ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Vol 8, Issue 12, December 2021

Assessment of the Applications of Economic Instruments for Improving Water Use Efficiency in Domestic Sector

[1]S. Ashwin Ram and [2]Zareena Begum Irfan

[1]Research Scholar, Madras School of Economics, Gandhi Mandapam Road, Chennai 600025, Tamil Nadu, India
[2]Associate Professor, Madras School of Economics, Gandhi Mandapam Road, Chennai 600025, Tamil Nadu, India
ashwinram@mse.ac.in

Abstract— Water is an essential and exhaustible natural resource that is fast depleting due rapid population growth and climate change. There is a growing consensus among global development community that water security is increasingly becoming one of the biggest development and environmental challenge of the century next to climate change. Predominant effort towards the supply and allocation of water resource resulted in inefficient water usage across different sectors leading to water scarcity. The Dublin statement in 1992 recognized water should be treated as an economic good among its competing uses. Since then several countries across the globe started to experiment with the applications of economic instruments to address water security. This paper provides an exhaustive review of literature highlighting some critical research gap on the applications of economic instruments in water sector aimed at improving water use efficiency in domestic sector.

Index Terms—Water security, Water scarcity, Economic Instruments, Water Demand Management, Water Use Efficiency, Water Pricing

I. INTRODUCTION

There is a growing consensus among global development community that water security is increasingly becoming one of the biggest development and environmental challenge of the century which requires immediate attention (WEF, 2015). Water is an integral part of the ecosystem which enables both economic and non-economic activities to flourish. There are several estimates and forecasts depicting a gloomy future that represents fast depletion of freshwater and its availability will become very limited making it difficult to meet even the basic human needs for survival (IPCC, 2014). Many countries across the globe including both developed and developing countries are already facing severe water shortages accompanied by prolonged periods of drought and are unable to meet their growing water needs. A majority of the Asian countries rank high among water stress indicators and rankings (WRI, 2015) [1–5].

Water is one of the primary inputs in agriculture and industrial sectors. It is also being increasingly used in the energy sector for electricity generation. Water is thus a finite and exhaustible resource which has competing uses among different users. Globally, agriculture is the biggest consumer of water which accounts for over 70 percent of the world's freshwater consumption followed by industry at 20 percent and domestic sector at 10 percent (UNESCO, 2016). Though water holds such significance, people often fail to realize and acknowledge the true value of water.

The economic, social and environmental cost in expanding and providing water supply infrastructure is actually huge. Expanding water delivery networks often requires massive amount of expenditures and technical expertise. This is particularly a serious challenge for LDCs where governments are faced with both financial and technical constraints. In the coming decades, population growth and climate change is further expected to exacerbate the problem leading to demand far exceeding supply (UNDP, 2016). Because of these reasons among others, of late there is an increasing shift in focus from supply to water demand management.

Though applications of Economic Instruments (EIs) have gained prominence in addressing various environment challenges for instance in climate change and energy policies, its applications in water sector continues to be limited. This is because water presents special challenges for economic analysis including measuring benefits and costs and establishing appropriate institutional arrangements (Scheierling, 2014). Water has some unique physical, economic, social, political and cultural characteristics which make it challenging to establish EIs. Determining the economic value of water is often difficult as people are generally against the notion of pricing water resource and hence is often considered as a low valued commodity. It is essentially because of these unique characteristics of water, establishing EIs to manage water becomes extremely challenging.

As a result of inefficient water use leading to scarcity of water, the Dublin statement 1992, regarded water should be treated as both a public good and as an economic good among its competing uses and economics started to play an important role in water management. Since then there is a growing body of literature on the applications of EIs in water management. These studies have attempted to understand both quality and quantity aspects of water security. Research and literature in this field is sector and region specific. There is also a stark difference in the use of EIs across the developed and developing regions.

In this context, this paper provides an exhaustive review of literature and highlights the findings of certain important studies on water demand management in domestic sector. Though declining quantity and deteriorating quality of water are the two major challenges of water security we particularly focus on studies that deal with the applications of EIs such as price, tax and subsidies to improve Water Use Efficiency (WUE) and conservation in residential sector [6].

2. Residential sector experiences with the applications of EIs

The following section discusses and highlights some of the important outcomes of EIs. The table included provides a brief summary of the country case studies on water pricing effects in residential sector. The papers selected for the present study was from 1991 to 2018, a timeline depicting key policy developments in water sector.

An ever growing population and rising temperature is increasing the domestic water demand. Countries like South Africa, Bangladesh, India and China are prone to extreme weather events such as drought and flood which affects the demand for and supply of water resource. Due to rapid urbanization there has been increase in migration from rural to urban areas since the beginning of the century. Large cities like Cape Town, Beijing, Delhi and Mumbai by themselves are struggling with declining water levels and increasing population [13]. Subsequently, the population growth in cities will put further stress on water resource. It is expected that the global urban population will increase from present 7 billion to 9 billion by 2050.

Though the global share of domestic water demand is less than that of agriculture and industrial sectors, residential water use was the first to be priced. USA has been charging municipal water since 1950s (Rogers *et.al,* 2002). Since the beginning of the 1990s most of the OECD counties started to make changes in water pricing strategies to curb inefficient water use behavior in residential sector.

While countries like Australia, California, Singapore and Israel have made significant developments in water sector and have made notable strides in water management, several other countries like India and China lag behind resulting in mismanagement of water resources. It is expected that the population of India will surpass that of China by 2022, becoming the most populous nation of the world. In this context, none of the cities in India provide 24x7 water services [14]. Lack of access to adequate and reliable water supply has also led to serious groundwater depletion with India being the largest consumer of groundwater in the world.

Regarding municipal water demand there is wide variations in the use of water across different countries and household groups. Water pricing have serious socioeconomic implications and it is evident that generally poor households pay a lot more to access water services than the rich households (Table 1) [7]**.** Naturally, increase in water prices affects the poor more adversely and this is particularly a serious policy concern in LDCs. Also Subsidies given to water in low income countries are inefficient putting additional burden on the government deficit [8–12]. Subsidies in these regions are not well targeted as a result the rich enjoy benefits leaving poor households vulnerable to water scarcity (Blanc, 2007). Therefore it is important to understand the welfare impacts of water pricing and subsidies among different income groups.

In past, Australia and California has witnessed a prolonged period of drought. They were able to efficiently manage and reduce water demand through appropriate pricing. Though pricing water has a greater impact in consumption reduction, many countries across the world, including the developed countries still continue rationing of water as a measure to reduce demand and consider pricing only as a second best alternative.

Grafton and Ward (2007) assessed the effectiveness of water pricing in comparison to rationing and its implications on household welfare. In response to the 10 year period drought, Australian water utilities introduced mandatory restrictions. They argue that rationing is not economically efficient and result in substantial welfare losses. When water is priced according to its highest value, consumer surplus is maximized and deadweight loss is minimized. They suggest volumetric pricing and removal of mandatory restrictions. To address equity concerns, higher prices can be transferred to low income households as lump sum payments through zero fixed charges. Appropriate water pricing have huge welfare gains than conventional water rationing. Olmstead and Stavins (2009) also support pricing water as efficient and cost effective compared to prescriptive regulations. Pricing is easier to monitor and enforcement than rationing.

On the other hand, Wichman *et.al* (2016) using household level panel data of water consumption studied the impacts of price and restrictions on household water demand in North Carolina. They find that higher income households are less sensitive to changes in price and price increase had adverse affects on low income households. While voluntary and mandatory restrictions had uniform reductions in water consumption across all income groups. In order to have the same reduction through pricing as under restrictions, they estimated that price has to be raised substantially which increases the average consumers monthly bill by 34 to 52 percent. They conclude mandatory restriction to be politically feasible and an effective tool to reduce demand across heterogeneous household group [15].

There are different pricing strategies to reduce household water demand but the most common is the IBT. Nauges and Whittington (2016) attempted to evaluate alternative municipal tariffs in achieving the three basic criteria of pricing viz; financial sustainability, social equity and economic efficiency. A modeling framework was developed to understand the effectiveness of uniform volumetric pricing and IBT to a hypothetical community. IBT serves to be regressive and fails to achieve neither of three goals. IBTs perform poorly in terms of targeting subsidies to the low income households. Boland and Whittington (1997) had also arrived at similar conclusions and recommend uniform pricing with rebates to promote greater incentive for conservation. Such a pricing mechanism with rebates helps in achieving efficiency and equity [16–20].

Table 1. Summary of Case Studies on Water Pricing in Domestic Sector

Author/Year	*Country*	*Pricing Strategy*	*Pricing Outcome*	*Key Policy Proposition*
Hoglund (1999)	Sweden	Water tax	• Water tax has greater impact on government revenue generation • It has negligible impact on consumption • Consumption is inelastic to income and price	• Water should be priced equal to its marginal cost • Increase awareness on reducing water consumption and bill • Important to design a water tax that does not hurt the poor
Arbues and Villanua (2006)	Spain	Tiered Pricing and average cost pricing	• Consumption is less sensitive to changes in price • Low average price does not encourage households to switch to water saving devices	• Average price is less efficient in terms of efficiency and equity • Shift to volumetric and marginal cost pricing seems more relevant to reduce demand
Ruijs *et.al* (2007)	Brazil	Marginal cost Pricing, Average cost Pricing and Block Rate Tariff	• Block rate tariff structure affects the poor than the rich • Demand is inelastic to price change • Block rate structure results in unintended welfare loss among lowest income quintile	• Progressive price system will result in equalized income distribution • Trade-off between efficiency and revenue generation • Focus on promoting water saving technologies
Rinaudo *et.al* (2012)	France	Increasing Block Tariff and Volumetric Pricing	• IBTs better serves as a redistributive tool • Large households reduce consumption under VP • Pricing does not affect indoor water use but highly influence outdoor water use	• Consider seasonal water pricing • Provide incentives to use water recycling technologies • Encourage households to use water saving devices • Designing an optimal pricing to achieve efficiency and equity is difficult

Willis *et.al* (2013)	Australia	Increasing Block Tariff	• Block rate structure hurts the low income household • Huge cost implies significant price differentials for urban and rural areas • Large households are averse to IBT • IBT has a detrimental social cost but positive environmental outcome	• Improve awareness on alternative pricing strategies to both consumers and utility managers • Important to understand and price water use in industry and commercial sector • A pro poor IBT can achieve equity but reduces utility revenues • Pricing should aim at full cost recovery than reducing consumption
Renzetti *et.al* (2014)	Canada	Increasing Block Tariff and across the board price increase	• Under across the board price system the elasticity is constant • Water use is inelastic to increase in price and income • Prices does not affect consumption of high income households but reduces water use among low income households	• IBT is generally considered to be regressive resulting in inefficient water use and inequality • Develop more robust methodologies to estimate price impacts on water demand • Design pricing strategy that minimize the aggregate welfare loss
Senante and Donoso (2016)	USA	Increasing Block Tariff and scarcity pricing	• Scarcity pricing reflects the environmental cost and reduces water demand during drought • IBT achieves equity but not WUE • Heavily subsidizing the poor results in water use inefficiency	• Designing a price structure that achieves economic efficiency, social equity and environmental sustainability is complex • Pricing should vary and cater to each region based on the socio economic and environmental factors
Tortella *et.al* (2017)	Calvia	Water and Sanitation Fee	• Failed to reduce water consumption • Water use varies across different	• Design a progressive block pricing structure that penalize heavy water users

			housing typologies resulting in inequitable use • Consumption is inelastic to price and income	• Fair prices are to be designed based on the housing typologies • Focus on income effect of the price reforms
Saidi (2017)	Yemen	Increasing Block Pricing, Uniform Price with Rebate and Uniform Price with Discount	• IBTs are pro poor but does not cover the O&M cost • IBTs results in inefficient use of water at first block by non poor households • The rich benefits from IBTs and associated subsidies • Cross subsidies benefits does not reach poor	• IBTs are regressive and uniform pricing best achieves efficiency and equity • Uniform pricing with rebate and discount incentivses consumers to use less water • Uniform pricing minimizes implementation and administration cost
Ahmad *et.al* (2017)	Pakistan	Fixed water tariff	• Price have limited impact on water demand • Demand is inelastic to changes in price and income • Pricing of alternative water sources does affect water use behavior	• Price is not a major factor influencing demand • Optimal tariff structure should consider demographic and socio economic characteristics • Promote other non price policy options

Source: Compiled by authors

Chan (2012) also note that IBT does not account for household size as a result benefits the rich households with few members compared to poor households with large members. As an alternative, he advocates for a two part tariff that recovers the cost of providing the services through a fixed charge and a variable charge that equals the marginal cost of additional water being consumed. Similarly, Sibly and Tooth (2014) also highlight the negative consequences of the IBT and point to the same conclusions in achieving efficiency and equity goals [21].

In our understanding from the literature review, rationing of water is inefficient and also inequitable. The very fact that a fixed amount of water supplied to all the households irrespective of size and highest value does not make economic sense. Moreover, rationing as a policy measure, results in overexploitation of alternative water sources. This is mostly the case in India, South Africa and other LDCs. This has also led to selling of water in the informal economy at exorbitantly very high price hurting the poor who lack access to the piped water supply (World Bank, 2010).

Water being an intricate good and because of political reasons, it is often priced below the marginal cost in most of the countries. Such poorly designed water tariffs fails to send strong signals to consumers resulting in inefficient use. While many out rightly reject pricing water for reasons such as that it hurts the poor, they fail to realize that it is the same poor and vulnerable households who also suffer from inadequate and unreliable water supply. In countries like India and Bangladesh, access to clean drinking water is still a distant dream to the poor. Hence pricing water is not just important to promote conservation but also to invest in recycling and water treatment technologies so as to provide quality water services to millions of people who lack this basic need [22].

Water consumption by the household in most cases is inelastic to changes in price and income. This does not mean that prices are ineffective in reducing demand. A pro poor and optimal tariffs have the potential to reduce demand but often the design of such tariff is complex and involves significant implementation cost [23]. In most cases, price elasticity of household water demand vary between -0.15 to -0.85 and that of income elasticity vary between +0.30 to

+0.65 (Arbues and Villanua, 2006; Ruijs *et.al*, 2008). Hence, as expected water use is negatively correlated to increase in price and positively with income.

In order to allow pricing as an effective tool to reduce demand and promote conservation, increasing focus should be given to the design of pro poor optimal water tariffs catering to the local needs and environmental factors. Seasonal and scarcity water pricing is one such pricing strategy that could strongly reduce demand with absolutely minimum welfare losses (Rinaudo *et.al* 2012; Senante and Donoso, 2016). Water pricing mechanism is complex and has conflicting goals. In reality, it is practically impossible to achieve all the three basic criteria of water pricing viz; financial sustainability, economic efficiency and social equity simultaneously. The primary aim of pricing water should be to achieve economic efficiency and recover the full cost of delivery so as to invest the generated revenues to expand the water supply infrastructure and provide universal access. The latter goal of social equity can be addressed through other policy measures such as targeted subsidies, lump sum payments and keeping the rate of lowest lifeline block at very minimum.

II. CONCLUSION

The authors have attempted to assess the applications of EIs and its impacts on water conservation in domestic sector. Water pricing is a controversial issue and is often subjected to widespread criticism across policy circles. With growing water scarcity and dwindling water supply there is an urgent need to consider and formulate effective pricing strategies primarily for the residential and industrial sector. Pricing water for agriculture sector in LDCs is more complicated and tend to have adverse welfare impacts on rural poor.

When formulating water pricing policies it is important to consider and assess the governance and institutional framework of water sector so as to effectively implement water pricing strategies. In order for the market to work efficiently in determining the price it is important to establish well defined property rights. Trading and allocation of scarce water resources through market mechanisms will result as failure if there is no proper regulatory and institutional framework in place. Therefore, a careful assessment of governance and institutional linkages, the distributional and welfare effects of various price and non-price policy options, involvement of all the stakeholders including the end users are important to effectively formulate and implement water pricing policies to improve WUE across sectors.

There is still some gap and ambiguity in the determinants of water pricing. Designing optimal water tariffs is really challenging and complex and it is imperative to consider economic, social, physical and environmental factors. While some developed countries acknowledge these factors while formulating and revising water tariffs, the design of tariffs in most of the LDCs is largely arbitrary and lack concrete economic analysis. One such important factor that fails to be recognized while formulating tariffs is the water quality.

Finally, the assessment of literature has displayed a highly skewed application of EIs across the sectors. The primary aim of water pricing in agriculture and residential sector is to reduce water use inefficiency while EIs in industries largely aim at reducing pollution. We would like to highlight this critical policy gap and hope that the future course of research moves in this direction to address this gap.

Acknowledgement:

The authors are grateful for their parent institute which provided them with the financial support and infrastructural benefit for conducting the research work. The present research study was conducted using the fund provided by the "Dr. A.C. Muthiah and Dr. Devaki Muthiah Research Fellowship" awarded by the host institute to the corresponding author for his doctoral research work.

REFERENCES

[1] Ahamad, S., Ali, H.S., Mirza, M.U and Lotia, H., (2017). The Limits of Water Pricing in Developing Countries Metropolis: Empirical Lessons from an Industrial City of Pakistan. Water, 9 (7), 533-551

[2] Arbués, F. and Villanúa, I. (2006). Potential for Pricing Policies in Water Resources Mangement: Estimation of Urban Residential Water demand in Zaragoza, Spain. Urban Studies, 43(13), 2421-2442

[3] Boland, J.J., and Whittington, D. (1997). Water Tariff Design in Developing Countries: Disadvantages of IBTs and Advantages of Uniform Price with Rebate Designs. John Hopkins University Working Paper.

[4] Chan, N.W.W. (2012). Urban Water Pricing: Equity and Affordability. Australia National University, Global Water Forum, Discussion paper 1209

[5] Grafton, R.Q., and Ward, M. (2007). Prices Versus Rationing: Marshallian Surplus and Mandatory Water Restrictions. Australian National University, Crawford School of Economics and Government, Working Paper, 07-05

[6] Hoglund, L. (1999). Household demand for water in Sweden with implications of a potential tax on water use. Water Resources Research, 35(12), 3853-3863

[7] Intergovernmental Panel for Climate Change, 2014. Climate Change 2014: Impacts, Adaptation and Vulnerability. Part A: Global and Sectoral Aspects. Chapter 3, Freshwater Resources. Contribution of working group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 229-269 Retrieved fromhttps://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap3_FINAL.pdf

[8] Nauges, C., and Whttington, D. (2016). Evaluating the Performance of Alternative Water Tariff Designs: Quantifying the Tradeoffs between Equity, Efficiency and Cost Recovery. World Development, 91, 125-143

[9] Olmstead, S.M., and Stavins, R.N. (2009). Comparing Price and Non Price Approaches to Urban Water Conservation. Water Resources Research, 45(4), W04301

[10] Renzetti, S., Dupont, P.D., and Chitsinde, T. (2015). An empirical examination of distributional impacts of water pricing reforms. Utilities Policy, 34, 63-69

[11] Rinaudo, J.D., Neverre, N., and Montginoul, M., (2012). Simulating the Impact of Residential Water Demand: A Southern France Case Study. Water Resource Management, 26(7), 2057-2068

[12] Rogers, P., De Silva, R., and Bhatia, R. (2002). Water is an Economic Good. How to use Prices to Promote Equity, Efficiency and Sustainability. Water Policy, 4, 1-17

[13] Ruijs, A., Zimmermann, A., and Van den Berg, M. (2007). Demand and distributional effects of water pricing policies. Ecological Economics, 66 (2),(3), 506-516

[14] Saidi, M.A. (2017). Urban water pricing in Yemen: a comparison of increasing block tariffs to other pricing schemes. Water International, 42(3), 1941-1707

[15] Scheierling, S.M. (2014). Why water presents special challenges: a brief rationale for water resource economics. World Bank Water Blog. http://blogs.worldbank.org/water/why-water-presents-special-challenges-brief-rationale-water-resource-economics

[16] Senante, M.M., and Donoso, G. (2016). Water scarcity and affordability in urban water pricing: A case study of Chile. Utilities Policy, 43(A), 1-10

[17] Sibly, H., and Tooth, R. (2013). The consequences of pricing increasing block tariffs to price urban water. The Australian Journal of Agricultural and Resource Economics, 58(2), 223-243

[18] Tortella, B.D., Garcia, C., Nilsson, W., and Tirado, D. (2017). Analysis of Water Tariff Reform on Water Consumption in Different Housing Typologies in Calvia (Mollorca). Water, 9(6), 425

[19] United Nations Educational Scientific and Cultural Organization, (2016). United Nations Word Water Development Report 2016, Water and Jobs: Facts and Figures. Retrieved from http://unesdoc.unesco.org/images/0024/002440/244041e.pdf

[20] United Nations Development Programme Support to the Implementation of Sustainable Development Goal 6, Sustainable Management of Water and Sanitation. (2016) Retrieved fromhttp://www.undp.org/content/dam/undp/library/Sustainable%20Development/6_Water_Jan15_digital.pdf

[21] Wichman, C.J., Taylor, L.O., and Von Haefen, R.G. (2016). Conservation Policies: Who responds to price and who responds to prescription? Journal of Environmental Economics and Management, 79, 114-134

[22] Willis, E., Pearce, M., Mamerow, L., Jorgensen, B., and Martin, J. (2013). Perceptions of Water Pricing during a Drought: A Case Study from South Australia. Water, 5(1), 197-223

[23] World Economic Forum, (2015). Global Risks 2015. Retrieved from http://www3.weforum.org/docs/WEF_Global_Risks_2015_Report15.pdf.