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The structure of water vending markets in Kathmandu, Nepal

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Abstract

To date, there has been limited empirical research on the structure of informal water vending markets in developing countries. From fieldwork conducted in Kathmandu in 2014, including a survey of different types of water vendors, household interviews, and in-depth interviews with key informants, we provide a detailed description of the activities of multiple types of water vendors and examine the profitability of tanker truck vendors and water source vendors. We find that several distinctive markets operate along the supply chain between source water and end users. We conclude that a detailed understanding of the different vending activities in which water vendors engage is essential to the design of public sector policy interventions aimed at improving performance in informal water markets.

Keywords: Informal markets; Market structure; Water vending

Introduction

Despite decades of effort by governments and donor agencies to expand piped water connections, water vending continues to play a major role in water supply for urban residents in many parts of Africa (Whittington *et al.*, 1991; Collignon & Vézina, 2000; Zuin *et al.*, 2014), South America (Casey *et al.*, 2006; Wutich *et al.*, 2016), and Asia (Crane, 1994; Conan & Paniagua, 2003). Because of the unreliability and poor service of piped water systems in many countries, even households connected to a piped network often rely heavily upon private vendors as a major source of water supply (Keener *et al.*, 2009; Ahlers *et al.*, 2013). In fact, inviting water vendors into public–private partnerships in the urban water supply and sanitation sector has emerged as a policy option (Opryszko *et al.*, 2009).

While there is no doubt that water vending has greatly improved access to potable water for millions of people, especially the poor, in developing countries, the social, economic, and environmental

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consequences of reliance on informal water markets need careful examination. Water supplied by informal water markets may pose serious human health risks (Zaroff & Okun, 1984; Kjellén & McGranahan, 2006; Appiah Obeng *et al*., 2010) and undermine policies to improve social equity (Wutich *et al*., 2016).

It is often assumed that the presence of many private water vendors, coupled with relatively few entry barriers, would keep such markets competitive (Ahlers *et al*., 2013). Yet, the high prices charged by private water vendors, ranging from 400 to 100 times the amounts charged under municipal water tariffs (Zaroff & Okun, 1984; Bhatia & Falkenmark, 1993; Crane, 1994; Snell, 1998; Solo, 1999), raise concerns about the presence of 'monopoly rent' in such markets (Whittington *et al*., 1991). The competitiveness of informal water markets may also be undermined by collusion among providers and by price fixing by water vendors' business associations (Whittington *et al*., 1991; Crane, 1994; Snell, 1998; Collignon & Vézina, 2000; Ahlers *et al*., 2013).

There has been limited empirical research on the structure and competitiveness of informal water markets (Ahlers *et al*., 2013). Researchers face several methodological challenges. First, record keeping and reporting among vendors operating in informal markets are generally poor. Second, it is often difficult to collect business information from water vendors regarding their operations, especially data regarding financial particulars such as sales, costs, and profits, as vendors may guard such information as proprietary. Third, systematic sampling is rare, due to a lack of knowledge about the appropriate sampling frame for informal markets, and, as a result, the representativeness of findings is often in question. Most of the existing empirical work has been based on surveys of tanker truck operators and of distributing vendors (e.g., individuals selling water door-to-door in pushcarts) and rarely includes surveys of owners of private water vending businesses.

Kathmandu, Nepal was chosen for a case study because its booming water vending industry arose from two conditions common to many cities: a municipal utility that fails to deliver adequate water to its population over a significant period of time and a rapidly growing population that is partly dependent on alternative sources of water. As we document below, because private water sales comprise a significant proportion of the water supplied to end users in Kathmandu, the city provides an opportunity for in-depth research into the structure of a large urban water market. Many cities in the developing world exhibit similar features and issues. Lessons learned from the analysis presented here may assist policymakers in other cities in developing countries.

Drawing upon data collected in 2014 from in-person interviews with 120 water vendors and from respondents in 1,500 households, as well as from key informant interviews, this analysis presents an in-depth portrait of the structure of the informal water market in Kathmandu. We document the presence of five main types of water vending (commercial water source abstraction, tanker truck delivery, bottled water production, household delivery by distributing vendors, and sale of both bulk and bottled water by retail outlets such as neighborhood kiosks and private shops) and show that these functions may be consolidated in various ways. Financial analysis of the revenues and costs of commercial water source vendors and tanker truck vendors reveals that these businesses do not appear to be earning monopoly rents. That is, these components of the water vending supply chain appear reasonably competitive.

Background and study area

Although Nepal is one of the least urbanized countries in the world (only 17% of its population lives in urban areas), it is urbanizing rapidly. The urban population has increased 6% annually since the

1970s. This growth has occurred within a context of political instability. The first local elections in more than two decades were held in May 2017. During the lengthy preceding interval, Kathmandu, the nation's capital city had not had an elected local government but was run by officials of the central national government. That government was unable to cope with extreme unplanned urban development that had been exacerbated by an influx of migrants from rural areas, due in part to the decade-long Maoist insurgency (1996–2006). Kathmandu became a sprawling urban metropolis, with high levels of pollution, inadequate water and sanitation systems, increasing traffic congestion, and a growing energy crisis.

The Kathmandu Valley lies upstream of the Bagmati River Basin, which is regarded as one of the most water-stressed basins in the country (Pandey *et al.*, 2010a, 2010b). Groundwater has long been and continues to be an important source of water supply in the area. Significant groundwater abstraction started in the mid-1980s, when the Nepal Water Supply Corporation (NWSC) introduced groundwater into the municipal water supply system, and it became the most reliable source of water for the increasing urban population (Pandey *et al.*, 2009). Since 1986, the abstraction rate has exceeded the recharge rate, which has resulted in falling groundwater levels.

The municipal water supply system in Kathmandu is comprised of four distinct components:

1. the traditional water system, consisting of stone spouts, dug wells, tanks, and ponds that were built over several centuries;
2. the piped network system;
3. private water extraction by households and industries; and
4. various types of water vending.

The traditional stone spout system is a unique aspect of the water supply system in the valley. Historically, the spouts were connected to a network of canals that delivered water from upland sources to storage ponds. These ponds, in turn, recharged shallow groundwater aquifers that maintained a flow to the stone spouts or dug wells. A study conducted in 2007 revealed that of the 400 original stone spouts in the valley, only about half were still functional (UN-HABITAT, 2007).

The first piped water distribution network was introduced in 1891. At the time, its main purpose was to serve the families of the rulers and elites in Kathmandu. In 1928, the system was expanded to supply the general public. In 1972, the World Bank made a loan to the Nepalese Government to improve urban water supply and wastewater services. The Water Supply and Sewerage Board, formed in 1974, was renamed the Nepal Water Supply Corporation (NWSC) in 1989. In 2006, the Kathmandu Valley Water Supply Management Board Act was passed, which divided the NWSC into three separate organizations. Since then, the Kathmandu Upatyaka Khanepani Limited (KUKL) has been designated as the sole service operator and responsible for providing water and sewerage services to the people of the entire valley.

Between 2001 and 2011, the population of Kathmandu increased from 1.1 to 1.7 million (CBS, 2012), but very little corresponding investment has been made in the piped water system, which led to a substantial gap between the supply and demand. In 2014, water demand in the valley was estimated to be 360 million liters per day (MLD). The public water utility's current production reaches only about 76 MLD in the dry season and 123 MLD in the wet season (KUKL, 2014). In addition, annual losses from the municipal piped water supply system have been estimated to be over 70% (Dixit & Upadhya, 2005).

The result of this state of affairs is that as of 2014, less than 20% of the population was receiving a reliable supply of piped drinking water (ADB, 2010). To overcome the shortages, a long-term investment program is in progress to divert water from the Melamchi River outside the valley and deliver it to Kathmandu via a long (26 km) tunnel (Dixit & Upadhya, 2005). This project has experienced protracted delays. The current gap between demand and supply in Kathmandu is being met primarily through private groundwater extraction by households and vendors and through sales of water from a variety of private water vendors.

Research design and fieldwork

For our research in Kathmandu Valley, we used a mixed-methods research approach that incorporated data from structured household and vendor surveys as well as from in-depth key informant interviews. This combined strategy made it possible to triangulate our findings from multiple sources and extrapolate these findings to the city as a whole. A mixed-methods approach seemed especially appropriate because only limited and dispersed knowledge was available about the various unregulated water vendors. All data collection activities were conducted in Kathmandu in 2014.

Adopting protocols for data collection from a similar study (Whittington *et al*., 1989), we conducted a survey of 120 water vendors engaged in various combinations of three activities along the water vending supply chain: (1) commercial abstraction of bulk water from natural sources or bore holes (i.e., not from the piped system), (2) tanker truck delivery of bulk water to end users, and (3) bottled water production. In our sample, 'vendors with commercial water sources' thus refer to vending businesses that owned water sources and sold bulk water in large or small quantities from supplies other than the piped water system. Our descriptor 'vendors with tanker trucks' refers to businesses that used tanker trucks to deliver bulk water to households and businesses. Our third category, 'vendors with bottled water facilities,' are operations that produce bottled water, that is, treated drinking water packaged in 20-L plastic 'jars' or 1-L bottles. For purposes of analysis, 'integrated vendors' involved in more than one of these operations were assigned compound names.

For the water vendor survey, lists of commercial water source vendors, tanker truck vendors, and bottled water vendors were collected from the central offices of the vendors' respective business associations: the Valley Drinking Water Source and Tanker Entrepreneurs Association (VDWTEA) and the Nepal Bottled Water Industries Association (NBWIA). The commercial water source list was verified by field visits and consultations with the owners of different boreholes and raw water sources, such as springs[1]. From in-depth interviews with KUKL and the heads of the business associations, we determined that the associations' membership lists were the best sampling frame for the water business population, representing the majority of vendors operating in the Kathmandu Valley. According to these two lists, there are approximately 67 commercial sources of water, 700 tanker trucks supplying the city with water through 210 vendors, and 200 bottled water vendors selling drinking water through 20-L jars and 1-L bottles. From the lists, we drew three random samples: (1) 40 from the list of commercial water source vendors; (2) 40 from the list of vendors with tanker trucks; and (3) 40 from the list of bottled water vendors. Figure 1 shows the location of the vendors we interviewed.

[1] This list only included commercial water source vendors who sold to independent tanker truck vendors and did not have their own tanker trucks. Vendors with commercial water sources who had their own tanker trucks were included on the tanker truck association list. Some tanker truck vendors had their own sources as well, but they were not categorized as 'commercial water source vendors' if they only supplied water to their own tanker trucks.

Fig. 1. Map of Kathmandu Valley, showing the location of vendors interviewed.

For all three types of vendors, we specifically wanted responses from the business owners. If an owner was unavailable, we instead solicited responses from the manager. Overall, of the 120 vendors we surveyed, 84% of the respondents were owners. Of the vendors with a commercial water source (along with any level of integration with other water business activities), 82% were owners. All of the vendors with only tanker trucks had owners as respondents. For vendors with only bottled water facilities, 70% of respondents were owners.

The water vending survey instrument presented questions that were common for all types of vendors, such as growth of their operations, customer numbers and types, relationship with the association (if a member), service details, operational and capital costs, and major challenges faced. The survey instrument also included three separate sections containing questions specific to the type of water vending (e.g., whether the vendor produced bulk water at a commercial water source, delivered bulk water with tanker trucks, and/or produced bottled water). The survey instrument was designed to allow for varying kinds and levels of consolidation among these three activities. We did not examine the distribution of bottled water or the sale of bulk water at retail outlets.

We also conducted a large household survey ($n = 1,500$), which included questions about the quantities of water a household purchased from different types of vendors and the prices paid (Gurung *et al.*, 2017). In addition, nine in-depth key informant interviews were conducted with government officials from KUKL and Kathmandu Valley Water Supply Management (KVWSM), the most recently elected mayor of Kathmandu, a retired university scholar, development practitioners, and the presidents of the two business associations (VDWTEA and NBWIA)[2].

The household survey covered respondents from 1,500 households across the five municipalities of Kathmandu Valley – Kathmandu itself, and Lalitpur, Madhyapur, Kirtipur, and Bhaktapur. These sample households had been previously surveyed in 2001 (Pattanayak *et al.*, 2005). In 2001, these household clusters were located using aerial maps provided by the Central Bureau of Statistics for the 1996/1997 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 and Training Center, 1999). For Kirtipur and Madhayapur, the 1991 population census was used as the sampling frame. Wards were then selected from the sampling frame on the basis of a probability-proportional-to-size sampling approach that ensured households had an equal opportunity of being included in the sample (Babbie, 1990). After a ward was selected for inclusion in the sample, sub-wards were drawn randomly. The final sample consisted of 60 clusters of 25 households each, covering all five municipalities in the Kathmandu Valley. In each cluster selected for inclusion in the sample, respondents from all 25 households were interviewed for the study. Because probability-proportional-to-size sampling depends on the size of population, some wards had more than one cluster in the final sample.

For the 2014 survey, if a household included in the 2001 survey could not be located, a nearby household in the same cluster was selected as a replacement. When a household head from the 2001 survey was unavailable, the present head or another responsible member of the household was chosen instead. In total, we were able to locate and re-interview a respondent in 927 of the 1,500 households visited in 2001. Thus, the 2014 survey included 573 replacement households.

The nine key informant interviews were audio-recorded with prior written permission obtained from the interviewees. In addition, written notes were taken during the interviews. Government officials and scholars were asked about the major milestones in the history of water infrastructure investment in Kathmandu Valley, major challenges faced in the development of urban water and sanitation services,

[2] Approval for the two surveys and for the informant questionnaire, and for their implementation protocols, was obtained from the National University of Singapore's Institutional Review Board.

institutional roles and responsibilities, and the growth of the private water market. We also discussed with key informants their interactions with the private water vendor market[3], access of vulnerable and poor populations to water and sanitation services, and impediments to expanding the piped network to all residents. Chairpersons of the two vendor associations were asked questions regarding the history and organizational structure of their respective organizations, their relationship and interaction with the government, and their main activities, including lobbying, as well as the factors that influenced whether water vendors joined their association.

The information obtained from the household and water vendor surveys was used to estimate the city-wide scale of quantities of water sold and of money paid and received at different points in the water vending supply chain. These estimates were cross-checked against information we had received from the informant interviews. In addition, we estimated the total water supplied by the public water distribution network, using water use data from our household survey and estimates of the total number of connections in the city (≈195,000).

Detailed financial data were collected from commercial water source vendors and the tanker truck vendors. These data enabled us to construct monthly accounts of revenues and costs using standard financial accounting methods. By constructing a basic financial statement for each vendor, we were able to assess the company's profitability.

Results

Overview of water vending in the Kathmandu Valley

As the population of the Kathmandu Valley has increased, the water vending market has expanded rapidly. According to the president of the commercial source and tanking business association (VDWTEA), in the early 1990s, only 60–70 tanker trucks delivered bulk water in the valley, and no commercial water sources existed to supply tanker trucks or the bottled water vendors. The tanker truck vendors obtained water primarily from natural sources (springs and rivers). In 1994, the first commercial water source (a borehole) for use by tanker trucks was constructed in Jorpati, in Kathmandu Municipality, which was quickly followed by several additional similar enterprises. The rest of the bulk water sold by tanker truck vendors was still obtained from natural sources. The years 1996–2000 witnessed the peak of the Maoist insurgency and the great migration from rural areas to Kathmandu and over that short interval the water vending industry in Kathmandu boomed. The number of tanker trucks increased from 160 to 500, and many more commercial water sources (boreholes) were constructed, because many natural water sources had become depleted and contaminated. The president of the bottled water business association (NBWIA) reported much the same history.

By the time our fieldwork began in 2014, about 700 tanker trucks supplied the city with water obtained from 210 commercial water sources. Approximately 200 bottled water vendors were selling 20-L plastic jars and 1-L bottles to shops and families. A majority of the water vendors included in our vendor survey had started business after 2010. The oldest business included in the survey was established in 1992.

[3] For example, the public water utility had its own tanker trucks for distributing bulk water, thus competing with the private water tanker vendors. KVWSM decided key regulations, such as permits for commercial water sources. Ultimately, the associations were formed, organizing the various types of water vendors.

A great majority (88%) of the water vendors in our sample were members of one or the other of the two business associations. At time of the survey, the main role of the associations was to represent the interests and needs of the vendors to the government. There were no legal or institutional mechanisms that specify the price of vended water, quantities sold, or quality standards (Moench, 2001; Janakarajan & Moench, 2006). The business associations had issued pricing guidelines for their members, but these guidelines were not enforced. Private vendors were required to pay some taxes (such as the road and vehicle tax for tanker trucks, value-added tax (VAT) for bottled water producers, and income taxes). In addition, commercial water source vendors must obtain licenses to extract water from boreholes. Licensure abides by a national legal standard but often depends on the approval of the local community where a borehole is located (Shrestha *et al*., 2012). There have been ad hoc instances of government testing of the quality of water sold by different types of vendors, but as yet no systematic public sector efforts have emerged to ensure that vended water meets recognized quality standards. As a result, individual vendors have created their own water quality standards to ensure that they retain the trust of their customers and to distinguish their product from those of competitors.

Until recently, and during the time of our survey, the national law requiring licensure for commercial water vendors was not enforced. Thus, apart from costs of extraction, commercial water source vendors did not pay a price for their raw water supply, either for surface or spring water or for groundwater. In 2018, growing concerns over groundwater depletion caused the national government to consider the introduction of a licensing framework for the use of commercial water sources. As the new framework was not yet enacted, the drilling of new boreholes was put on hold, resulting in a barrier to entry into the vending market. Aware of the vital role played by the vendors in providing water to underserved Kathmandu residents, authorities remained lenient with unlicensed water extraction from the existing commercial water sources.

How water and money flow through the water vending supply chain

Figure 2 illustrates the water vending system in Kathmandu and how water and money flow along some of the links in the supply chain[4]. Our calculations show that during the dry season of 2014, households and businesses purchased approximately 370,000 to 500,000 m^3/month[5] from the private water market, generating total revenues for commercial water source vendors, tanker truck vendors, and bottled water vendors of about US$1 million/month. This represents about 20% of the water used by households in Kathmandu in that dry season. Commercial water source vendors sold 269,000 m^3 of water each month and received US$103,000/month from households, businesses, and tanker truck vendors. Tanker truck vendors delivered and sold 371,000 m^3 of water and received US$806,000/month, of

[4] Whittington *et al*. (1991) presented the first such water-money flow diagram for an urban area (Onitsha, Nigeria), and Whittington *et al*. (1993) extended such analysis to sanitation-money flows in Kumasi, Ghana. The Sustainable Sanitation Alliance has promoted the use of similar flow diagrams (but without the money flows) to describe sanitation conditions in both urban and rural areas, and these 'shit flow diagrams' are now widely used by sanitation professionals in the Global South.
[5] Estimates of the quantities of vended water vary depending on whether one extrapolates using the vending sample or the household sample. If we use data from the vending surveys, the total estimate is about 370,000 m^3/month. If we use data from the household survey, the total is about 500,000 m^3/month.

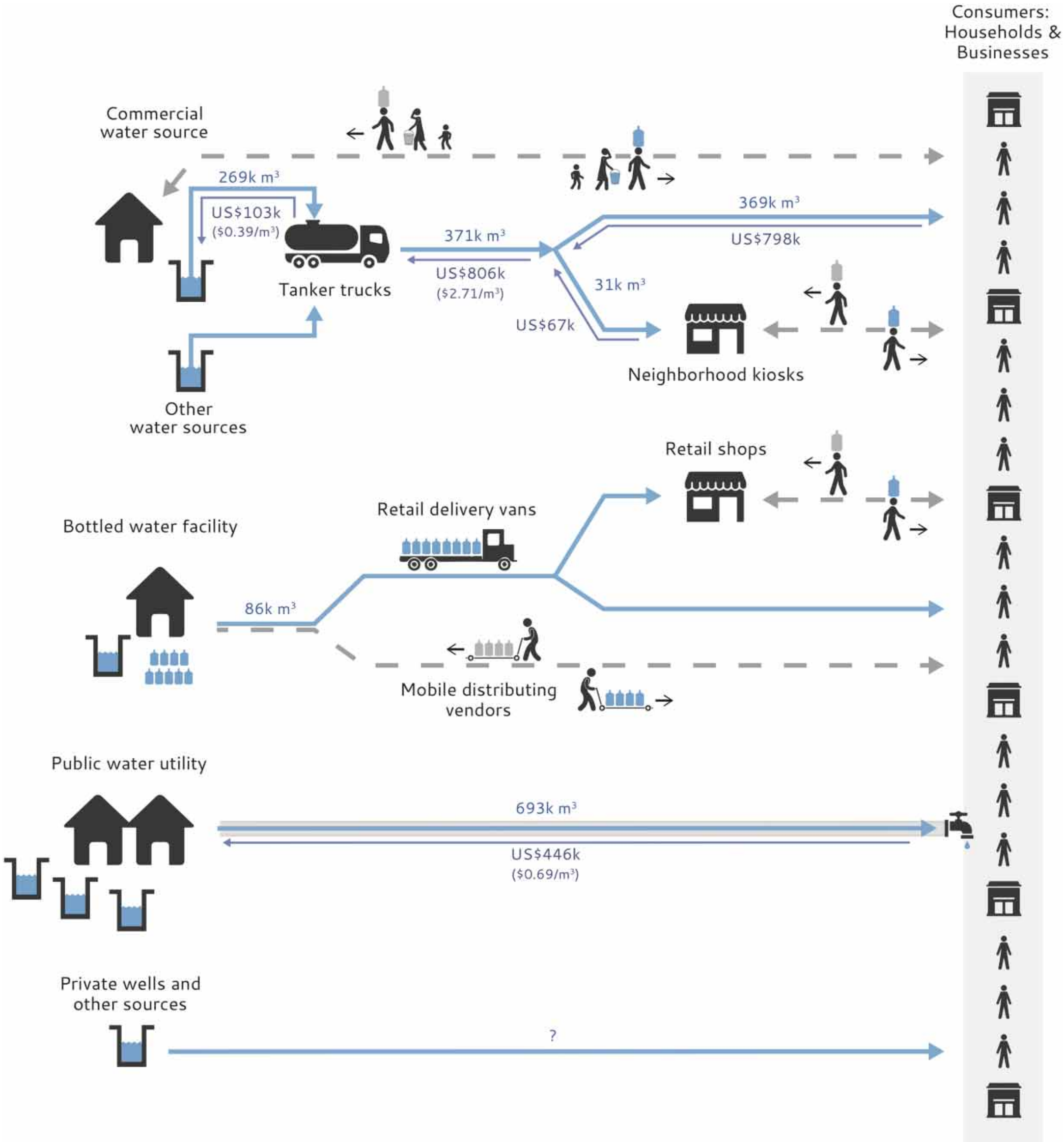

Fig. 2. Money and water flows in Kathmandu Valley, 2014 (dry season).

which 31,000 m^3 was sold to retail outlets[6]. The average price of bulk water sold by tanker truck vendors was US$2.17/$m^3$ at the time of our study.

[6] There is a discrepancy in our estimates of the amount sold by commercial water source vendors (268,701 m^3) and tanker truck vendors (370,860 m^3), as we would expect the amount sold by tanker truck vendors to be larger than that sold by commercial water source vendors. We speculate that this difference may be due to (1) tanker truck vendors drawing upon their own, noncommercial sources or (2) an underestimation of the number of commercial water source vendors.

From our household survey, we found that the public piped water network accounted for about a quarter of total household water use (693,000 m^3/month)[7]. For our sample of 1,500 households, private wells provided 45% of the total water respondents collected and used. The piped water network supplied 26% and vendors supplied 20%. The rest (about 10%) came from other sources, such as public wells, public taps, neighbors, rainwater, ancient stone taps, and surface water.

Structure of the water vending industry in Kathmandu Valley

Commercial water source vendors. Commercial water source vendors are at the beginning of the supply chain in the water vending industry (Figure 3). These vendors abstract water from natural sources or from boreholes. They sell water to tanker truck vendors, but most also give some water gratis to households. Most commercial water source vendors (87% of our sample) also treat this water before it is loaded into tanker trucks. The most common method of treatment is sand filtration.

Commercial water source vendors do not pay for their raw water supply but do incur capital costs for boreholes, pumps, and other facilities for delivering water to customers. Those who treat their raw water before selling to customers incur treatment costs as well. Other costs include electric, diesel, or petrol fuel for running pumps and other equipment, and labor costs for managing the facilities and sales.

In our sample, commercial water source vendors were clustered in nine areas in the Kathmandu Valley: Jorpati, Matatirtha, Swayambhu, Balaju/Bus-Park, Sundarijal, Chovar Chalnakhel, Jhaukhel, and Satdobato (Figure 1). Most (87%) offer free water to the communities within which their source is located. These vendors reported that they do so mostly to help their communities. However, our key informant interviews with government officials revealed that this policy was primarily pursued because over time, community resentment tended to grow regarding the private sale of a common resource. This rationale was corroborated in the interview with the president of the commercial vendors' business association (VDWTEA), who said that it had become extremely difficult to dig new boreholes as local people were no longer willing to give permission (as required by licensing authorities). Communities began to feel that the water source was no longer administered for the people but rather for the source vendor. Thus, the provision of free water to the local community had become the norm, and families came freely to the source with their own buckets and collected water for household use. Another common practice was for the commercial water source vendor to provide the police force with one free tanker load of water per week.

Commercial water source vendors have two main options for consolidating their operations with other components of the supply chain. First, they can purchase their own tanker trucks and use those trucks to expand into the delivery of bulk water directly to households and businesses. Or, second, they can take up bottled water vending, using their commercial sources as the raw water input into more sophisticated water treatment facilities. This treated 'drinking water' is then bottled into the common 20-L plastic jars and 1-L bottles for distribution to households and businesses. These two consolidation options are not mutually exclusive. Some vendors have consolidated all of these operations, covering the entire process from commercial water source extraction, to tanker truck distribution, to treatment, and bottling of drinking water.

[7] Calculated using the number of private water connections in Kathmandu Valley (194,718), as reported by KUKL. Our survey included 1,051 households using private water connections, and we calculated the average estimated volume of water collected from each connection based on household estimates.

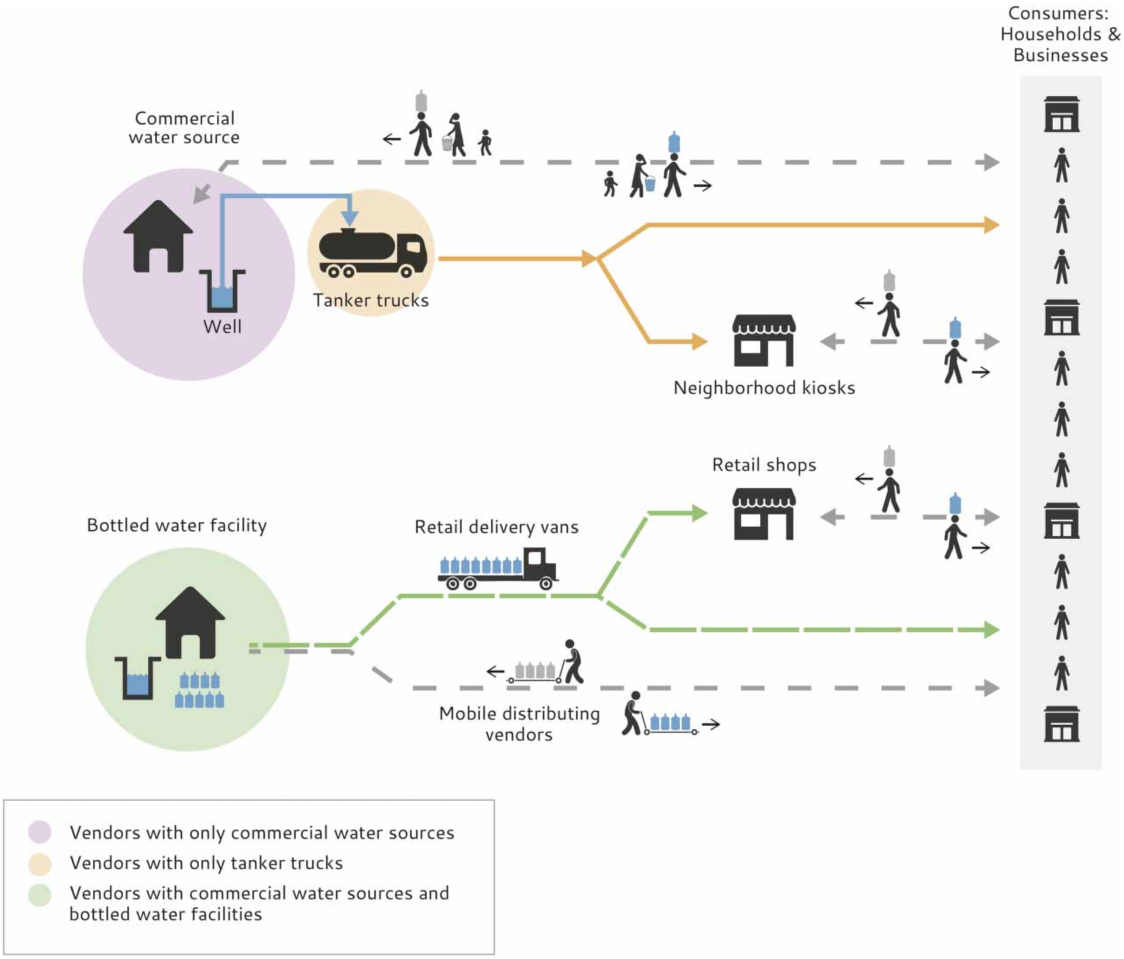

Fig. 3. Water vending industry structure.

Almost all the water from commercial water source vendors received by households in our study was delivered through tanker trucks. Only 15 of the 39 commercial water source vendors (38%) ran a source water-only operation, selling water to other, privately owned tanker trucks and to households. Another 46% of the commercial water source vendors in our sample had their own tanker truck operations. A few (3%) had their own bottled water operations, and 13% had both their own tanker trucks and bottled water facilities.

Tanker truck vendors. Vendors with tanker trucks collect water from commercial water source vendors and deliver it to both households and businesses (Figure 3). Households use bulk water for a variety of purposes. It may be used for drinking, but usually only after additional treatment (either boiling or filtering) by the households themselves. Two-thirds of the bulk water sales for tanker truck vendors in our sample were to households. Another 17% of sales were to businesses. Sales to neighborhood kiosks and to construction sites accounted for 7% each, and 2% went to hospitals.

The tanker trucks in businesses included in the survey were of varied capacities (5–15 m^3, predominantly 7 m^3). During the rainy season, each vendor sold about three to four tank loads per day, thus making three to four trips back to the commercial water source to refill. During the dry season, each sold approximately twice that amount, requiring seven to eight trips per day for refilling. During the rainy season, most tanker truck vendors were able to fulfill demand within about 4 h. The same process took much longer in the dry season, with customers waiting an average of 1–2 days for their order. A large majority of tanker truck vendors (79%) reported that in the dry season, they had more orders than they could fulfill.

The main operating costs for a tanker truck were fuel for the truck, and labor costs for the driver and an assistant, who helps with filling the tank at the source and discharging the tank at points of sale. A majority of tanker businesses (62%) had only one truck and employed only one driver and one driver's assistant. Owners of two trucks comprised most of the rest of the total (31%), and only a few (7%) had three trucks. A vendor who only deploys tanker trucks also incurs costs of purchasing water from a commercial water source vendor. Tanker truck vendors are also subject to taxes, fees, and regular maintenance and repairs on their trucks. Their only capital costs are expenditures to purchase their tanker trucks and for major repairs.

A tanker truck vendor has two main options for further integration with the water vending supply chain. The first is to integrate backward along the supply chain and drill (or purchase) a commercial water source, thus both selling bulk water and self-supplying tanker(s). In our sample, 30% of the vendors with tanker trucks had their own source of water (not necessarily a commercial water source), about half from groundwater and half from surface water sources. Second, the vendor can integrate forward in the chain and begin selling bottled water (Figure 4(b)). This combined strategy enables the tanker vendor to supply bulk water to households and other businesses via tanker trucks and also to deliver higher-quality bottled drinking water directly to households and businesses (using different delivery vehicles).

Bottled water vendors. Vendors that produce high-quality bottled drinking water necessarily have a proprietary source for their water. Some may use natural water sources (e.g., springs), and others may use groundwater (their own boreholes)[8]. Bottled water vendors often sell 20-L plastic jars of drinking water to mobile distributing vendors who, in turn, deliver them to households and businesses.

The main capital costs for a bottled water vendor are the water treatment and bottling facilities, and the land and building needed for these operations. They primarily use reverse osmosis technology to treat their raw water. Many in our survey used automated bottling and packaging machines (see photographs in Appendix 4, available online). Bottled water facilities also have labor costs for running and maintaining their equipment and handling sales of their product.

A bottled water vendor can expand by establishing its own retail distribution network, delivering water directly to households, often with motorized delivery vehicles and with its own employees. Alternatively, it can expand by supplying bulk water and operating its own fleet of tanker trucks, and/or acquire and sell bulk water from its source.

Mobile distributing vendors. Our study did not include interviews with mobile distributing vendors that sell bottled water. We did learn from our household respondents and bottled water vendors that mobile distributing vendors purchase 20-L jars of water from bottled water facilities and transport these to households. In 2014, the price of a 20-L jar water was most commonly US$3.15. This price included a refundable deposit for the jar upon return. These 20-L jars can be refilled, at a price ranging

[8] It is possible that some use the public piped water distribution system.

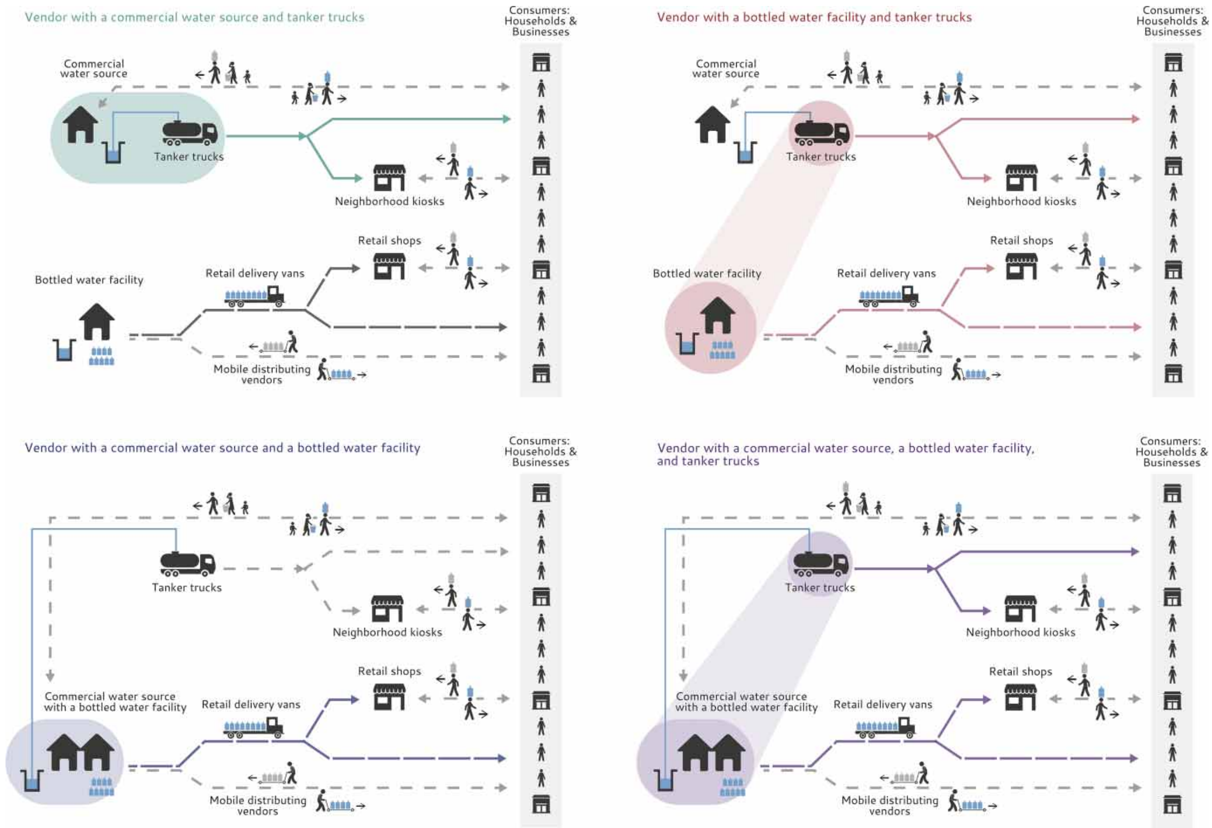

Fig. 4. Water vending consolidation options.

from US$0.10 to US$0.74, the most common amount being US$0.32. If the household owned its jar, the mobile distributing vendor delivered a full jar and picked up an empty one.

Retail outlets: kiosks and stores. Both bulk water and bottled water are also sold to households through retail outlets. Tanker trucks may deliver water to neighborhood kiosks, which then sell water to households in smaller quantities. The tanker truck vendor fills the kiosk's large storage containers, and from these, the kiosk vendor fills smaller containers for customers. Bottled water vendors likewise sell water to retail outlets, usually to small neighborhood stores, where households can walk to purchase 20-L jars and 1-L bottles and carry them home, or can request home delivery.

Entry into the market

The oldest vending business in the sample (a tanker truck vendor) began operations in 1992. Others began to enter the market in the early 2000s. The number of vendors entering the business was greatest in 2009 and 2010, then declined up until 2014, the year of the survey. Half of the source water and bottled water vending enterprises were owned by one person. Most (79%) of the tanker truck vending businesses in our sample also were owned by one person.

Average start-up costs for a commercial water source vendor were US$76,000 (median of US$49,000 and adjusted for inflation). For a tanker truck vendor, average start-up costs were US$27,500 (median of US$20,600). For a vendor with both a commercial source and tanker trucks, average start-up costs were US$87,000 (median US$69,000). Most vendors (74%) needed to borrow money to start their businesses. Most such start-up loans came from banks (59%) or cooperatives (18%), both of which charged a median interest rate of 5% for both banks and cooperatives (range 2–10%). Friends and families also provided loans, commonly with 5% interest as well.

Markets along the supply chain

The two main products delivered through the water vending supply chain – bulk water from natural sources or boreholes, and drinking water produced by bottled water facilities – were sold in four main markets.

The first of these (market 1) was the sale of bulk water from commercial water source vendors to tanker truck vendors (vendor–vendor) (Figure 3). In 2014, commercial water source vendors charged tanker trucks US$2.15 on average to fill for a 5,000 L tanker truck and US$4.86 for a 14,000 L truck. Averaging over different size tanker trucks, commercial water vendors charged tanker truck vendors an average of US$0.38/m^3 (Table 1).

Market 2 was the sale of bulk water from tanker trucks to households and businesses (vendor–end user sale). Tanker truck vendors charged households and businesses an overall average of US$2.25/m^3, about six times the price they paid the commercial water source vendors. Charges were, on average, US$13.78 for a 5,000 L tank to US$24.73 for a 14,000 L tank. Although demand for tanker truck water was much higher in the dry season than in the rainy season, tanker truck vendors charged the same price in both seasons. It is not clear to us why they did not to raise their prices in the dry season.

Table 1. Description of four markets for vended water (prices in the dry season).

Product	Bulk water		Bottled water	
Market	Upstream market	Consumer market	Upstream market	Consumer market
Sellers	Source owners	Tanker truck operators[a]	Bottled water operators	Bottled water operators, distributing vendors
Buyers	Tanker truck operators	Businesses, households	Distributing vendors	Businesses, households
Price (US$/m^3)				
Mean	0.38	2.25		
Standard deviation	0.08	0.57		
10th percentile	0.29	1.75		
Median	0.38	2.19		
90th percentile	0.50	2.74		

[a]Our numbers are calculated using tanker truck sales to consumers. Very few source owners sell directly to households. Large businesses often will have their own water tanker trucks, which would purchase water directly from the source.

Market 3 was the sale of drinking water produced by bottled water facilities to mobile distributing vendors for subsequent purchase by households and businesses (vendor–vendor). Our research protocol did not collect information permitting an estimate for the price at which bottled water vendors sold water to mobile distributing vendors. From interviews, we learned that some bottled water vendors delivered to distributing vendors for a delivery charge of between US$13 and US$16 for a minimum order of 150 20-L jars.

Market 4 was the sale of 20-L jars delivered by mobile distributing vendors and bottled water vendors directly to households and businesses (distributing vendor–end user). In 2014, the price for household delivery and exchange of a 20-L refill jar were US$0.47–US$0.63, depending on water quality and company policy. Additional market transactions occurred at kiosks for bulk tanker truck water and at neighborhood retail outlets for 20-L jars.

From the households' perspective, the water vending supply chain offered two products and six main purchase options. (1) A household member could walk to a commercial water source vendor and collect bulk water for free. (2) The household could pay a tanker truck to deliver the same quality bulk water directly to the home, again purchasing in large quantities. (3) In some neighborhoods, households could purchase this same quality of water from kiosks in smaller quantities. (4) A household (or business) could travel to a bottled water vendor and collect 20-L jars of drinking water (with a minimum purchase). (5) A household could pay either the bottled water vendor or an independent mobile distributing vendor to deliver 20-L jars of water to the home. (6) A household could purchase 20-L jar(s) or 1-L bottles from neighborhood retail outlets and carry the water home themselves.

Figure 4 summarizes the four main ways that water vending entrepreneurs could integrate activities to serve more than one of these markets:

1. Commercial water source vendors could purchase their own tanker trucks in order to deliver water straight from the source directly to households, selling in both Markets 1 and 2. We found that this was a common integration strategy.
2. Commercial water source vendors could expand their product line by integrating bottled water vending, thus selling in Markets 1, 3, and 4.
3. A tanker truck vendor could integrate operations with a bottled water vendor, thus selling in Markets 2, 3, and 4. In 2014, this option was uncommon in the Kathmandu Valley. Only two of the vendors in our sample had adopted this integration strategy.
4. A bottled water vendor could integrate a retail distribution of 20-L bottled water into its operations, thus eliminating sales in Market 3, selling its product only in Market 4.

Additional options might have included even more aggressive integration strategies, but to the best of our knowledge, these have not yet materialized in Kathmandu.

Most of the commercial water source vendors (100%), tanker truck vendors (78%), and bottled water vendors (56%) in our sample stated that they adhered to the prices set by their business associations. However, when questioned further, the tanker truck vendors admitted they often reduced prices to fight off competition. When tanker truck vendors were asked how they priced the water they sold, 82% stated that their business association rules did not factor into their pricing decisions. In contrast, it seems that bottled water vendors used water quality instead of price to differentiate their product from that of competitors.

Financial accounts for commercial water source vendors and tanker truck vendors

Our data allowed us to take a more detailed look at the revenues, costs, and profits by constructing income statements for three types of vendors in the supply chain (Markets 1–3). We could then assess performance of the three types of vendors involved: (1) commercial water source vendors selling water to tanker trucks (Market 1); (2) tanker truck vendors without other vending activities (Market 2); and (3) vendors that owned both a water source and tanker trucks (Markets 1 and 2). (We did not create income statements for participants in Market 4, bottlers and mobile distributors.) To construct the income statements for sellers in Markets 1, 2, and 3, we calculated the monthly revenues, financial costs, asset productivity, and three different measures of profitability for each enterprise, in both the dry and wet seasons (Tables 3, 4 and 5). Appendices 1, 2, and 3 (available online) present the full set of vendor-specific results.

From these income statements, we could assess the profitability of each business and compare businesses with each other. Profitability is arguably the most important criterion for evaluating the performance of a firm (Smith *et al.*, 1998). Profitability metrics, which measure the return that the firm's owners receive from their investments, have been widely used in research on information systems, strategic management, and finance (Smith *et al.*, 1998). There are four key metrics: return on assets (EBITDA/average assets), gross margin (direct product costs/revenue), operating margins (EBITDA/revenue and EBIT/revenue), and net profit margin (net income/revenue) (Smith *et al.*, 1998; Agrawal & Hall, 2014). Return on assets (ROA) is a commonly used metric for overall company performance (see Hunton *et al.*, 2003; Andres, 2008; Adams *et al.*, 2009). Our calculations for each vendor's income statement began with an estimate of total monthly revenue. From this, we estimated four different measures of profit: (1) gross margin; (2) earned income before interest, taxes, depreciation, and amortization (EBITDA); (3) earned income before interest and taxes (EBIT); and (4) net income.

The first, gross margin, shows the profit made from making and selling a product, without taking into account overhead and other fixed costs. Gross margin is a reflection of how much value to the basic inputs is added by the company utilization of capital and technology. In competitive markets, gross margins should be similar across firms, because companies with larger gross margins can lower their prices to outcompete companies with smaller gross margins. Gross margin is calculated by subtracting the cost of goods sold from monthly revenue. The cost of goods sold include only direct costs attributable to the product, including material input costs (or product costs), transportation costs (or supply chain costs), and direct labor costs. These are all variable costs; in other words, they are a function of the quantity of the product sold. For example, for tanker truck vendors, the cost of purchasing bulk water from a commercial source counts as a product cost; the fuel cost of transporting water from the source to the consumer is one component of the supply chain costs; salaries of truck drivers and truck driver assistants are direct labor costs. Our survey did not allow for direct attribution of cost of goods sold for source vendors and bottled water vendors because we did not ask these vendors how much was spent per unit produced (e.g., variable pumping costs and costs of each bottle for bottling). While we inquired about the cost of diesel, petrol, and electricity, we were unable to separate out the proportion of those costs used to pump water from the source (what would be attributed to product costs). Additionally, we did not inquire about direct labor costs for the source and bottled water vendors.

The second measure of profit, earned income before interest, taxes, depreciation, and amortization (EBITDA), provides a measure of the amount of money a company makes before accounting for the costs of capital assets and debt. It provides an idea of a company's profits independent of decisions about location (which determines taxes) and investment (in capital equipment), and it disregards sunk costs (i.e., costs already incurred that are difficult to reverse, such as drilling a borehole). EBITDA is calculated by subtracting from the gross margin the costs of selling the product, and general and administrative costs. These costs include overhead and management, maintenance and repairs, rent and utilities, and marketing and other sales costs. In our calculations, for the vendors with tanker trucks, we included, in the overhead and management category, any labor costs of staff not associated with the direct operation of tanker trucks. For source vendors, we were unable to separate direct labor from indirect labor costs and deducted all labor costs from the gross margin. For maintenance and repairs, we used estimates of monthly spending on equipment breakdowns, replacement of parts, and maintenance of trucks, equipment, pumps, and other equipment. For rent and utilities, we included the costs of renting the business premises and any other related buildings, and utility costs (electricity). We did not impute any costs for land and buildings that a business already owned. The costs of any permits, association membership, and insurance were included in 'marketing and other sales costs.'

The third measure, earned income before interest and taxes (EBIT), deducts from gross margin the costs of the company's capital assets. This is the operating income – that is, profits from operations, independent of debt or taxes. Debt structure can change depending upon how owners decide to raise money, access to loans, etc., and has little to do with the day-to-day operations of the business. EBIT is calculated by subtracting depreciation and amortization from EBITDA. To calculate depreciation costs, we used straight-line depreciation based on typical useful lives of different assets (see Table 2). We did not amortize intangibles such as software, etc. (Stickney *et al.*, 2010).

The fourth measure, 'net income,' shows the amount of money a company makes after deducting from revenues all costs (variable, fixed (or overhead), and sunk (difficult to reverse)), as well as taxes and interest on debt. This estimate is obtained by subtracting interest and taxes from EBIT. The interest included in our calculations was the interest on company start-up loans that were still being paid off during the time of the survey. Our survey did not ask about loans taken out after the inception of a company, so our reported interest paid constitutes a lower bound. Taxes included the VAT, income tax, vehicle and road taxes, and a village development committee (VDC) tax.

Table 3 shows that water source vendors without their own tanker trucks had small mean (US$699) and median (US$614) monthly gross margins in the dry season and reduced mean (US$310) and median (US$359) monthly gross margins in the rainy season. Estimates of mean and median monthly net

Table 2. Useful life estimates of capital assets.

Asset	Useful life
Buildings	20
Water storage tank/reservoir	15
Bottling and packaging	15
Equipment for bottled water treatment	15
Computers	5
Filters	5
Generator	15
Pumps and piping	10
Delivery van	10
Others: CCTV camera	5
Tanker truck	20

Table 3. Profits of vendors with only commercial water sources (dry and rainy seasons, US$/month).

	Mean	SD	10th percentile	Median	90th percentile
Dry season					
Revenue	942	673	404	771	2,053
Cost of goods sold					
Product costs	16	19			
Supply chain costs	228	278			
Labor costs (direct)	0	0			
Gross margin	699	692	−173	614	1,723
Selling, general, and administrative costs					
Overhead and management	95	113			
Maintenance and repairs	47	58			
Occupancy and real estate	151	106			
Marketing and other selling costs	7	10			
EBITDA	398	603	−307	296	1,254
Depreciation	415	483			
EBIT	−17	864	−1,198	75	1,058
Interest	104	252			
Taxes	6	9			
Net income	−27	852	−1,213	−195	1,048
Wet season					
Revenue	554	336	177	556	1,067
Cost of goods sold					
Product costs	16	19			
Supply chain costs	228	278			
Labor costs (direct)	0	0			
Gross margin	310	430	−271	359	883
Selling, general, and administrative costs					
Overhead and management	95	113			
Maintenance and repairs	47	58			
Occupancy and real estate	151	106			
Marketing and other selling costs	7	10			
EBITDA	9	411	−473	−10	612
Depreciation	415	483			
EBIT	405	574	−1,169	−393	371
Interest	104	252			
Taxes	6	9			
Net income	−516	521	−1,184	−574	290

income proved negative for both the dry (−US$127, −US$195) and rainy (−US$516, −US$574) seasons. Figure 5(a) presents a distribution of monthly net incomes of vendors with only commercial water sources. More than half were losing money. These results suggest that commercial water source vendors without their own tanker trucks are not earning monopoly rents and appear to be operating in a very competitive market.

Table 4 presents estimates of the same measures for tanker truck vendors that were not integrated with a commercial water source. Tanker truck vendors had somewhat higher mean and median monthly gross margins in both the dry season (US$846, US$749) and the rainy season (US$176, US$228). However, our estimates of mean and median monthly net income approached zero in the dry season (US$148,

Table 4. Profits of vendors with only tanker trucks (dry and rainy seasons, US$/month).

	Mean	SD	10th percentile	Median	90th percentile
Dry season					
Revenue	3,836	2,230	1,971	3,057	6,859
Cost of goods sold					
Product costs	693	459			
Supply chain costs	1,656	1,464			
Labor costs (direct)	641	575			
Gross margin	846	1,268	−325	749	2,426
Selling, general, and administrative costs					
Overhead and management	99	90			
Maintenance and repairs	266	115			
Occupancy and real estate	9	36			
Marketing and other selling costs	45	23			
EBITDA	427	1,306	−683	338	2,131
Depreciation	189	156			
EBIT	238	1,263	−991	193	1,762
Interest	58	86			
Taxes	32	37			
Net income	148	1,256	−1,073	83	1,541
Wet season					
Revenue	2,035	1,175	1,061	1,629	4,093
Cost of goods sold					
Product costs	373	244			
Supply chain costs	1,051	969			
Labor costs (direct)	434	345			
Gross margin	176	809	−814	228	769
Selling, general, and administrative costs					
Overhead and management	91	91			
Maintenance and repairs	266	115			
Occupancy and real estate	9	36			
Marketing and other selling costs	45	23			
EBITDA	−235	837	−1,352	−90	493
Depreciation	189	156			
EBIT	−424	844	−1,552	−241	375
Interest	58	86			
Taxes	32	37			
Net income	−515	845	−1,564	−373	301

US$83) and were negative in the rainy season (−US$515, −US$373). Table 4 also presents 90th percentile statistics for each variable. The measures for 90th percentile monthly gross margin (US$2,426 in the dry season) and 90th percentile monthly net income (US$1,541 in the dry season) are positive, suggesting that some tanker truck vendors were profitable. Vendors with more trucks had higher mean and median net incomes. Figure 5(b) shows the distribution of monthly net incomes for tanker truck vendors, which is centered slightly above zero. Together, these results suggest that tanker truck vendors as a whole were not earning monopoly rents and, like the commercial water source vendors, appear to have been operating in a competitive market.

Table 5. Profits of vendors with commercial water sources and tanker trucks (dry and rainy seasons, US$/month).

	Mean	SD	10th percentile	Median	90th percentile
Dry season					
Revenue	5,504	2,640	2,451	5,507	8,046
Cost of goods sold					
Product costs	144	231			
Supply chain costs	1,410	872			
Labor costs (direct)	686	283			
Gross margin	3,264	2,465	823	2,984	5,418
Selling, general, and administrative costs					
Overhead and management	216	247			
Maintenance and repairs	499	1,000			
Occupancy and real estate	301	294			
Marketing and other selling costs	49	38			
EBITDA	2,200	2,619	−1,637	2,116	4,895
Depreciation	604	465			
EBIT	1,596	2,457	−1,885	1,412	4,331
Interest	126	168			
Taxes	39	34			
Net income	1,430	2,486	−2,187	1,271	4,300
Wet season					
Revenue	3,093	1,704	1,364	2,665	5,457
Cost of goods sold					
Product costs	97	139			
Supply chain costs	991	497			
Labor costs (direct)	484	207			
Gross margin	1,521	1,579	−39	773	4,108
Selling, general, and administrative costs					
Overhead and management	212	248			
Maintenance and repairs	499	1,000			
Occupancy and real estate	301	294			
Marketing and other selling costs	49	38			
EBITDA	460	2,115	−1,787	298	3,308
Depreciation	604	465			
EBIT	−145	2,004	−2,035	−147	2,862
Interest	126	168			
Taxes	39	34			
Net income	−310	2,012	−2,336	−373	2,783

Table 5 presents estimates of the same financial measures for commercial water source vendors with their own tanker trucks. The average monthly dry season revenues of these vendors (US$5,504) are higher than monthly revenues of tanker truck vendors (US$3,836) or commercial water source vendors without tanker trucks (US$942). These vendors also had higher mean and median monthly gross margins in both the dry season (US$3,264, US$2,984) and the rainy season (US$1,521, US$773). However, although estimates of mean and median monthly net incomes are positive in the dry season (US$1,430, US$1,271), they become negative in the rainy season (−US$310, −US$373 per month). Table 5 also presents 90th percentile statistics. The 90th percentile measures for both monthly gross margin (US$5,4180) and monthly net income (US$4,300) in the dry season are positive and substantial. As

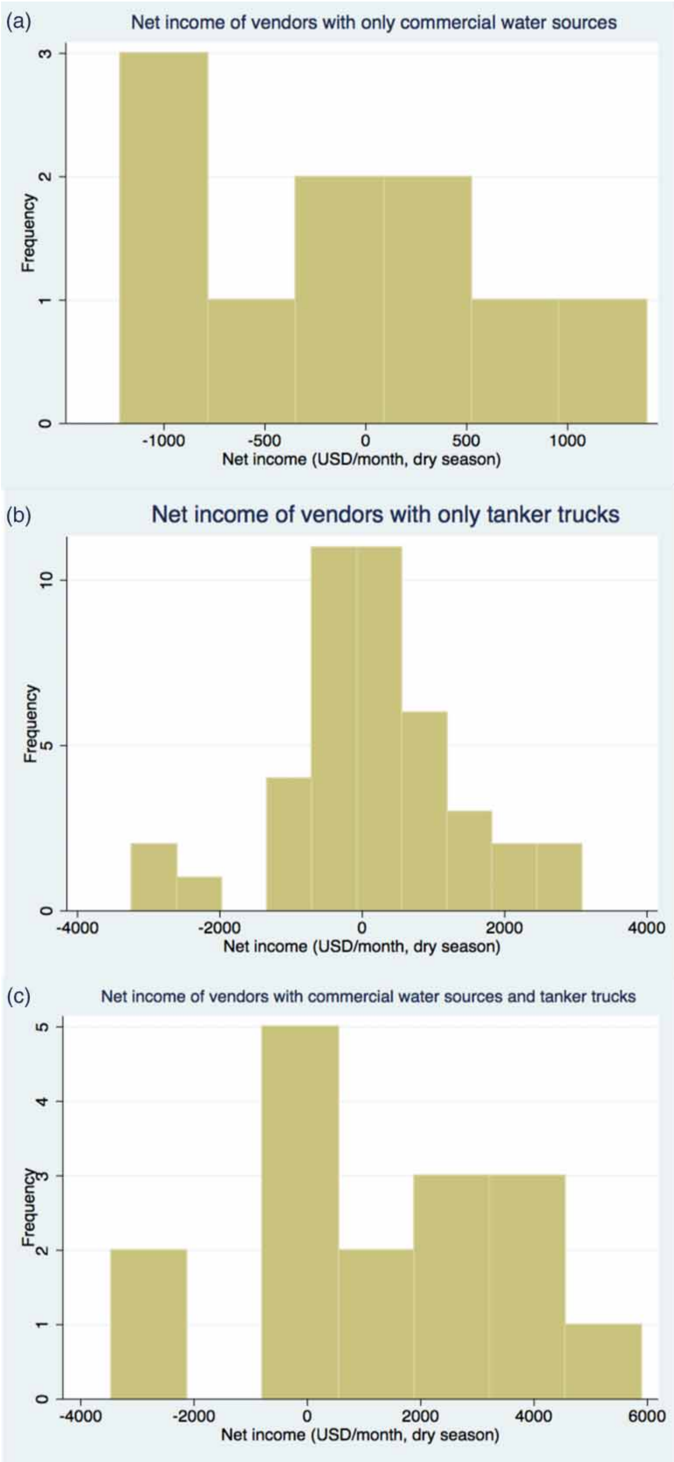

Fig. 5. Distribution of vendor net income by type.

Table 6. Firm productivity and profitability.

	ROA (%)	Gross margin/revenue		EBITDA/revenue		EBIT/revenue	
		Dry	Rainy	Dry	Rainy	Dry	Rainy
Commercial source vendor							
Mean	0.93	0.64	0.37	0.26	−0.37	−0.49	−1.23
SD	2.57	0.55	0.74	0.55	1.03	1.31	1.27
10th percentile	−0.82	−0.33	−0.83	−0.61	−1.77	−2.35	−2.34
Median	0.23	0.85	0.67	0.46	0.06	0.05	−2.00
90th percentile	4.70	0.96	0.95	0.76	0.67	0.73	0.55
Tanker truck vendor							
Mean	0.71	0.23	0.10	0.10	−0.14	0.05	−0.24
SD	10.87	0.33	0.44	0.35	0.48	0.35	0.49
10th percentile	−3.22	−0.05	−0.25	−0.21	−0.41	−0.31	−0.56
Median	0.96	0.25	0.14	0.10	−0.07	0.06	−0.17
90th percentile	8.47	0.59	0.54	0.42	0.26	0.39	0.17
Vendor with commercial source and tanker truck(s)							
Mean	3.43	0.53	0.38	0.32	−0.06	0.21	−0.28
SD	6.83	0.22	0.28	0.38	0.82	0.39	0.86
10th percentile	−5.78	0.31	−0.03	−0.45	−0.71	−0.52	−1.03
Median	2.07	0.51	0.41	0.36	0.12	0.25	−0.08
90th percentile	13.37	0.80	0.75	0.71	0.66	0.63	0.55

with stand-alone tanker truck vendors, these results suggest that some commercial water source vendors with their own tanker trucks were profitable. These findings further suggest that integrating commercial water source vending with tanker truck vending does result in increased market power. Figure 5(c) shows that most of the vendors with commercial water sources and tanker trucks were earning net profits, with only two vendors losing significant amounts of money. Of the three types of firms, the integrated commercial water source and tanker truck vendors appear from our estimates to have been the most profitable as a whole.

Table 6 summarizes vendor productivity and profitability. The average return on assets (EBITDA/assets) was less than 1% for both commercial source vendors and tanker truck vendors. However, results for vendors with both commercial sources and tanker trucks showed greater mean (3.4%) and median (2.1%) return on assets. Results for gross margins show that tanker truck vendors (Market 2) had the highest production costs, due to labor (drivers and assistants) and fuel costs, as their gross margins were the lowest (a mean of 0.23 in the dry season). Vendors with both commercial sources and tanker trucks had larger gross margins that were also more consistently positive. The standard deviation is low (0.22 compared to a mean of 0.53), indicating that the integrated vendors appear to have been operating in a competitive market. Operating margin without depreciation (EBITDA/revenue) illustrates the firm's profitability at its current level of assets. Integrated vendors with both commercial sources and tanker trucks are shown once again to be the most profitable of the three market types (0.32, compared to 0.10 for tanker truck vendors and 0.26 for commercial source vendors). Operating margin with depreciation takes into account the firm's capital investment decisions (such as the purchase of additional trucks and pumps) and reveals that many commercial source vendors were losing money, and tanker truck vendors were not profitable (with a mean operating margin of 0.05), whereas integrated vendors with commercial sources and tanker trucks remained profitable with a mean operating margin of 0.21. We did not include net profit margins in these calculations because of incomplete collection of data for interest on loans.

In summary, while there are some regulatory barriers to entry into Markets 1 and 2, such as restrictions on issuance of licenses for source vendors, these two markets appear to be quite competitive. Our estimates of net income are not excessive. There are no constraints on commercial water source vendors or tanker truck vendors regarding how much water can be extracted and sold, where their products can be sold, to whom their products can be sold, or the prices at which water can be sold. There seem to be many independent tanker truck vendors present in the market, and households purchasing from tanker trucks report that they are not dependent on any one vendor.

Concluding remarks

Our research shows that at the time of our study (2014), water vendors in the Kathmandu Valley operated a diverse, heterogeneous group of businesses. There was a supply chain with two main products: bulk water and bottled drinking water. Transactions occurred in four main markets: two upstream markets (between water source owners and tanker trucks, and between bottled water vendors and distributing vendors) and two consumer markets (between tanker truck vendors and consumers and between distributing vendors and consumers).

Each type of water vending business faced its own unique operational challenges and competitive pressures. Revenues, costs, and profits varied along the supply chain depending on the type, size, and integration of business operations. The characteristics of buyers and sellers also varied. Some water vendors were both buyers and sellers of water. Some water vendors were vertically integrated in the sense that they were involved in different phases in the supply chain, while others focused on only a single activity.

The portions of the water vending supply chain that we examined were all quite competitive. Yet, the fact that tanker truck prices for water did not respond to substantial changes in demand between the dry and wet seasons remains puzzling. Our research also discovered two active professional associations representing different types of water vending businesses in Kathmandu. But the influence of these associations on the behavior of different types of water vendors seems to have been modest; many water vendors reported that they did not follow the pricing guidelines promoted by the associations. It appears that competitive pressures are too strong for the associations to exert price control.

Understanding the structure and complexity of the water vending supply chain is a necessary first step in developing appropriate policy responses to improve the performance of informal water markets in any area and economy where they play a part. Policy interventions such as designing governance structures and regulatory frameworks may be needed in the future to address potential negative welfare consequences resulting from water vending (Collignon & Vézina, 2000; Conan & Paniagua, 2003; Kjellén & McGranahan, 2006; Banerjee, *et al*., 2011). Such interventions can be targeted toward parts of the water vending supply chain where efficiency gains are most feasible and competition is most vulnerable. However, our research has not uncovered problems that would appear to require urgent attention.

Indeed, water vendors in the Kathmandu Valley have played a crucial role in filling the water supply and demand gap that arose first historically, then critically in recent years, from inadequate public water supply. Approximately 20% of the water for households and business use in the Kathmandu Valley is delivered by this water vending supply chain. However, these water vending services have not been cheap. In the dry season, end users of vended water (both tanker truck water and bottled water) pay approximately 3.4 times as much for vended water as they pay for water from the public piped water distribution system.

These large amounts of money flowing through the water vending supply chain illustrate the revenue potential associated with improved services offered by the public piped distribution system. In Kathmandu, at the time of our writing (2018), the Melamchi Water Supply Project is nearing completion. There is the possibility that KUKL will be able to improve the quantity and quality of the water supplied through the piped water system. The results of our research suggest that most households are already paying much more to water vendors than to KUKL, and that the completion of the Melamchi Water Supply Project offers KUKL a rare opportunity to raise water tariffs simultaneously with the delivery of improved piped services.

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Supplementary material

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