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Drivers of non-revenue water: A cross-national analysis☆

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ABSTRACT

Reducing water losses is seen as key to sustainable water management, but turns out to be challenging. This paper applies a panel data analysis with fixed effects to assess the major drivers of non-revenue water, some of which are under the control of utilities and some of which are not. The analysis finds that the most important drivers are population density per kilometer of network and type of distribution network, which are mostly resulting from urbanization patterns which are factors mostly out of the control of the utility. Yet, low opportunity costs of water losses and high repair costs of water losses have an important adverse effect on water loss reduction. We also found that the country environment in which the utility operates has an important impact on non-revenue water levels.

1. Introduction

Rapid population growth, income growth, and urbanization in combination with a fixed supply of total renewable water resources accelerate pressure on available per-capita renewable water resources, and increase the gap between supply and demand. The fourth World Water Development Report (2012) estimates that by 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world's population could be living under water stressed conditions. Climate change is likely to make the challenge even more daunting, as it will increase the variability of fresh water supplies. At the same time, climate change will increase the likelihood and frequency of water-related disasters. The IPCC (2014) estimates that, as surface temperatures are projected to rise, this is very likely to result in more longer-lasting heat waves while extreme precipitation events will become more intense and frequent in many regions.

The water sector will have to improve the way it uses its available water resources significantly in order to deal with the challenges ahead. In the municipal sector, water productivity is less than optimal as the difference between water put into the distribution system and the amount of water billed to consumers (i.e., "non-revenue water") tends to be large. For too many systems, high levels of non-revenue water (NRW) reflect huge volumes of water being lost through leaks (real losses) and drinking water not being invoiced to customers (apparent losses) and unbilled authorized consumption (Lambert et al., 2014). Kingdom et al. (2006) estimate that the total cost to water utilities caused by NRW worldwide is $141 billion per year. McKinsey (2013) includes water leakage management as an important instrument for reducing the gap between supply of and demand for municipal water. NRW reduction programs are a standard recommendation in virtually every policy paper or report focused on improving the sustainable use of water resources (for instance, European Community, 2006; European Environment Agency, 2009; UNWater, 2012; and McKinsey, 2010, 2013). The cited benefits associated with a reduction in NRW are manifold. A reduction in water losses will help to postpone or avoid supply investments and/or improve the financial health of the utility, allowing it to invest in service quality improvements. In utilities where water coverage is not universal

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and/or water is provided intermittently as is the case in many utilities around the world, recovered water could be sold to enhance revenues. Frauendorfer and Liemberger (2010) note that utility owners need to be made sufficiently aware that they are "sitting on a goldmine"; and that utility owners will need to incentivize their staff by informing them about the level, causes, and cost of NRW, along with the potential for improvement so that comprehensive NRW management can be supported by the entire organization.

If the reasons for reducing NRW are so compelling and so much money can be saved and significant volumes of water can be used for more productive purposes, then why has it turned out to be so difficult to reduce NRW? The present paper looks into understanding the reasons why reducing NRW is so difficult.

This paper is organized as follows. In Section 2 we undertake a literature review. In Section 3 we define NRW, review how it is measured, and we look at the trends in NRW using the database of the International Benchmarking Network for Water and Sanitation Utilities (IBNET).[1] This database covers financial and operational performance data from utilities all over the world. In the fourth section, we define a panel data model with fixed effects to analyze what drives NRW. The estimation results of the model are presented in the fifth section, and we conclude in the last section.

2. Literature review

Many articles have been published on NRW reduction, but they tend to be mostly practical guidelines as to how to reduce NRW (Farley and Trow, 2003; and IWA Water Loss Task Force, 2003; and Frauendorfer and Liemberger (2010)) focusing on the processes required to design and implement a NRW loss strategy. These articles often focus on reducing NRW in developed countries. We found success stories of reducing water losses in Phnom Penh, Cambodia (Biswas and Tortajada, 2010) and Singapore (Luan, 2010). There is also some literature on how to determine the economically optimal level of water losses reduction (Wyatt, 2010).

As for what drives NRW, the literature is still rather scant, even for developed countries, and dominated by an engineering perspective. This is an interesting finding, as one would assume more interest in knowing more accurately what drives NRW will help in identifying the best way forward in reducing water losses. Overall, the existing studies provide different explanations as to what impacts NRW. Skipworth et al. (1999) show in a study of England, that a large number of mostly technical and environmental factors affect municipal leakage rates. These factors include the age of the systems, the length and type of networks, pressure in the systems, climate, soil conditions, traffic loading, and density of connections. The authors also mention that topography can explain regional differences in water losses between utilities. Farley and Liemberger (2005) note the importance of physical factors, but they also place considerable emphasis on management factors. Poor management practices, poor materials and infrastructure, and local social, cultural, political, and financial factors are identified as NRW drivers. Their study does not delve into the details of how these factors drive NRW and how this affects the design and implementation of water loss strategies. Yet, the range of factors that drive NRW can easily be seen as factors that are either under the utility's control such as management practices, while others are less so (including physical, social, cultural and political factors).

[1] IBNET has been developed by the World Bank with the objective to provide comparative international benchmark performance information that can inform utilities and policymakers on how to improve service delivery (for more information, see www.ib-net.org).

In a study by Gonzalez-Gomez et al. (2011) on why NRW is so high in developing countries, the authors conclude that the lack of incentives is the main reason for differences in water losses between utilities. Water utilities normally lack the resources to pay for the cost associated with a reduction of water losses, while corruption and a lack of knowledge about NRW among users and taxpayers further add to the lack of interest to plug water leaks. In a follow-up study for Spain, using data from 133 municipalities in the Andalucia region, González-Gómez et al. (2012) conclude that NRW measured as percentage of system input volumes is driven by various physical, management, and other characteristics. They find that the type of distribution system (gravity-fed or pumped) is a particularly important driver of NRW for these 133 Spanish municipalities. Saez-Fernandez et al. (2011) focus on the low opportunity cost of water losses which does not provide much incentive for utility managers to reduce NRW. The paradox of high NRW levels coupled with the absence of respective measures to reduce water losses in areas that are dealing with water scarcity has also been studied in small water distribution systems in four Mediterranean countries (Kanakoudis et al., 2013b). Kanakoudis et al., 2015 also mention that tariff structure characteristics provide few incentives in Kazoni, Greece to reduce water losses.

3. Overview of non-revenue water

3.1. Definition of NRW

Non-revenue water is the difference between the volume of water put into a water distribution system and the volume that is billed to customers (IWA Water Loss Task Force, 2003 and Kankoudis et al., 2013b). NRW is comprised of three components:

- Physical losses include leakage from all parts of the distribution system and overflows at the utility's storage tanks. They can be caused by poor operations and maintenance, the lack of active leakage control, and poor quality of underground assets;
- Commercial losses include customer meter under-registration, data-handling errors, and theft of water in various forms;
- Unbilled authorized consumption includes water used by the utility for operational purposes, water used for firefighting, and water provided for free to certain consumer groups.

3.2. Measurement of NRW

The measurement of NRW is complicated. Many different indicators are used to measure NRW and virtually all of them have limitations and drawbacks. The most commonly used indicator is NRW defined as a percentage of water produced, although many authors have reservations about its use (Liemberger, 2002; Kanakoudis et al., 2013a and Lambert et al., 2014). The International Water Association (IWA) generally recommends alternative indicators, such as water losses per connection, water losses per main length, or the infrastructure leakage index (Alegre, 2006; and Winarni, 2009). The infrastructure leakage index is a complex indicator that includes data on system pressure, length of mains, number and length of service connections (i.e., distance between property line and water meter) and a water balance. This information is not necessarily easy to collect. Collecting pressure data, for instance, is complicated as pressure can vary widely within a piped water network. Lenzi et al. (2014) note that the strong dependence of the ILI on average operating pressure makes it sensitive to the way this parameter is defined and potentially unsuitable for comparing different systems. Recently, even more specific water loss indicators related to amongst others age,