Extended Abstract
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Paper/Poster Title	Achieving sustainable water management: Perspective from residential household farming in South Africa

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Abstract	*200 words max*

The growing interest to strengthen and intensify local food production in order to mitigate the adverse effect of global food shocks and food price volatilities has significantly increased the incidence of residential household farming in developing countries. However, the choice of water for use in these households is usually limited to either the more regulated piped water or less regulated groundwater sources such as boreholes or wellpoints. Many households with home gardens and backyard farms find it beneficial to secure water access by investing in groundwater sources for their consumption and use on the farm, consequently, putting the groundwater resource at risk of excessive extraction. This paper uses a simple utility maximization model that yields both a water-type choice model and a demand specification whose parameterization allows examining farming households' responses to regulated price changes. Our analysis shows empirical evidence in favour of the determinants of households' choice of water type. Our estimation also shows evidence for the increased household choice of piped water when a counterfactual price rebalancing strategy that influences the fixed charge and variable volumetric charge does exist. Furthermore, we provide insights on the potential effect of the piped water rebalancing strategy on welfare changes.

Keywords	Residential household farming, Piped water, groundwater, public utility regulation, Africa.
JEL Code	Q12, Q25, Q31, Q50, L95 see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	*100 – 250 words*

Home gardens and backyard farm systems are an integral part of local food systems and the agricultural landscape of developing countries all over the world and have endured the test of time. However, the availability of water resources to residential households is often affected by several bottlenecks including climate change, the strategies of regulatory water agencies, and changes dietary habits of consumers. In the case of residential farming households, sources of water for use are limited to either piped supply from water utilities or groundwater sources. However, given the market imperfection that characterizes the water industry and the nature of water as a commodity, many households find it beneficial to secure access and consumption by investing in the less regulated groundwater sources. Consequently, putting the resource at the risk of exploitation, acute aquifer depletion, and contamination. The purpose of this paper is to investigate the effect of water pricing structures and other

factors on the substitution threshold of piped water and groundwater sources. We argue that regulatory policies are significant determinants of farming households' decisions to consume from particular water sources, since they may act as incentives or constraints to drive institutional and behavioural changes. First, we examine the determinants of farming households' decision to use piped and groundwater supply. Second, we determine the distributional impact of a counterfactual price rebalancing scenarios that influence the fixed charge and variable volumetric charge on piped water users. Lastly, we estimate the elasticities of both piped water and groundwater demand. This present paper contributes to the still short literature on residential water demand by going well beyond the single-equation model often used in developing countries.

Methodology	100 – 250 words

Our data source is the National Income Dynamics Study (NIDS), which explores the livelihoods of households in the nine provinces of South Africa. The panel dataset is in its 5th wave and tracks household demographics, water source choice, home activities and expenditures over time. The core survey has been repeated with this household member every two to three years, with the latest interview round conducted in 2017 (wave 5). This paper used the whole panel dataset (waves 1 to 5) in its estimations. Our final sample comprises 10,050 observations. The piped water tariff data we employed comes from the South African Department of Water & Sanitation (DWS) and we compute the shadow price of groundwater based on the monthly pumping cost of electricity.

We build on Deaton & Muellbauer (1980) by constructing a utility-maximization model of demand that explicitly considers groundwater as a substitute for piped water. The estimation yield both a water-type choice model and a demand specification whose parameterization allows examining farming households' responses to regulated price changes. We then employed a standard binary logistic model to investigate the likelihood of households choosing between the groundwater and piped water sources. For our second objective, we examine the effect of a counterfactual tariff rebalancing scenario whereby only the level of piped water tariff changes. We estimated the expenditure elasticity for piped water price, groundwater, and other goods households spend their income on by using the quadratic almost ideal demand system (QUAIDS) (Poi, 2012). Lastly, we evaluate welfare effects using the compensating variation (CV) measure.

Results	100 – 250 words

Our empirical analysis of the determinants of farming households' decision to use piped water or groundwater supply shows that ownership of dwellings, large household size, type of backyard farm, crop farming, household year of participation in agricultural activities, and those with many rooms within their residence are factors that explain the reason for high groundwater usage. Due to the high quantity of water needed to process red meat, our analysis attempted to investigate if the constant

presence of red meat in households' diets, suggesting wealthy households, is a predictor of investment in groundwater. However, our result shows this to be negatively correlated. We suggest that a more robust relationship may be more evident at the province level than at the country level. Furthermore, a rebalancing strategy that leads to a 20% decrease in piped water volumetric charge (Rand per kilolitre), with a consequent increase in fixed charges strategy increases the likelihood of increased piped water subscription in five of the nine provinces of South Africa. This result is essential in the policy discussion of water price regulation since high regulated price levels are frequently blamed for shortfalls in households' access rates. The analytical framework that we use to analyze the potential effect of piped water rebalancing on welfare changes is based on the compensating variation, assuming that households are entitled to their pre-shock level of utility. Our results indicate that, on aggregate, the tariff rebalancing scenario could lead to an average monthly welfare gain of nearly 4%.

| **Discussion and Conclusion** | *100 – 250 words* |

A key policy implication of this paper is that to achieve the required reduction in groundwater exploitation while simultaneously increasing piped water subscription, residential water demand needs to be disaggregated based on the characteristics of each province. We estimate a model specification that allows for the understanding of measures to reduce and manage the extraction of the groundwater resources while simultaneously increasing piped water subscription and access. Our study provides an empirical understanding of how regulated price changes impact access and welfare when users can opt for an unregulated substitute.

Furthermore, one of the most significant operational difficulties encountered by water policymakers in designing demand-side management programs is a lack of adequate information to determine how supply-oriented policies would be affected. We recommend a strategy to bridge this gap by providing evidence for increased piped water use due to implementing a counterfactual tariff rebalancing scenario. Our results suggest that the rebalancing method estimated in this paper could assist water utilities in cost recovery while nudging users to minimise potential impacts of the rebalancing on their water bills by reducing the volume of use. Furthermore, the increased use of piped water by farming households due to tariff rebalancing also has a direct implication for lowering the rate of domestic groundwater exploitation.