of middle wealth enhances access by 8.5%. In Column 5, the dummy on storage is included and does not have a significant effect on access. The complete table for this estimation can be found in Appendix 4, Table A3.

The Hosmer-Lemeshow goodness-of-fit test (with the null being that the model is correctly specified) on the complete model (with a result of chi square value being 7.44 and an associated *P*-value of 0.9 with nine groups) reveals that the model has been specified correctly. Additionally, when the Pregibon's link test is conducted, the prediction squared does not have explanatory power and indicates that the independent variables have been correctly specified[1]. Lastly, the Wald test was also

[1] The Pregibon link test is a model specification test that consists of using the predicted values and the predicted values squared as the only predictors for a second-round model. The expectation is that if the model is specified correctly, then the prediction squared would have no explanatory power. The predicted value would, of course, be significantly different from zero because it is the predicted value from the model. If the predicted squared is significant, then it implies the presence of omitted variables.

conducted (chi-square value of 332.85 with an associated P-value of less than 0.00001) which implies that the selected independent variables collectively affect the outcome variable in a statistically significant manner.

4.2. Do the private water vendors practice discriminatory pricing and charge the poor a higher price for the same water?

The regression results in Table 3 reveal that even while controlling for factors such as ethnicity, location of residence and infrastructure like roads, poorer households pay a higher unit price for tanker water. The number of observations drops to approximately 450 households because this analysis takes into account only those households that participate in the private water market. Column 1 shows that wealth does affect the price of tanker water where the rich households pay significantly less for the water they purchase from tanker trucks. This amounts to 155.2 NPR (1.45 USD) per cubic metre less than poor households. Columns 2 and 3 show that there is a significant difference in the amounts charged to different ethnic groups (Table A4 in Appendix 4). Ethnic groups lower on the human development index (as per the UNDP Nepal Human Development Report, 2014) tend to pay less than the higher caste Newars and Brahmins, which shows that there is price discrimination, though in a positive way when it comes to ethnic differences. Column 4 shows that living near narrow brick roads, which in Kathmandu are usually found in the older sections of the city, leads to a higher price charged to households (Table A4 in Appendix 4). This is likely because longer pipes are needed to access the homes in such areas. It further reveals that having a storage tank (overground or underground) reduces the price

Table 3. Factors affecting the unit price per metre cube that households have to pay for tanker water.

Dependent variable: price/m^3 for private tanker water per household (in Nepali Rupees)						
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Wealth group: middle	−73.10	−71.17	−67.29	−35.12		
	(61.44)	(61.91)	(62.54)	(63.7)		
Wealth group: rich	−155.2**	−163.6**	−173.8**	−131.1**		
	(59.64)	(60.00)	(63.04)	(62.8)		
Wealth index					1.01	
					(3.8)	
Log of household income						−35.38
						(36.16)
Storage				−151.48***	−178.29***	−197.13***
				(69.15)	(67.28)	(69.17)
Ethnicity FE		Yes	Yes	Yes	Yes	Yes
Ward FE			Yes	Yes	Yes	Yes
Road FE				Yes	Yes	Yes
Constant	522.0***	543.7***	392.9**	272.52**	283.56***	691.4*
	(51.00)	(54.42)	(52.09)	(77.23)	(73.8)	(398.0)
N	454	454	454	454	454	453
R-squared	0.012	0.022	0.105	0.142	0.134	0.129

Notes: Base group for wealth is poor. Robust standard errors in parentheses *$P < 0.1$, **$P < 0.05$, ***$P < 0.01$. FE: fixed effect.

faced by the household, presumably because they are able to purchase in greater quantities. The R-squared of the complete model in column 4 of Table 5 is also substantially greater than before. However, as before, despite accounting for the effects of other meditating factors like ethnicity and road and storage, wealth is still a significant determinant of the price charged to the household for tanker water. Households from the rich wealth bracket pay 131 NPR (1.2 USD) less per cubic metre of water than poor households.

In order to detect whether there was any misspecification in the model, the Ramsey RESET (Regression specification-error test for omitted variables) was conducted (Ramsey, 1969). The result of the test where the null hypothesis states that the model is specified correctly (f-statistic of 1.25 with an associated *P*-value of 0.3) confirmed that there were no omitted variables in the model. Additionally, Pregibon's link test was also conducted, the results of which also confirmed that the model is specified correctly.

4.3. Do poorer households bear a greater financial burden in meeting their household water needs?

The results in Table 4 show that poor households spend a greater proportion of their income on meeting their household water needs (accounting for expenditure on both public and private water sources),

Table 4. Factors affecting percentage of income spent on purchasing water to meet household needs.

Dependent variable: percentage of income spent on all purchase costs related to water, including both private and public water sources					
Variables	(1)	(2)	(3)	(4)	(5)
Wealth group: middle	−0.225*	−0.267*	−0.256*	−0.338**	
	(0.134)	(0.148)	(0.154)	(0.152)	
Wealth group: rich	−0.214	−0.279*	−0.272*	−0.382**	
	(0.151)	(0.167)	(0.163)	(0.162)	
Wealth index					−0.0223**
					(0.0112)
Household size	−0.0741***	−0.0682***	−0.0711***	−0.0692***	−0.0994***
	(0.0271)	(0.0256)	(0.0253)	(0.0233)	(0.0258)
Dummy for whether household buys *only* tanker water				0.715***	0.699***
				(0.127)	(0.125)
Dummy for whether household buys *both* tanker and bottled water				1.685***	1.660***
				(0.306)	(0.302)
Dummy for whether household buys *only* bottled water				1.281***	1.262***
				(0.152)	(0.154)
Ethnicity FE		Yes	Yes	Yes	Yes
Ward FE			Yes	Yes	Yes
Road FE			Yes	Yes	Yes
Constant	1.562***	1.473***	0.952***	0.894***	0.862***
	(0.206)	(0.184)	(0.284)	(0.277)	(0.261)
N	1,353	1,353	1,353	1,353	1,353
R-squared	0.010	0.016	0.056	0.130	0.126

Notes: Base group for wealth is poor. Standard errors in parentheses *$P < 0.1$, **$P < 0.05$, ***$P < 0.01$. FE: fixed effect.

Table 5. Average unit price of water (NPR per cubic metre) in the dry season by household wealth group and access to government piped connection.

		Connected to government piped network		
Wealth group		*No*	*Yes*	Total
Rich 20%	NPR/m^3	249.82	371.58	366.80
	N	4	98	102
Middle 40%	NPR/m^3	357.20	454.28	448.95
	N	10	172	182
Poor 40%	NPR/m^3	373.04	545.36	522.04
	N	23	147	170

while controlling for household size. Column 1 and Column 2 include only wealth and ethnicity predictor variables and test results show that they are not well-specified models. The Wald chi-square test showed that the independent variables together do not significantly contribute to the determination of the outcome variable. Column 3 shows that when ethnic differences between households and location of residence and roads (which affected price of water as seen in the previous regression result) are controlled for, rich households spend 27.2% less on water when compared to the poor households at 0.1 level of significance. Column 4 includes variables that look at the household's involvement in the private market in terms of what type of water they buy. Here it can be seen that all households that purchase water in the private market, regardless of type, spend significantly more. Again, while controlling for all these factors, households from higher income brackets are likely to spend between 34 and 38% less on meeting their household water needs than poor households. The level of significance at which the coefficient is statistically significant also increases to 0.5 for the wealthier households in the complete model.

The Wald test was conducted to identify the suitability of explanatory variables included in the model. Since the associated *P*-value of the chi square statistic is zero, it implies that the independent variables contribute significantly as a group to the explanation of the determinants of percentage of income spent of meeting household water needs. The Ramsey RESET also confirmed that there were no omitted variables in the model (f-statistic of 30.39 with an associated *P*-value of 0). Additionally, Pregibon's link test was also conducted, the results which also confirmed that the model is specified correctly.

As a further robustness check, all the three estimations used above were re-run 50 times with randomized wealth groups. The mean of the distribution of the coefficients (results available in Appendix 5) were found to not be statistically different from zero, illustrating the fact that the wealth effects seen are not due to a random effect and that the findings are robust.

5. Discussion and conclusions

Equity is an important concept that can be used to evaluate the fairness and effectiveness of a distribution system (Rawls, 1972). It attempts to identify what is socially just and aims to address unequal outcomes (Walzer, 1984; Sayed, 2000). The results of this study reveal there is evidence of both horizontal and vertical inequity in the Kathmandu informal water market. This implies that poor households

have poorer access to and pay more for the water they purchase compared to rich households. Being among the richest 20% of the households enhances the access to vended water by 8.2% and reduces per cubic metre price of vended water by 1.22 USD[2]. While infrastructure, specifically roads, impedes access to households if they are not paved, and more so if they are narrow brick roads, wealth still has a significant effect on access. In addition, the poor also spend a greater proportion of their income on meeting their household water needs, implying a greater financial burden. Rich households spend 38.2% less on water than poor households. All these results point to a need to bring the informal water economy into a more formal fold in order to counterbalance the deficiencies of the market.

Looking at the price differences between the poor and non-poor households more deeply, it is evident that (as seen in Table 5), in general, households connected to the government water network pay more per cubic metre of tanker water than those not connected. Therefore, this would prima facie imply that vendors do not charge a higher price to those who are more dependent on them.

However, consistently, poor households (whether connected or not to the government network) pay more than the middle and rich households, i.e. between 53–155 NPR more per cubic metre. One explanation for this could be that vendors give a discount for those who purchase in larger quantities. From Table 6, it can be seen that poorer households do purchase a lower quantity of water each time they buy water. This would seem to be a plausible reason for the difference in pricing because the cost of providing a small quantity of water is higher than delivering in bulk quantities.

This explanation is partly supported by the regression results, where households with a storage facility tend to pay less (approximately 151 NPR or 1.42 USD) than those who do not. Purchasing in larger quantities is only possible when a household has sufficient storage space in the form of an overground tank or an underground storage, which is more feasible for wealthier homes, in terms of both physical space as well as associated costs. This resulting inequity is not necessarily due to the profiteering mindset of the vendor, but related to the marginal costs of delivering different quantities of water. This kind of practice is known as second degree price discrimination (Pigou, 1932) where price varies by the quantity demanded and often, larger quantities are sold at a lower unit price. By setting different prices for different groups of people, vendors would be able to capture a greater portion of the total market surplus. While this in itself is not discriminatory towards poor households, the pricing scheme leads to a greater financial burden on the poor that could lead to a trade-off with other important essential expenditures, because they are forced to spend a high proportion of their income on obtaining water. However, it is essential to note that, despite accounting for having storage, the results show that

Table 6. Quantity of water purchased from tanker truck drivers each time in the dry season by different wealth groups.

Wealth group	Quantity of water purchased each time (mean)	Median	Std. Dev.	Freq.
Rich 20%	4,660.8	5,000	3,086.5	102
Middle 40%	3,727.3	3,000	3,165.2	182
Poor 40%	2,559.2	1,000	2,868.0	170
Total	3,499.6		3,138.8	454

[2] Being among the middle wealth group enhances the access to vended water by 6.3%, reduces per cubic metre of vended water price by 0.32 USD and reduces proportion of income spent on meeting household water needs by 33.8%.

the richest 20% of the sample still pay less than the poorest 40%. This implies that there is still some differentiation in the price charged to households based on wealth, which could be due to the lower bargaining power of the poor because of their greater dependence on the vendors. It has already been seen that half of the poorer households consume water in quantities deemed insufficient to meet basic hygiene and consumptions needs. Since water as a good is not substitutable, affordability and access are key criteria of equity.

These results demonstrate that the market does not serve poor households adequately. Poor households tend to have less access to government connections and ability to afford their own private wells, and so exhibit inelastic demand for water and, therefore, have to accept the price that the vendors set. The limitation faced by the poor in the quantity of water they can afford to buy and store exacerbates the inequities since it further raises the price of the water they buy. Thus, taking these results together, it is evident that an inequitable situation exists in Kathmandu whereby the poor households have poorer access to affordable public water and have to rely on the informal private water market, where they pay more than the rich households to buy water, leading to low levels of consumption that can have negative socio-economic and health impacts[3]. Therefore, the results highlight the need for the government to step in and address these inequities because, at the same time, one cannot deny that the vendors are still indispensable providers of water across the different types of households.

The water usage data from this study's survey showed that the vendors are an important source of water for poor households without a piped water connection, along with providing supplementary water to middle and rich income households, because of the gross inadequacy of the public water utility system (Raina, 2017). Richer households tend to use private wells to meet most of their household needs (56% of their water in the dry season comes from private wells). Therefore, without a doubt, these water vendors in the private water market, who are filling the demand and supply gap, are providing an essential service. However, at the same time, the results of this study show that the private water market in Kathmandu is not ideal in the way it currently functions. It seems to favour wealthier households in access and, possibly due to purchasing power differences, charge poor households more per unit of water than richer households. This leads to a vicious cycle, where the consequent prices reduce the ability of poor households to purchase more water and so, they eventually consume less and pay more.

Given the choice, households would always prefer a piped water supply if it is reliable and supplies adequate water, because of ease of access and affordability. This ideal is also not unachievable as has been witnessed in Phnom Penh, Cambodia, where service coverage was enhanced from 38% to 90% of the population and from 10 to 24 hours per day between 1993 and 2008 (Chan, 2009). The Phnom Penh Water Supply Authority was also able to reduce the supply of non-revenue water to 6%, provide subsidies to the poor and achieve successful billing collection of over 99% (Chan, 2009). This requires high governmental commitment as well as engineering solutions, which given the current turbulent political and social issues in Nepal are unlikely in the near future. Therefore, in the short to medium term, optimizing the services of the water vendors is extremely important and would require regulation in order to correct the market inadequacies and enhance consumer welfare across different wealth groups. Water vendors should be incentivized through market instruments such as taxes or subsidies to provide water to more under-served areas. In order to ensure affordability, there are primarily two ways a

[3] The health impacts here refer to the health risks associated with inadequate amount of water for drinking, cleaning or sanitation, not due to poor quality (an aspect that is not measured in this research).

government can regulate prices. One is by enforcing prices that are set by the regulating body. This requires a deep knowledge of the cost structure of the different types of firms, so as to ensure that the imposed tariffs do not drive the vendors out of business. Making water vending financially unsustainable could have an unintended negative consequence of enhancing inequity and making the urban poor significantly worse off without their access to the privately vended water. Therefore, this path requires high government capability. The second method is to use market mechanisms to encourage efficiency gains and reduction in prices by inducing competition. This can be done by making vendors bid for operating licences and permits, providing financial support for new market entrants and possibly setting up a publicized benchmarking regime that would incentivize vendors to improve their performance as well as compete on their pricing structure. This method reduces monitoring and implementation costs, even though it does require technical capability in drafting the contracts and setting up competitive tenders.

Thus, there are several policy implications of this research with regard to improving equity in urban water service delivery and incorporating the informal water vendors into the formal water supply system. However, at the same time, it is important to note that given the numbers of and diversity in the type of water vendors, their small-scale operations and current informal nature, formulating and implementing regulations (even drafting of contracts and holding of tenders) would involve non-trivial costs which would need to be mitigated. Above all, the ecological risk of such regulation should also be analysed by assessing the permissible limits of groundwater abstraction. There are also issues of corruption, weak contract enforcement and rent-seeking behaviour that need to be addressed. Therefore, identifying the exact regulation that would be effective will require further research and strong political capacity to effectively implement the policy instruments.

There are certain limitations in the analysis conducted in this study. First, while roads play a significant role in the access to and price of water, and the type of road captures a lot of the different elements that could affect delivery, the analysis could have been stronger if it had been possible to include the width (along with the type) of road. Secondly, knowledge of exactly what size of storage tank is used specifically for the purpose of storing vended water would have allowed for a deeper analysis of the link between the price and storage, since water storage tanks are used for storing water from all major sources including the government piped connection and private wells. Thirdly, the 2014 sample is wealthier than the average population of Kathmandu. This implies that it is likely the levels of inequity in the current context of Kathmandu are greater than those seen in this study because there has been a surge of migrants living in peri-urban and slum neighbourhoods in the last decade that are not accounted for in our sample. Lastly, the presence of price discrimination in the market could be reflective of market power, which would require anti-trust issues to be addressed by the government. Developing effective anti-trust policies requires understanding of firm behaviour, which is where further research is suggested. Understanding the nature of the market and the profitability levels of vendors is essential to gauge the scope of reducing water prices and enhancing consumer welfare (without forcing them out of business) through various different governmental policies and regulations.

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