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**The Challenge of  
Improving Water and  
Sanitation Services in  
Less Developed Countries**

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# The Challenge of Improving Water and Sanitation Services in Less Developed Countries

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## The Challenge of Improving Water and Sanitation Services in Less Developed Countries

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### Abstract

This paper argues that there are many challenges to designing and implementing water and sanitation interventions that actually deliver economic benefits to the households in developing countries. Perhaps most critical to successful water and sanitation investments is to discover and implement forms of service and payment mechanisms that will render the improvements worthwhile for those who must pay for them. In this paper, we argue that, in many cases, the conventional network technologies of water supply and sanitation will fail this test, and that poor households need alternative, non-network technologies. However, it will not necessarily be the case that specific non-network

improved water supply and/or sanitation technologies will always be seen as worthwhile by those who must pay for them. We argue that there is no easy panacea to resolve this situation. For any intervention, the outcome is likely to be context-dependent. An intervention that works well in one locality may fail miserably in another. For any given technology, the outcome will depend on economic and social conditions, including how it is implemented, by whom, and often on the extent to which complementary behavioral, institutional and organizational changes also occur. For this reason, we warn against excessive generalization: one cannot, in our view, say that one intervention yields a rate of return of  $x\%$  while another yields a return of  $y\%$ , because the economic returns are likely to vary with local circumstances. More important is to identify the circumstances under which an intervention is more or less likely to succeed. Also for this reason, when we analyze a few selected water and sanitation interventions, we employ a probabilistic rather than a deterministic analysis to emphasize that real world outcomes are likely to vary substantially.

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# 1

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## Introduction

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The 1980s were designated the International Water and Sanitation Decade, and the international community committed itself to ensuring that everyone in the world would have access to at least basic water and sanitation services by 1990. This target was not met. While hundreds of millions did receive access to new services, at the end of the decade well over 1.1 billion people still lacked improved water supplies, and more than 2.7 billion lacked sanitation services. By the year 2000, although another billion people had obtained access to improved water and sanitation services, population growth had left the number of those still unserved at roughly the same absolute level. In 2002, at the Johannesburg World Summit on Sustainable Development, the global community made a new commitment to a set of Millennium Development Goals (MDGs), including environmental sustainability. One of the targets under the environmental sustainability MDG is to cut by half the proportion of people in the world living without access to water and sanitation by 2015.

While we certainly hope that the global target for water and sanitation will be met this time, there are grounds for concern. Some important physical and economic features of water supply and

## 2 Introduction

sanitation make it inherently difficult to achieve broad-scale goals such as those of the Water and Sanitation Decade and the MDG water and sanitation target — more difficult than for other MDG targets such as providing access to affordable essential drugs or communication and information technology. These features of water and sanitation have not been well recognized in the existing economics literature or in the policy literature.

Several factors are involved, but a key issue contributing to the difficulty in achieving improved access has been a fundamental misunderstanding of the economics of investment in the water and sanitation sector. The core problem is to ensure that the benefits of *improved* water and sanitation access will be large enough to cover or possibly exceed the costs for those who will bear them: yet surprisingly often, this need is overlooked. There are two aspects to this statement. One is distributional: those who pay the costs are not necessarily those who will receive the benefits. An additional complication is that large-scale water supply infrastructure investments often have multiple goals (e.g., flood and drought protection, hydropower generation, navigation, fisheries, and recreation), which further exacerbates the challenge of designing appropriate payment mechanisms for services delivered to a diverse set of beneficiaries. The second issue is perhaps more surprising but, we believe, no less real. Even considering water supply alone (for which externalities are less significant than for sanitation, as most of the benefits accrue directly to those who consume the water), the incremental benefits of improved access to water and sanitation network infrastructure may simply not be large enough to cover the costs of improved access.

This happens for two reasons. First, for the network infrastructure technologies presently available, the cost of improved access to water is typically large. These high costs are due to the capital intensity of the investments associated with improved water supply, although the longevity of the capital means that it will provide benefits for many years into the future. Second, the incremental benefit can be small. This statement too may seem surprising — after all, we know that water is essential for life. Herein lies the paradox: precisely because water is

essential for life, everybody does manage to have some sort of access to water, however inadequate and cumbersome. It is for this reason that the *incremental* benefit from *improved* access to water may not be so large. Contrast, for example, water supply with electrification. Because electricity is *not* essential for life, by no means everybody has access to electricity in their homes. Without access in the home, there is no affordable or convenient way to use electricity because there is no way to carry electricity home. Therefore, when it becomes available, access to in-home electricity may be *perceived* as a greater boon than access to in-home piped water and sewerage. Consequently, users' willingness to pay for access to electricity may be greater than their willingness to pay for access to piped water and sewerage, even though water is essential for life and electricity is not.

The key to successful water and sanitation investments is to discover forms of service and payment mechanisms that will render the improvements worthwhile for those who must pay for them. In this paper, we argue that, in many cases, the conventional network technologies of water supply and sanitation will fail this test, and that poor households need alternative, non-network technologies. However, for some of these technologies, too, it will not necessarily be the case that improved water supply and/or sanitation will always be seen as worthwhile by those who must pay for it.

We argue that there is no easy panacea to resolve this situation. For any intervention, the outcome is likely to be context-dependent. An intervention that works well in one locality may fail miserably in another. While it may be the same physical technology that is being applied, the outcome depends on economic and social conditions, including how it is implemented, by whom, and often on the extent to which complementary changes — in behavior, in institutions, and sometimes in economic organization — also occur. For this reason, we warn against excessive generalization: one cannot, in our view, say that one intervention yields a rate of return of  $x\%$  while another yields a return of  $y\%$ , because the economic returns are likely to vary with local circumstances. More important is to identify the circumstances under which an intervention is more or less likely to succeed. Also for this reason,

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when we analyze a few selected water and sanitation interventions, we employ a probabilistic rather than a deterministic analysis to emphasize that real world outcomes are likely to vary substantially.

This paper is organized in three parts. Section 2 focuses on conventional network technologies for water supply and sanitation. It opens with some general observations that are central to an understanding of the economics of municipal water and sanitation network infrastructure. We proceed from there to a focus on the costs of providing such infrastructure services, and then summarize some empirical evidence on the economic benefits derived from them. We then discuss the economic costs and the benefits involved and note the limitations of the analytical approach used in most such applications. Section 2 closes with some observations regarding the implications of these results.

Section 3 presents the probabilistic analytical approach that we use to analyze investments in the water and sanitation sector. We then illustrate this approach for the case of network infrastructure services. In Section 4 we deploy this analytical framework to examine the costs and benefits of three specific low-cost, non-network water and sanitation interventions (deep boreholes with public hand pumps, total community-led sanitation campaigns, and biosand filters) and one high-cost intervention (large multipurpose dams in Africa).

## References

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- Alberini, A. and A. Chiabai (2007), 'Urban environmental health and sensitive populations: How much are the Italians willing to pay to reduce their risks?'. *Regional Science and Urban Economics* **37**, 239–258.
- Allan, S. (2003), *The WaterAid Bangladesh/VERC 100% Sanitation Approach; Cost, Motivation and Subsidy*. London: London School of Hygiene and Tropical Medicine.
- Altaf, A., D. Whittington, V. K. Smith, and H. Jamal (1993), 'Rethinking rural water supply policy in the Punjab, Pakistan'. *Water Resources Research* **29**(7), 1943–1954.
- Arnold, B. F. and J. M. J. Colford (2007), 'Treating water with chlorine at point-of-use to improve water quality and reduce child diarrhea in developing countries: A systematic review and meta-analysis'. *American Journal of Tropical Medical Hygiene* **76**(2), 354–364.
- Bahl, R., A. Sinha, C. Poulos, D. Whittington, and S. Sazawal et al. (2004), 'Costs of illness due to typhoid fever in an Indian urban slum community: Implications for vaccination policy'. *Journal of Health Population and Nutrition* **22**(3), 304–310.
- Bhatia, R., M. Scatista, R. Cestti, and R. P. S. Malik (2005), *Indirect Economic Impacts of Dams: Methodological Issues and Summary*

- Results of Case Studies in Brazil, India and Egypt*. Washington: The World Bank.
- Bhattacharya, S., A. Alberini, and M. L. Cropper (2007), 'The value of mortality risk reductions in Delhi, India'. *Journal of Risk and Uncertainty* **34**, 21–47.
- Block, P. (2006), 'Integrated management of the blue Nile basin in Ethiopia: Precipitation forecast, hydropower, and irrigation modeling'. PhD Dissertation. Department of Civil, Environmental and Architectural Engineering. Boulder, Colorado, University of Colorado: 160 p.
- Boardman, A. E., D. Greenberg, A. Vining, and D. Weimer (2005), *Cost-benefit Analysis: Concepts and Practice*. Upper Saddle River, NJ: Prentice Hall.
- Bockstael, N. E. and K. E. McConnell (2007), *Environmental and Resource Valuation with Revealed Preferences: A Theoretical Guide to Empirical Models*. Dordrecht, The Netherlands: Springer.
- Briscoe, J. and D. De Ferranti (1988), *Water for Rural Communities: Helping People Help Themselves*. Washington, D.C.: The World Bank.
- Briscoe, J., P. F. di Castro, C. Griffin, J. North, and O. Olsen (1990), 'Toward equitable and sustainable rural water supplies: A contingent valuation study in Brazil'. *The World Bank Economic Review* **4**(2), 115–34.
- Brown, J. (2007), 'Effectiveness of ceramic filtration for drinking water of treatment in Cambodia'. PhD Dissertation. Department of Environmental Sciences and Engineering. Chapel Hill, University of North Carolina at Chapel Hill: 275 p.
- Cairncross, A. M. (1990), 'Health impacts in developing countries: New evidence and new prospects'. *Journal of the Institute of Water and Environmental Management* **4**(6), 571–577.
- Carson, R., N. E. Flores, and N. F. Meade (2001), 'Contingent Valuation: Controversies and Evidence'. *Environmental and Resource Economics* **19**, 173–210.
- Carson, R. T., N. E. Flores, K. M. Martin, and J. L. Wright (1996), 'Contingent valuation and revealed preference methodologies:

- Comparing the estimates for quasi-public goods'. *Land Economics* **72**(1), 80–99.
- CAWST (2007), *Biosand Filter Description*. Calgary, Canada: Centre for Affordable Water and Sanitation Technology.
- Cernea, M. (1999), *The Economics of Involuntary Resettlement: Questions and Challenges*. Washington, D.C.: The World Bank.
- Choe, K., D. Whittington, and D. T. Lauria (1996), 'The economic benefits of surface water quality improvements in developing countries: A case study of Davao, Philippines'. *Land Economics* **72**(4), 519–537.
- Churchill, A., D. De Ferranti, R. Roche, C. Tager, and A. Walters et al. (1987), *Rural Water Supply and Sanitation: Time for a Change*. World Bank Discussion Paper Series. Washington, D.C.: The World Bank.
- Clasen, T., I. Roberts, T. Rabie, W. Schmidt, and S. Cairncross (2006), 'Interventions to improve water quality for preventing diarrhea (Cochrane Review)'. In: *The Cochrane Library*. Issue 3, 2006. Oxford, UK.
- Clasen, T. F. and A. Bastable (2003), 'Faecal contamination of drinking water during collection and household storage: The need to extend protection to the point of use'. *Journal of Water and Health* **1**(3), 109–115.
- Cook, J., M. Jeuland, B. Maskery, D. Lauria, D. Sur, J. Clemens, and D. Whittington (2008), 'Re-visiting socially-optimal vaccine subsidies: An empirical application in Kolkata, India'. *Journal of Policy Analysis and Management*. Under review.
- Curtis, V. and S. Cairncross (2003), 'Effect of washing hands with soap on diarrhea risk in the community: A systematic review'. *The Lancet Infectious Diseases* **3**(5), 275–281.
- Cutler, D. and G. Miller (2005), 'The Role of Public Health Improvements in Health Advances: The 20th Century United States'. *Demography* **42**(1), 1–22.
- Davis, J. (2004), 'Corruption in public services delivery: Experience from South Asia's water and sanitation sector'. *World Development* **32**(1), 53–71.

- Davis, J., A. Kang, J. Vincent, and D. Whittington (2001), 'How important is improved water infrastructure to microenterprises? Evidence from Uganda'. *World Development* **29**(10), 1753–1767.
- Davis, J., H. Lukacs, M. Jeuland, A. Alvestegui, and B. Sotto et al. (2007), 'Sustaining the benefits of rural water supply investments: Experience from Cochabamba and Chuquisaca, Bolivia'. Submitted for publication.
- Dufo, E. and R. Pande (2007), 'Dams'. *Quarterly Journal of Economics* **122**(2), 601–646.
- Earwaker, P. (2006), *Evaluation of household BioSand Filters in Ethiopia*. Silsoe, UK: Department of Water Management, Cranfield University.
- Esrey, S. (1996), 'Water, waste, and well-being: A multicountry study'. *American Journal of Epidemiology* **43**(6), 608–623.
- Esrey, S. A., J. B. Potash, L. Roberts, and C. Schiff (1991), 'Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma'. *Bulletin of the World Health Organization* **69**, 609–621.
- Feacham, R. G., D. J. Bradley, H. Garelick, and D. D. Mara (1983), *Sanitation and disease: Health aspects of excreta and wastewater management*. Chichester, U.K.: John Wiley and Sons.
- Fewtrell, L., R. Kaufmann, D. Kay, W. Enanoria, and L. Haller et al. (2005), 'Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: A systematic review and meta-analysis'. *Lancet Infectious Diseases* **2005** **5**(1), 42–52.
- Grey, D. and C. Sadoff (2007), 'Sink or swim? Water security for growth and development'. *Water Policy* **2007** **9**(6), 545–571.
- Griffin, C., J. Briscoe, B. Singh, R. Ramasubban, and R. Bhatia (1995), 'Contingent valuation and actual behavior: Predicting connections to new water systems in the State of Kerala, India'. *World Bank Economic Review* **9**(3), 373–395.
- Hammitt, J. K. and J. Liu (2004), 'Effect of disease type and latency on the value of mortality risk'. *Journal of Risk and Uncertainty* **28**, 73–95.
- Hanemann, W. M. (2006), 'The economic conception of water'. In: P. P. Rogers, M. R. Llamas, and L. Martinez-Cortina (eds.): *Water*

- Crisis: Myth or Reality?* London and New York: Taylor and Francis, pp. 61–91.
- Hutton, G. and L. Haller (2004), *Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level*. Geneva: Water, Sanitation, and Health, Protection of the Human Environment, World Health Organization.
- IPCC (2007), *Climate Change 2007: Impacts, Adaptations and Vulnerability: Scientific-technical Analyses*. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge and New York: Cambridge University Press.
- Jalan, J. and M. Ravallion (2003), ‘Does piped water reduce diarrhea for children in rural India?’. *Journal of Econometrics* **112**(1), 153–173.
- Jamison, D., J. Breman, A. Measham, G. Alleyne, and M. Claeson et al. (2006), *Disease Control Priorities in Developing Countries*. New York: Oxford University Press.
- Johnston, R. (2006), ‘Is hypothetical bias universal? Validating contingent valuation responses using a binding public referendum’. *Journal of Environmental Economics and Management* **52**, 469–481.
- Kaiser, N., K. Liang, M. Maertens, and R. Snider (2002), *BioSand household water filter evaluation 2001: A comprehensive evaluation of the Samaritan’s Purse BioSand Filter (BSF) projects in Kenya, Mozambique, Cambodia, Vietnam, Honduras, and Nicaragua*. Calgary, Canada: Samaritan’s Purse.
- Kariuki, M. and J. Schwartz (2005), ‘Small-scale private service providers of water supply and electricity: A review of incidence, structure, pricing and operating characteristics’. World Bank Policy Research Working Paper 3727. The World Bank: Washington, DC.
- Komives, K., B. Akanbang, W. Wakeman, R. Thorsten, and B. Tuffuor et al. (2007), ‘Community management of rural water systems in Ghana: Post-construction support and water and sanitation committees in Brong Ahafo and Volta regions’. In: L. W. Mays (ed.): *Water Resources Sustainability*. McGraw-Hill. 2006.

- Komives, K., V. Foster, J. Halpern, and Q. Wodon (2005), *Water, Electricity, and the Poor: Who Benefits from Utility Subsidies?* Washington, D.C.: The World Bank.
- Komives, K., D. Whittington, and X. Wu (2003), 'Infrastructure coverage and the poor: A global perspective'. In: P. Brook and T. Irwin (eds.): *Infrastructure for Poor People: Public Policy for Private Provision*. Washington, D.C.: The World Bank Public-Private Infrastructure Advisory Facility, pp. 77–124.
- Kosek, M., C. Bern, and R. L. Guerrant (2003), 'The global burden of diarrheal disease, as estimated from studies published between 1992 and 2000'. *Bulletin of the World Health Organization* **81**(3), 197–204.
- Kremer, M., J. Leino, E. Miguel, and A. P. Zwane (2007), *Spring Cleaning: A Randomized Evaluation of Source Water Quality Improvement*. UC-Berkeley, Working Paper. <http://elsa.berkeley.edu>.
- Kremer, M., C. Null, E. Miguel, and A. P. Zwane (2008), *Trickle Down: Diffusion of Chlorine for Drinking Water Treatment in Kenya*. UC-Berkeley, Working Paper. <http://elsa.berkeley.edu>.
- Krupnick, A., S. Hoffman, B. Larsen, X. Peng, and C. Yuan et al. (2008), 'Willingness to pay for mortality risk reductions in Shanghai and Chongqing, China'. World Bank. (forthcoming).
- Lovei, L. and D. Whittington (1993), 'Rent-seeking in the water supply sector: A case study of Jakarta, Indonesia'. *Water Resources Research* **29**(7), 1965–1974.
- Mahmud, M. (2007), 'On the contingent valuation of mortality risk reduction in developing countries'. *Applied Economics* pp. 1–11.
- Maskery, B., Z. Islam, J. Deen, and D. Whittington (2008), 'An estimate of parents' value of statistical life for their children in rural Bangladesh'. Paper presented at the annual meetings of the European Association of Environmental and Resource Economists. June 27, 2008. Gothenburg, Sweden.
- McIntosh, A. (2003), *Asian Water Supplies Reaching the Urban Poor: A Guide and Sourcebook on Urban Water Supplies in Asia for Governments, Utilities, Consultants, Development Agencies, and Nongovernment Organizations*. Asian Development Bank and International Water Association.

- Mrozek, J. R. and L. O. Taylor (2002), 'What determines the value of life? A meta-analysis'. *Journal of Policy Analysis and Management* **21**(2), 253–70.
- Nauges, C. and C. van den Berg (2008a), 'The impact of sector reform on the supply and demand for water supply services in Moldova'. Working paper, Toulouse School of Economics (LERNA-INRA).
- Nauges, C. and C. van den Berg (2008b), 'Spatial heterogeneity in the cost structure of water and sanitation services: A cross-country comparison of conditions for scale economies'. Working paper, Toulouse School of Economics (LERNA-INRA).
- Pattanayak, S., J. L. Blitstein, J. C. Yang, K. L. Dickinson, S. R. Patil, C. Poulos, and K. M. Wendland (2007a), 'Promoting latrine use and improving child health: Design and baseline findings from a randomized evaluation of a community mobilization campaign in Bhadrak, Orissa'. RTI Working Paper 06\_05, Research Triangle Institute, NC.
- Pattanayak, S. K., K. L. Dickinson, J. C. Yang, S. R. Patil, and C. Poulos (2007b), 'Nature's call: Can social mobilization promote toilet use and improve welfare? Results from a field experiment in Orissa, India'. Working paper, Research Triangle Institute, NC.
- Pattanayak, S. K., C. J. Yang, D. Whittington, and K. C. B. Kumar (2005), 'Coping with unreliable public water supplies: Averting expenditures by households in Kathmandu, Nepal'. *Water Resources Research* **41**(2), W02012.
- Powers, T. (1978), 'Benefit–cost analysis of urban water projects'. *Water Supply and Management* **1**, 371–385.
- Powers, T. and C. A. Valencia (1980), *SIMOP Urban Water Model: Users' Manual: A Model for Economic Analysis of Potable Water Projects in Urban Areas*. Inter-American Development Bank Papers on Project Analysis, No. 5. Washington, D.C.: Inter-American Development Bank, Economic and Social Development Department, Country Studies Division, Project Methodology Unit.
- Priscoli, J. D. (2000), 'Water and civilization: Using history to reframe water policy debates and to build a new ecological realism'. *Water Policy* **1**(6), 623–636.

- Prokopy, L., R. Thorsten, A. Bakalian, and W. Wakeman (2007), 'Evaluating the role of post-construction support in sustaining drinking water projects: Evidence from Peru'. Submitted for publication.
- Russell, C., W. J. Vaughan, C. D. Clark, D. J. Rodriguez, and A. Darling (2001), *Investing in Water Quality: Measuring Benefits, Costs and Risk*. Washington, D.C.: Inter-American Development Bank.
- Samaritan's Purse (2007), *BioSand Water Filter: In Depth*. Calgary, Canada: Samaritan's Purse — Canada.
- Sannan, D. and S. G. Moulik (2007), *Community-led Total Sanitation in Rural Areas: An Approach that Works* (field note). New Delhi, India: Water and Sanitation Program — South Asia.
- Sara, J., A. Gross, and C. van den Berg (1996), *Rural Water Supply and Sanitation in Bolivia: From Pilot to National Program*. Washington D.C.: UNDP–World Bank Water and Sanitation Program.
- Sara, J. and T. Katz (1997), *Making Rural Water Supply Sustainable: Report on the Impact of Project Rules*. Washington D.C.: UNDP–World Bank Water and Sanitation Program.
- Stauber, C. E. (2007), 'The microbiological and health impact of the BioSand filter in the Dominican Republic: A randomized controlled trial in Bonao'. PhD Dissertation. Department of Environmental Sciences and Engineering. Chapel Hill, USA, University of North Carolina at Chapel Hill: 213 p.
- Therkildsen, O. (1988), *Watering White Elephants? Lessons from Donor-funded Planning and Implementation of Rural Water Supplies in Tanzania*. Uppsala: Centre for Development Research Publications, Scandinavian Institute of African Studies.
- Thorsten, R. (2007), *Predicting Sustainable Performance and Household Satisfaction of Community-oriented Rural Water Supply Projects: A Quantitative Evaluation of Evidence from Ghana and Peru*. Unpublished manuscript. Department of City and Regional Planning, UNC-CH, Chapel Hill.
- UNDP (2006), *Beyond Scarcity: Power, Poverty and the Global Water Crisis*. New York: United Nations Development Programme.
- UNEP (1998), *Sourcebook of Alternative Technologies for Freshwater Augmentation in Africa*. By J. Thornton. Nairobi, Kenya:

- International Environmental Technology Centre, United Nations Environment Program, 182 p.
- US Environmental Protection Agency (2000), *Guidelines for Preparing Economic Analyses*, EPA-R-00-003. Washington, D.C.
- VanDerslice, J. and J. Briscoe (1993), 'All coliforms are not created equal: A comparison of the effects of water source and in-house contamination on infantile diarrheal disease'. *Water Resources Research* **29**(7), 1983–1995.
- Vassandumrongdee, S. and S. Matsuoka (2005), 'Risk perceptions and value of a statistical life for air pollution and traffic accidents: Evidence from Bangkok, Thailand'. *Journal of Risk and Uncertainty* **30**(3), 261–287.
- Viscusi, W. K. and J. E. Aldy (2003), 'The value of a statistical life: A critical review of market estimates throughout the world'. *Journal of Risk and Uncertainty* **27**(1), 5–76.
- White, G., David Bradley, and A. White (1972), *Drawers of Water: Domestic Water Use in East Africa*. University of Chicago Press.
- Whittington, D., J. Briscoe, X. Mu, and B. Barron (1990a), 'Estimating the willingness to pay for water services in developing countries: A case study of the use of contingent valuation surveys in southern Haiti'. *Economic Development and Cultural Change* **38**(2), 293–311.
- Whittington, D., J. Davis, and E. McClelland (1998), 'Implementing a demand-driven approach to community water supply planning: A case study of Lugazi, Uganda'. *Water international* **23**(3), 134–145.
- Whittington, D., J. Davis, L. Prokopy, K. Komives, and R. Thorsten et al. (2007), 'How well is the demand-driven, community management model for rural water supply systems doing?'. Evidence from Bolivia, Peru, and Ghana. Submitted for publication.
- Whittington, D., D. T. Lauria, V. Prabhu, and J. Cook (2004), 'An economic reappraisal of the Melamchi water supply project, Kathmandu, Nepal'. *Portuguese Economic Journal* **3**(2), 157–178.
- Whittington, D., D. T. Lauria, A. M. Wright, K. Choe, and J. A. Hughes et al. (1993), 'Household demand for improved sanitation services in Kumasi, Ghana: A contingent valuation study'. *Water Resources Research* **29**(6), 1539–1560.

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- Whittington, D., X. Mu, and R. Roche (1990b), 'Calculating the value of time spent collecting water: Some Estimates for Ukunda, Kenya'. *World Development* **18**(2), 269–280.
- Whittington, D., M. Mujwahuzi, G. McMahon, and K. Choe (1988), *Willingness to Pay for Water in Newala District, Tanzania: Strategies for Cost Recovery*. WASH Field Report No. 246. Washington, D.C.: USAID Water and Sanitation for Health Project.
- Whittington, D., S. Pattanayak, J. C. Yang, and B. Kumar (2002), 'Household demand for improved piped water services in Kathmandu, Nepal'. *Water Policy* **4**(6), 531–556.
- Whittington, D., C. Suraratdecha, C. Poulos, M. Ainsworth, V. Prabhu, and V. Tangcharoensathien (2008), 'Household demand for preventive HIV/AIDS vaccines in Thailand: Do husbands' and wives' preferences differ?'. *Value in Health*. Forthcoming.
- Whittington, D. and V. Swarna (1994), *The Economic Appraisal of Potable Water Supply Projects*. Manila: Asian Development Bank.
- World Bank (2006), *Managing Water Resources to Maximize Sustainable Growth: Country Assistance Strategy for the Federal Democratic Republic of Ethiopia*. Washington, D.C.: The World Bank.
- World Commission on Dams (2000), *Dams and Development: A New Framework for Decision-making*. London: Earthscan Publications, Ltd.