

*The Economic Value of Moving Toward
a More Water Secure World*

By Dale Whittington, Claudia Sadoff and Maura Allaire

**Global Water Partnership
Technical Committee (TEC)**



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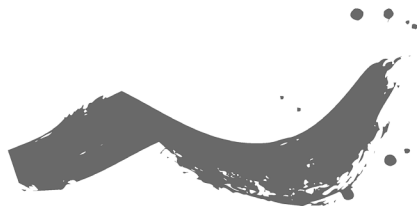
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FOREWORD

Recent global events, such as increasing food and energy prices, severe droughts, and floods, have heightened our concerns about water security. Water is not like other natural resources. It renews itself annually and moves through the hydrological cycle and across national boundaries. It has proved to be a difficult natural resource for States to understand and control. In a period when public financial resources are particularly limited, how do we prioritize investments in water security? Which aspects are most critical for growth? What are the most significant investments needed to increase water security? And how can economics inform policy-makers who must decide how to allocate resources to the management of water?

This paper explores these pressing issues and asks another, more fundamental question – what is the economic value of increased water security? In other words, how much is an improvement in water security worth? The authors say that if we are looking for a set of empirical estimates of the economic value of increased water security, we will be disappointed. They argue that aggregate, global estimates are not useful for guiding investment decisions for solving local water resources problems. What they do provide, however, is an excellent synthesis of current thinking about this complex issue and guidance about what should be done. They describe how States and individual households have very different views on the value of water security. They reason that there is no alternative but for the State to roll up its sleeves and do the hard analytical work required to understand complex hydrological systems, to determine the economic costs and benefits of specific policy interventions, and to make difficult decisions about the inevitable tradeoffs in water management and development.

I am grateful to the authors Dale Whittington and Claudia Sadoff, who are members of GWP's Technical Committee, for their stimulating and thought provoking paper. They present key, complex issues in a manner accessible to a broad set of stakeholders in and outside the water sector. I would like to acknowledge Maura Allaire who contributed significantly to this paper. Thank you also to the GWP Technical Committee for their invaluable comments and suggestions made during the draft stages.

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Dr Mohamed AIT KADI
Chair, GWP Technical Committee

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1. INTRODUCTION

This paper is an inquiry into the economic value of moving toward a more water secure world. Our intuition tells us that water is essential, that “water is life.” It tells us that water is fundamental to the biology of life, the geomorphology of the earth, and human health. It also tells us that water is an economic good, a social good, and an environmental good; that it is both a productive natural resource and a destructive natural hazard. Our intuition is often so strong about these insights that investments made to increase water security are not subjected to rigorous economic analysis.

Yet precisely because water is so central to life and livelihoods, because it is so complex in the way it is valued by society, and because it is used in so many ways in the economy, it is too complex to manage by intuition. Analysis is needed.

Grappling with the question, “What is the economic value of increased water security?” requires a careful analysis of the economic value of water across a wide range of uses – and hazards. Analysts must examine not only the costs and benefits of different infrastructure interventions, but also different water allocations to various users. The economic value of a unit of water varies widely across different water uses. A unit of water for drinking or industrial use generally has a much higher economic value than the same volume of water used to produce cereal crops. Moreover, different configurations of water use and infrastructure in a river basin can lead to different aggregate values, or system values, for the same quantity of water as it moves through a river system (Sadoff, Whittington, and Grey, 2003). System values, unlike individual user values, aggregate the economic value of water in all of its uses within a river basin or watershed. So a unit of water that is withdrawn and consumed in the headwaters of a basin is likely to produce a lower system value than the same unit of water that first passes through a series of hydropower plants and provides navigational or ecosystems benefits in critical reaches, and only then is withdrawn for consumptive use.

The concept of the economic value of any good or service (including water) rests on the notion of exchange – how much of something else an individual or household would trade in exchange for the good or service in question.

The economic notion of value is thus focused on understanding individuals' preferences for different "states of the world"—some in which an individual or household has specific goods and services and others in which the individual does not.

Everyone living today already has some access to water services (without access they could not survive) and hence some level of water security. Economically attractive investments in the water sector therefore result in *improved* water security. An important question for finance ministries and households themselves is – “How much is an improvement in water security worth (compared to other pressing needs)?” Or conversely – “What is it worth to reduce the risks associated with poorly managed water resource systems?” Developing a better understanding of the economic value of water security is important because the costs of water infrastructure are often high, and societies face many types of risks other than those related to poor water resources management.

One way for both States and households to conceptualize “water security” is as a future “state of the world” in which a multitude of water-related problems have been solved. In a water-secure world people do not die or lose their property or livelihoods from water-related diseases, floods, or droughts. Their jobs are not in jeopardy due to unreliable water supplies. They may enjoy recreational opportunities afforded by both man-made reservoirs and free-flowing streams, and the aesthetic and quality of life associated with plentiful, reliable piped water supplies in their homes and offices.

It is easy for both States and households to visualize a water-secure world because approximately a billion people in the industrialized world already have it – they live in a water-secure world now. This is not to say that all water-related risks have disappeared from high-income countries, but very few people in industrialized countries die from water-related diseases, floods, or droughts, and the economic costs of the risks that remain can be largely mitigated by insurance and other risk-spreading and risk-pooling mechanisms.

Nor is it hard for States or households to visualize a state of the world in which water-related risks are more significant in some people's lives. The bottom billion people in the world today continue to face the ever-present risk of water-related diseases like typhoid, cholera, and diarrhea. Unregulated rivers in many developing countries fail to provide irrigation water during

droughts and can cause flood deaths on a scale that is now only a distant memory to most citizens of industrialized countries.

People in both industrialized and less developed countries want improved water security to minimize the risks of water supply disruptions, water-related diseases, drought, and flooding, and they want reliable supplies to maximize the beneficial uses of water. But water-related risks are only one of many dimensions along which the lives of people in developing and industrialized countries differ, and it is an empirical question (open to analysis) as to how large water-related risks loom in the lives of people relative to other concerns.

States and households approach the challenge of valuing improvements in water security differently. To understand the economic value of improved water security, it is crucial to appreciate why the perspectives of the State and the household are different. Estimates of the economic value of water to different users suggest that solving water problems where supplies are scarce and unreliable should be simple and straightforward. Nowhere in the world would the reallocation of limited water supplies from low-value to high-value uses seem to require large amounts of money. High-value water users should be able to compensate low-value users, and everyone should be able to be better off. For economists, if the economic value of water in some uses is low (e.g., in agriculture), this is *prima fascia* evidence that the magnitude of the agreements needed to resolve a water scarcity problem is quite small.¹

But this is not how States typically see the value of water. States behave as if water is much more valuable than economists think it is. States strive to ensure their survival and seek security from systemic risks wherever they arise, whether from military, political, public health, or natural resource threats (including threats to water supply). States seek power to enhance their security, and may deploy water assets strategically to advance foreign policy interests. Economic notions of value based on exchange and tradeoffs do not fit easily into the calculations of States about their national security and survival.

¹ For example, Fisher et al (2005) developed an economic optimization model of water resources utilization in Israel and the West Bank. Their analysis showed that from an economic perspective, the magnitude of the regional water problem was small and manageable. If a water market were allowed to work its magic, the solution to the regional water problem would probably cost less than the value of a few small information technology (IT) firms in the high-tech Israeli economy.

Households seek improved water security to minimize water-related risks that threaten their health and livelihoods. They also want “food security” to minimize the risks of famine. They want “national security” to reduce the risk of war and conflicts, and “financial security” to minimize the risks of unemployment and theft. People want “health security” to reduce the risks of diseases and accidents, and “social security” to mitigate the financial consequences of old age. Because water affects so many aspects of human lives as it moves through the hydrological cycle, improved management of water resources can increase not only water security, but also food security, financial security, social security, and national security as well.

In this paper we examine some of the key questions surrounding the economic value of increased water security and try to unravel the puzzle of why States and households often see the economic value of increased water security so differently. Readers looking for a set of empirical estimates of the economic value of increased water security will be disappointed. We do not present global values for increased water security or numerical estimates that could be used for planning purposes. In fact, we argue that generic, global estimates of the economic value of increased water security are not useful for guiding investment decisions at the country or regional level.

In the next section of the paper we discuss some of the basic concepts about the economic value of increased water security. We present key economic questions about water security and provide a broad framework of the components of the economic value of increased water security. We introduce the ideas of the “user value” and “system value” of water to distinguish between the economic value of an intervention in a water resource system to a single water user and to all users in the system. We also discuss the concept of “water development paths” in order to consider how investments, projects, and regulations can move societies along different trajectories toward a water-secure future (Wolff and Gleick 2002; Grey and Sadoff 2006). In the third section we consider the value of water security from the perspective of the State and identify five roles – or responsibilities – of the State in relation to water resources management. In the fourth section we examine some of the available empirical evidence about how households value reductions in water-related risks. Contrary to expectations, we find that from the households’ perspective the economic value of reducing water-related risks is often surprisingly modest. In the fifth section we conclude by discussing what these two differing perspectives on the economic value of increased water security mean for States, and especially Ministries of Finance, as they

choose alternative water development paths and specific steps along a chosen water development path. And we ask what the role of economics should be in the pursuit of improved water security.

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THE ECONOMIC VALUE OF WATER SECURITY: BASIC CONCEPTS

Key Economic Questions about Water Security

The economics of water security is an evolving intellectual construct. There are two broad sets of questions that economists are being asked to address in the dialogue on water security. These questions involve not only the potential benefits of investments in increased water security, but also the potential costs of delay and inaction. The first is a set of macro-economic questions, “What is the economic impact of achieving or failing to achieve water security?” In other words, “What is the right level of effort or investment in water security?” There is a strong general sense that water security is fundamental to economic growth, that it is a sector (like health, education, roads, and power) that justifies a strong government role, particularly in developing countries. Failure to provide basic water and sanitation services, flood control, and drought mitigation is seen as compromising economic productivity and undermining growth. The varied and far-reaching benefits that water infrastructure investments provide underpin this belief, but the very fact that these benefits are varied and far reaching also makes them extremely difficult to quantify and value in economic terms.

Returns to investments in water security are extremely sensitive to location, context, and sequencing, making rigorous calculations of the ‘universal value’ or even the national value of increased water security impossible to defend. Still, policy-makers will and should allocate resources to the management of water. How can economics inform these decisions?

- How do we prioritize and scale investments to improve water security?
- What evidence can economics provide regarding whether or not the water sector is a priority for investment? Is lack of water infrastructure an obstacle to growth? What are the economic constraints that water insecurity poses for growth and development?
- What evidence can economics provide regarding the scale of the challenge and hence a sense of the magnitude of investment that is justifiable? What is the broad magnitude of the costs associated with a failure to attain water security?

- Which aspects of water security are the most costly to ignore and the most critical for enabling growth? What are the big ticket items? What are the most significant investments needed to increase water security?

The second is a set of micro-economic questions – “given the complexity of water, how does one apply economic discipline to the choice, design, and sequencing of investments to increase water security?” In other words, how do you know a really good water project when you see one? The challenge of quantifying the economic benefits of these fundamental services has often been dealt with by arguing that they are simply basic needs that require no further calculations. This has led to sectoral advocacy based on emotional appeals and intuition, rather than evidence and analysis. Still, even if one accepts that water security is an area that justifies the priority attention and investment of governments, all investments are not equally attractive. The prioritization, design, and sequencing of specific projects should be subjected to careful economic analysis.

- What are the costs and benefits to households?
- What are the costs and benefits to different sectors of the economy?
- How might costs and benefits change during the transition from a low-growth to a high-growth economy?
- Where can investments be targeted for the highest economic returns?

A Historical Perspective and the Diamond-Water Paradox

Economists and philosophers have long puzzled over how to think about the value of water and other natural resources such as land and ecosystem services that are essential for human survival. In the mid-1700s the Physiocrats, members of an early school of economists in France, attributed economic growth to natural resources, especially agricultural land. They believed that the economic surplus from agriculture was the foundation of national wealth and the driver of economic growth. The Physiocrats argued that agricultural resource development was the only viable regional economic *development path*.

Adam Smith’s rebuttal of the Physiocrats’ argument foretold one of the main findings of 20th century economic growth theory, i.e., the fundamental importance of technological change as a determinant of economic growth and development. Smith pointed out that the Physiocrats failed to take into account the roles of capital, trained labor, and particularly technological advance in creating economic wealth.

There is, in fact, a long intellectual tradition of attributing economic growth and development to a single factor input in the production process, relegating other factor inputs to a subsidiary role. For example, in the 19th century, ignoring Smith's critique of the Physiocrats, Karl Marx again ascribed economic surplus to a single input, this time labor, and proposed the "labor theory of value."

In the last three decades of the 20th century, ecologists and ecological economists became captivated by Howard T. Odum's idea that economic wealth derived from the flow of energy through the economy and ecosystems (Odum and Odum, 1976). Odum proposed focusing on the energy content of primary biological production as the foundation of economic wealth and growth. Odum (1995) introduced the concept of "emergy" and proposed that economic value be measured "objectively" in terms of a single factor input (BTUs).

If a single factor input is conceptualized as the sole driver of economic growth, this factor then is seen as uniquely valuable, and great attention must be paid to using this "special" factor input wisely because it is a necessary precondition for economic growth. A narrow focus on using this special factor input efficiently avoids the harder task of finding the optimal combination of all factor inputs (e.g., capital, labor, natural resources – including water) needed to maximize profits (or social returns) from production at a particular time and place given different factor input prices.

As we begin to think about the economic value of increased water security, we need to avoid this same conceptual error. Water resources are important, but they are not the sole or primary driver of economic development and human well-being. Moreover water resources are integrally linked with other key factors of production, such as the health of laborers. We must also avoid a narrow focus on water use efficiency or "water footprints" as guides for optimal water use (e.g., "maximizing crop per drop"). Water will be scarce in some places where other factors of production are plentiful (e.g., the Gulf States); and water may be plentiful in some places where other factors are scarce (e.g., central Africa.) Determining the optimal mix of resources to be used, and the sustainability of water withdrawals for a given area are more important goals than simply minimizing water use.*

* See explanation in Annex p. 65

In *An Inquiry into the Nature and Causes of the Wealth of Nations*, Adam Smith (1776) described the paradox that water was essential for survival but had little value in exchange (and the price of water was typically low), while diamonds were extremely valuable in exchange, but were superfluous for survival (and their price was very high).²

“Nothing is more useful than water: but it will purchase scarce anything; scarce anything can be had in exchange for it. A diamond, on the contrary, has scarce any use-value; but a very great quantity of other goods may frequently be had in exchange for it.”

This “diamond-water paradox” is now explained in introductory economics textbooks through the use of marginal utility theory. An additional unit of water has a very low utility (value) to someone when it is already in plentiful supply because the basic needs for which water is so essential for survival have already been met. Diamonds are so valuable to people because they are very scarce; their marginal utility is high because of their aesthetic beauty to an owner, as well as the social status they may convey due to the fact that few people have them.

The fundamental insight of marginal utility theory was that most commodities exhibit diminishing marginal utility – each additional unit obtained by a person or firm has less value than the unit obtained before (Young, 2005). This is especially true for water. The first few liters per day that an individual has are essential for survival, and a person will pay almost anything for them. The measurement of the economic value of these first few units is thus not a particularly useful or interesting concept to either an individual or a State. Both individuals and States will do whatever it takes to obtain the minimal amount of water needed for survival.

But if more water is available, it is no longer needed for drinking and will be used instead for cooking and essential hygiene. This second provision of water is also very valuable, but not as valuable as the first tranche of drinking water. A third provision will be put to other, less valuable uses, and the individual will be willing to pay less and less for additional water supplies.

² Adam Smith spent his life in the United Kingdom, a water-rich country, and thus never experienced firsthand the challenges of establishing an economic value of water in conditions of scarcity.

The economic value of an additional unit of water is thus highly variable depending on the availability of water at a particular time and place. When water is limited in supply, it will have a higher marginal value since the last additional units of water used will be allocated to purposes more closely linked to survival. In an extreme emergency, people would trade diamonds willingly to obtain life-saving water.

The concept of diminishing marginal utility can also be applied to risk reductions. An individual will value the first reduction in risk the most. Each successive risk reduction will become less and less valuable. At some point risks reach a point where they appear tolerable or “something one can live with.” What different individuals perceive as a tolerable risk will decrease as economic development proceeds and household incomes grow because risk reduction is what economists call a “normal good” (people want more of the good or service as they get richer).

Marginal utility theory showed that to understand the economic value of water, risk reduction, or any good, it is necessary to compare an individual in two situations (or “states of the world”). In the first condition an individual has a given quantity of water, and in the second condition, the individual has a greater quantity of water (the given quantity plus one additional unit). The economic value of the additional unit of water in the second situation is determined by the comparison, i.e., how much additional utility the individual obtains by moving from the first state of the world to the second state of the world.

Similarly from the perspective of the individual, the economic value of increased water security is defined by the comparison between two states of the world with different levels of water security. A change from one state of the world (with one level of water security) to another state of the world (with a different level of water security) results in a change in the individual’s utility (or “well-being”). Such a change in water security might result, for example, from an investment in new infrastructure, an international treaty that resolved competing claims among riparian countries to the waters of an international river, a new flood forecasting system, or a new water quality regulation or tariff policy for a municipal water supply.

User Values vs System Values

Water resources economists distinguish between the economic value of water to specific users (“user value”) and the economic value of water to all

users within a water resources system (“system value”) (Sadoff et al. 2003, Whittington et al. 2005). The difference between the user value of water and the system value of water can be seen as a shift in the definition of the user—from an individual economic entity in a specific location along the river to the sum of all water users throughout the river system.

The “user value” is the amount of money (or something else) that a household or firm would exchange for an additional unit of water at a specific location and point in time, such as a household with a private connection using water for domestic purposes, or a farmer abstracting water for irrigation. The “user value” of an additional unit of water will be determined by the use to which this water will be put, the amount of money the user has, and how much water the individual already has. This user value of water is determined by its transaction value in a world of scarcity.

The user value of water is the concept that Adam Smith puzzled over in the diamond-water paradox.³ The “system value” of water takes a broader perspective, and incorporates the aggregate value of water to all of the inter-related users in the river basin or other water resource system. A policy intervention, regulation, or investment in a water resources system can result in a change in system-wide benefits and costs to multiple users and to the user value to a specific water user at a location on the system.

The economic value of water from a systems perspective will be different from that of a single user’s perspective because of the physical interdependencies of water use in a river basin that result in opportunity costs and positive and negative externalities. These interdependencies drive the need for Integrated Water Resources Management (IWRM).

In a river basin the system value of water will be determined by the interactions and magnitude of several different relationships, including the size of the evaporation and seepage losses, the hydroelectric power generation potential at different sites, and the magnitude of the agricultural user values in different locations. In a municipal system the system value of

³ Adam Smith used the term “use value”. In the 20th century economists have noted that some individuals may be willing to pay to leave water in its natural state, not just because they want to fish or preserve wildlife that they may someday enjoy seeing, but simply to preserve a natural environment for its own sake, because it is the “right” or moral thing to do. This “existence” or “nonuse” value is also a component of the economic value of water if people are willing to sacrifice (or pay) to preserve water in the natural environment (Krutilla, 1967).

water will be determined not only by the user values of customers, but also by the costs imposed on others by both the abstraction of raw water supplies and the discharge of (treated or untreated) wastewater into receiving surface water bodies.

There are far fewer estimates in the literature of the “system value” of policy interventions in a river basin or other water resources system than estimates of the “user value” of water in a particular sector (e.g., irrigated agriculture). This is in part because there are few institutions charged with the task of taking a systems perspective on the economic value of large-scale water resources infrastructure. Also, the data and models needed for the calculation of system values typically do not exist or are not publicly available.

Both user values and system values can incorporate water-related risks. Users at a particular time and place are willing to pay for interventions that reduce water-related risks. Interventions that change water-related risks to multiple users in a water resource system will be reflected in the system value of water.

Components of the Economic Value of Increased Water Security

To begin to address the macro questions of water security, we need to look at the economic value of increased water security to a range of users and sectors in the economy. What are the basic building blocks or components of the total economic value to all users in an economy that result from an improvement in water resources infrastructure and management? Water has both productive and destructive economic consequences (Grey and Sadoff, 2007). Better water management and infrastructure can increase the total economic value of water to multiple sectors of the economy and diminish the destructive impacts of floods and droughts.

Part of the economic benefits of such investments comes from improvements in the adequate and reliable availability of water for ecosystems, drinking and sanitation, agriculture, services and industry, energy production, and navigation.

Water infrastructure and management may also diminish the destructive impacts of water by reducing a wide range of water-related hazards to different sectors of the economy. Part of the economic value of such investments may therefore result from reducing the risks associated with floods, droughts, contaminated drinking water supplies, and unhealthy ecosystems.

Figure 1 presents one way to conceptualize the changes in the different components of economic value that result from an intervention (e.g., an investment, policy, project, or regulation) designed to increase water security. This intervention causes a movement from ‘state of the world A’ to ‘state of the world B’. Each block in Figure 1 reflects the magnitude of one component of the total economic value of water used in one “state of the world.” Components above the horizontal axis show economic benefits to different water users or sectors. For example, the magnitude of agricultural incomes is in part determined by the quantity of irrigation water provided in a given “state of the world” (A or B in Figure 1). The components below the horizontal axis show different economic costs associated with the water infrastructure and policies existing in that “state of the world.”

The relative magnitudes of these ‘blocks’ may give policy-makers insights into the economic value of increasing water security by moving from the current “state of the world A” to an improved “state of the world B” by intervening with a new water resources investment, policy, or regulation. Many investments in water infrastructure and management can increase multiple components of the total economic value by both increasing benefits of water use in productive sectors of the economy and decreasing losses from floods, droughts, and contaminated water supplies. For example, strong water resources management institutions and information systems can provide farmers with advice that can increase their production by better timing their planting, fertilizing and harvesting. These same systems can also provide forecasts and warnings to diminish the destructive impacts of extreme weather and hydrology. Multipurpose dams with adequate reservoir storage can deliver timely water to increase agricultural production, provide reliable drinking water supplies and generate hydropower – thereby enhancing the productive uses of water. At the same time storage dams can be operated to diminish floods and deliver water during droughts – thereby diminishing the destructive impacts of extreme hydrology.⁴

But investments to increase water security may also have negative consequences for some users and sectors in the economy. To some degree mitigation measures can be taken, for example by ensuring environmental flows to mitigate ecosystem disruption when dams and diversions are built. But mitigation measures entail increased expenses, and even the best

⁴ There can be some tradeoffs in operating dams for multiple uses.

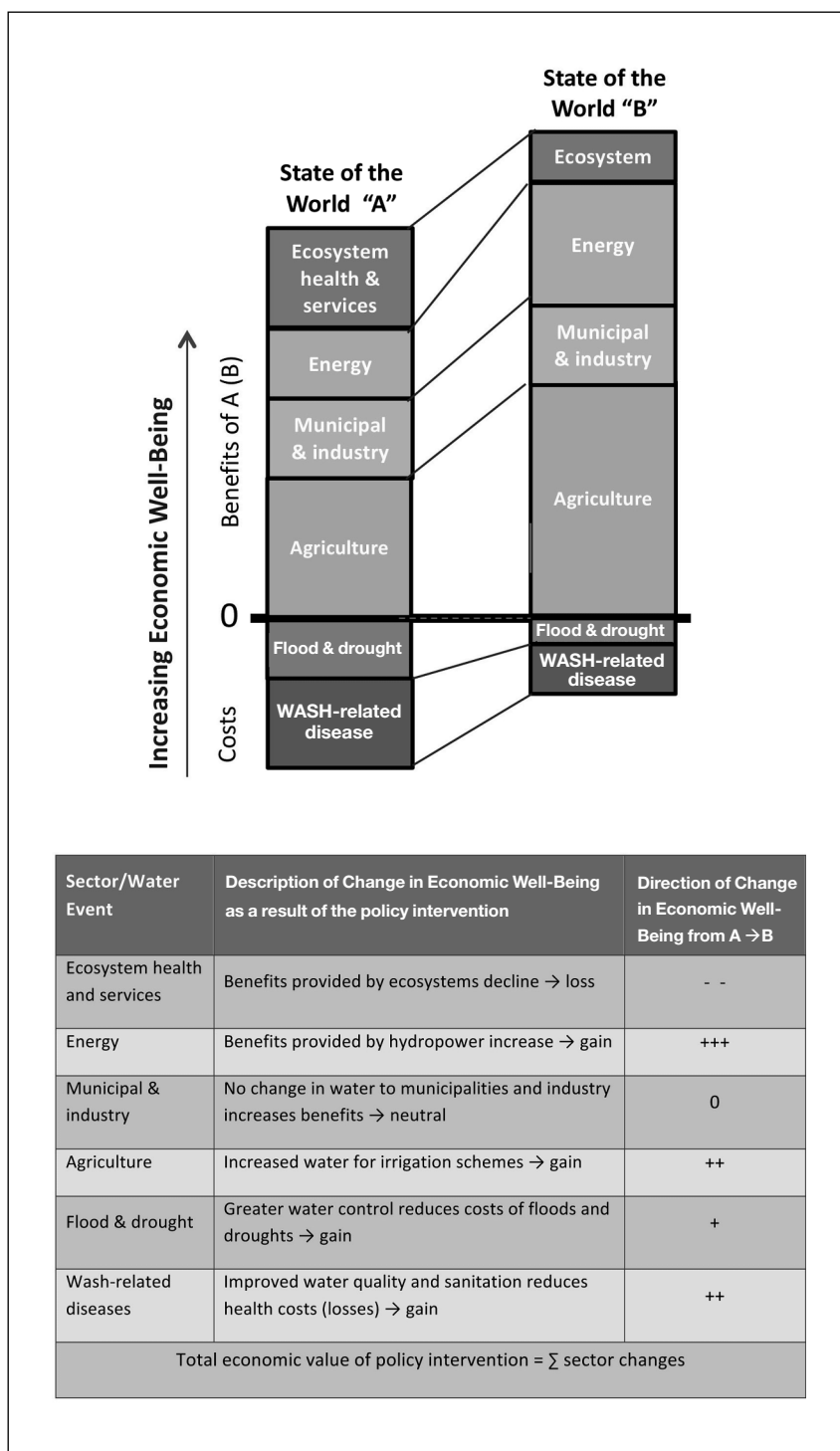


Figure 1. The economic value of a change in water security due to a movement from “state of the world” A to B.

designed, most successful projects are likely to involve tradeoffs and some negative impacts, so in the new “state of the world (B)” the magnitude of some components may decrease compared to “state of the world (A).”

To move beyond intuition, economic tools can be used to identify and measure these tradeoffs associated with particular investments to increase water security. Economists can help to estimate the economic benefits and costs of water sector investments and inform societies about the tradeoffs they face. But ultimately the State must make the judgment as to whether or not any particular set of tradeoffs is desirable.

Water Development Paths

The sequencing of water investments may set in motion path-dependent patterns of development that will change the expected returns to, and hence incentives for, subsequent investments in all sectors. This could result, for example, by significantly diminishing disease, delivering large scale irrigation services, or providing reliable water or hydropower inputs for potential industrial uses. In effect, transformational water resources investments can potentially dictate one economic development path for a region instead of another. Such investments are the most difficult to assess because the opportunity cost of this water resources development “path” is the benefit of

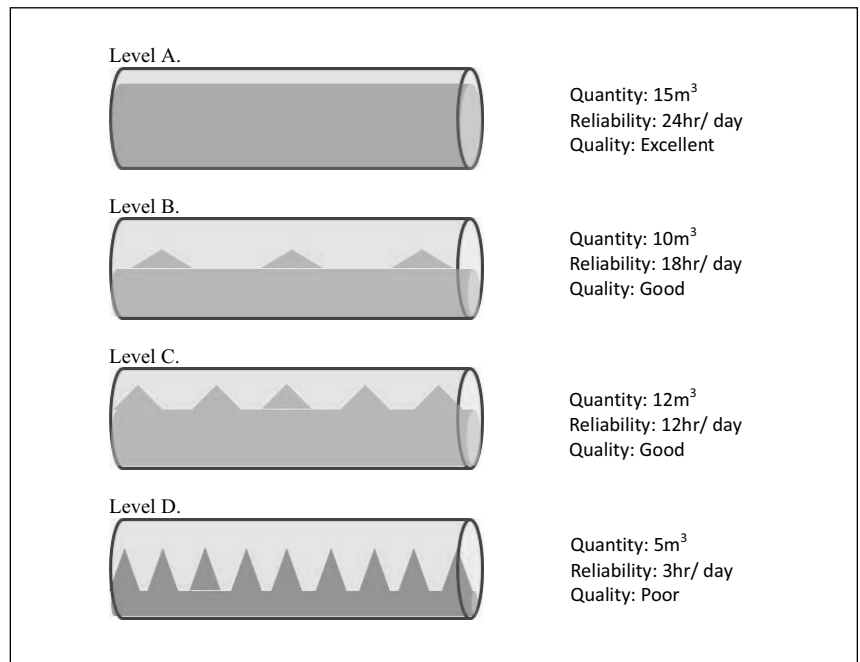


Figure 2 – Comparing different water service levels with different attributes.

the development path not chosen, which is difficult to know (Whittington et al. 2009).

The economic value of “water security” can refer to the economic value of a single change due to a project, regulation, or policy change, or it can refer to a sequence of different changes. For example, in Figure 2, suppose that obtaining water service of Level A (with high quantity, excellent quality, and high reliability) would require two investments. The first could improve the Level D service to Level C service, and the second investment would result in a further improvement from Level C to the Level A. One could estimate the economic value of the change from Level D service to Level A service, knowing that the change would take two steps (investments), and thus incur greater costs. The economic value of this “two-step” change would be different from the economic value of the change from the Level C service to Level A service, i.e., the economic value of the second investment assuming that the first investment had been made. We refer to a sequence of such steps as a “water development path.”

Figure 3 shows a water development path in which efforts are first focused on minimizing water’s destructive effects, and then later on productive uses. For example, if we think of time and investments unfolding along the horizontal

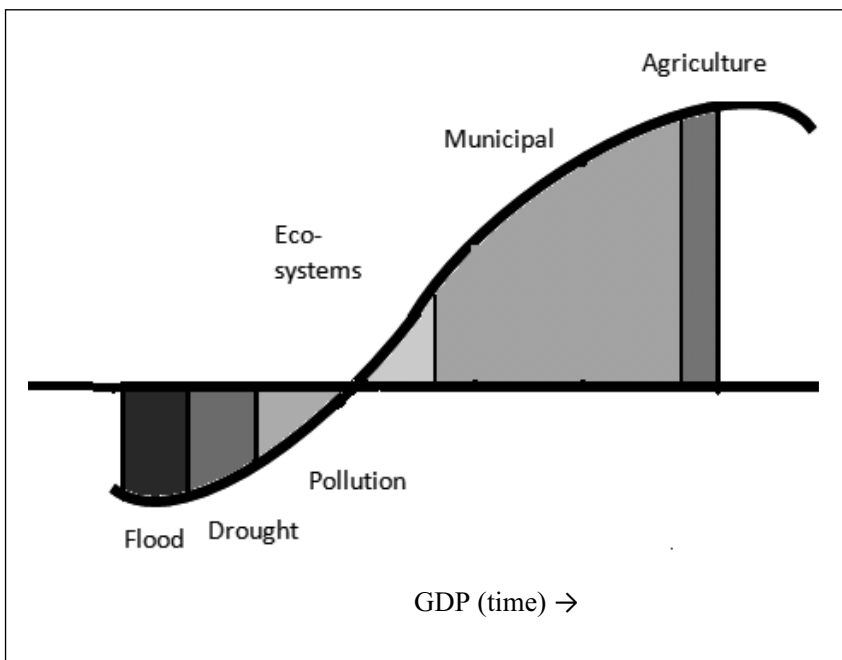


Figure 3 – From destructive to productive uses of water: a possible water development path.

axis, moving from left to right, first the destructive effects of water are reduced, and then more and more productive uses are achieved. It may be conceptually appealing to imagine a water development path in which efforts are first focused on minimizing water's destructive effects, and then later on productive uses because reducing lives lost from contaminated water supplies and from floods and droughts seems to have a higher priority than improving economic activities. But in reality, most large water resources infrastructure investments achieve multiple objectives simultaneously by reducing risks and enhancing productive uses of water at the same time. Dams control floods and provide water for irrigation schemes. Piped and sewer water systems reduce childhood mortality, enhance the productivity of small firms, and save households the time spent collecting water from sources outside the home.

The development path for a poor country to go from where it is now to become a high-income country with “water security” will likely take decades. Along this development path, many investments will need to be made in the water resources sector. The appropriate timing and sequencing of these investments depends on local conditions and the opportunities in both the water resources and other sectors. A “water development path” may involve a technological transition, or it may entail the use of well-established technologies (Geels 2005, 2006). Each investment has associated costs and benefits, and if these investments in water resources infrastructure are chosen wisely (the benefits exceed the costs), each will move the society one step closer to a water secure, high-income state of the world. Conceptually one could calculate the economic value of each small, incremental change toward this vision.

Deng Xiaoping characterized the process of moving from a centrally planned to market economy as “crossing the river by feeling the stones.” The investment planning process of moving incrementally toward a water-secure state of the world is similarly difficult, requiring both intuition and careful analysis. The timing and sequencing of the policy changes and investments needed depends on local conditions, on the opportunities in both the water resources and other sectors – it requires “feeling the stones.” This precludes rigid adherence to comprehensive master plans or to generic policy advice about how to achieve water security. In practice decisions on investments on large water resources projects are typically made incrementally, without a clear vision of next steps.

As economic growth proceeds and incomes rise, households and governments increasingly have access to the financial resources needed to reduce losses from all types of water-related risks. And, as risks are reduced, opportunities for economic growth are enhanced, in part because households and businesses are more confident and more financially able to undertake investments with higher returns and higher risks. This two-way relationship – or feedback – between risk reduction and economic growth makes it especially challenging to unravel the economic value of reductions in specific water-related risks. Water services are deeply embedded in so many activities of both households and firms that it is practically impossible to keep track of all the interactions that result when improvements in water services are made in a dynamic, growing economy.

Our intuition about the importance of water makes it tempting to simply assert that water infrastructure is a necessary condition for economic development, and that it should take precedence over investments in other sectors. This is similar to the argument that the French Physiocrats made about the primacy of agriculture over industry. But deeper, context-specific analysis is warranted (Lin, 2011). Many of the high-growth economies in the developing world have launched their transition to middle income countries without such water infrastructure. For example, India has entered the club of high-growth economies with infrastructure in many cities that provides contaminated water for only a few hours a day and millions routinely exposed to significant flood and drought risks. Japan was the first Asian economy to achieve high-growth status, yet Tokyo did not install water-borne sewerage until quite late on its water development path. Of course, we do not know the counterfactual. Perhaps China, India, and Japan would have grown even faster if they had invested more in the water resources sector earlier. But high investments in water infrastructure would have meant less investment elsewhere in the economy: determining the economic value of steps toward “water security” in a dynamic, high-growth economy turns out to be a difficult task.

Because most water problems are primarily local, perhaps regional, and are embedded in so many economic activities, it is difficult to reach broad general conclusions about investment strategy in the water resources sector. An attractive investment in one time and place may not be suitable elsewhere because of differences in the local water resources situation and what else is going on in the economy. In his book *The Next Convergence*, Michael Spence (2010) notes that Deng Xiaoping was keen for Western knowledge

to aid China's transition from a centrally planned to a more market-oriented economy, but he was skeptical of economic theory and policy prescriptions from industrialized countries. Addressing local or regional water resources problems requires similar skepticism about the universal applicability of policy prescriptions and broad generalizations about the economic value of steps toward increased water security.

The imagery of an investment and policy reform process as “feeling the stones” emphasizes that these policy and investment decisions are not easy, that missteps are common. Some investment options will have benefits that are less than costs, and this may be difficult to see *ex ante* because estimating benefits and costs is difficult. Despite careful planning and analysis, unforeseen events happen. *Ex post* the economic value of different steps along this development path may be quite different than anticipated, so public sector decision-makers undertaking investments in water resources infrastructure require Keynes' “animal spirits” and intuition just as much as private investors. But animal spirits and intuition are not enough.

An obvious question is whether a government could choose a development path to a water-secure world before reaching high-income status, i.e., if development efforts were concentrated on the water resources sector, could water security be achieved faster? If such a development path exists, a related question is – Would it be economically preferable? Thus, one could ask about the economic value of this *alternative development path*. This is different than the economic value of an incremental step along a given development path. Determining the economic value of an alternative development path requires that one estimate the difference in human welling in two different dynamic trajectories of economic development. Estimating the economic value of an incremental step along a single development trajectory is challenging, but it is far simpler, more manageable task than comparing two different development paths. The economic value of a specific investment or policy intervention could be quite different if it is undertaken in different development paths. This is because a single project may complement (or substitute) other investment projects in one development path in quite different ways than along another development path.⁵

⁵ For example, along a “sustainable development path” that included investments in renewable energy and low-carbon consumption patterns, investments in rainwater capture for urban water supply might complement investments in parks and bikes paths that would not exist in more traditional urban transportation and recreation plans.

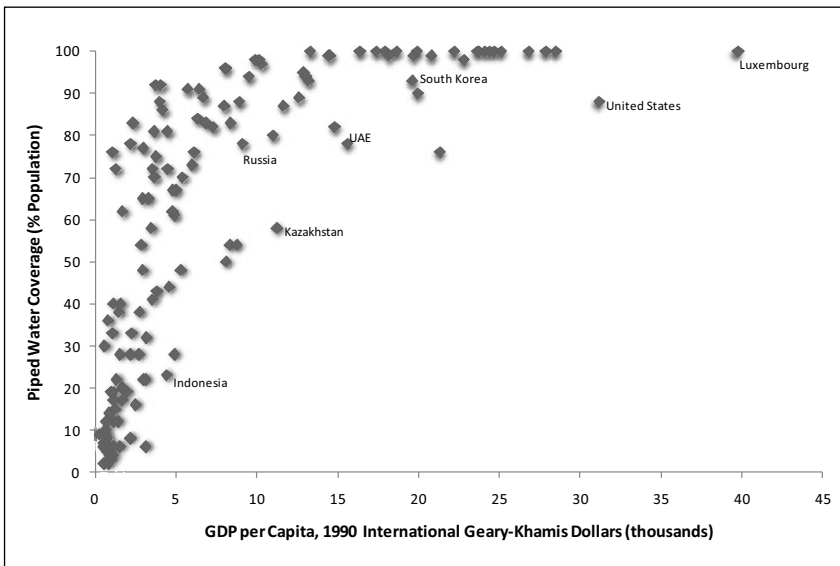


Figure 4 – Piped water coverage vs. GDP per capita.

Historical experience and available data suggest there is relatively little variation in the broad water development paths that countries have chosen as they move from low to high levels of economic development with regard to municipal water supply and sanitation services. Figure 4 plots the average GDP per capita and percentage of the population with piped water service for 139 countries in 2008. As expected, there is a strong positive association between GDP per capita and piped water infrastructure.

In the municipal water and sanitation sector, all industrialized countries have moved from non-piped services to piped water and sewerage networks, and then to increasingly sophisticated wastewater treatment technologies. Some have raised the question of whether piped water and sewerage networks are a sustainable solution given their high capital intensity and high water use (Esrey, 2001; Thomas and Ford, 2005). Some donors and NGOs have argued for non-piped solutions such as point-of-use water treatment, hand-pumps, composting toilets, and Ventilated Improved Pit (VIP) Latrines, not only as intermediate steps along a water development path, but also as “appropriate” final technologies in a sustainable, water-secure world. But to-date these have been distinctly minority views. No country has ever explicitly chosen such appropriate technologies as a final solution along a water development path. Countries have instead opted for traditional piped water and sewer networks, even though the journey to reach 100% coverage with piped services is long and expensive.

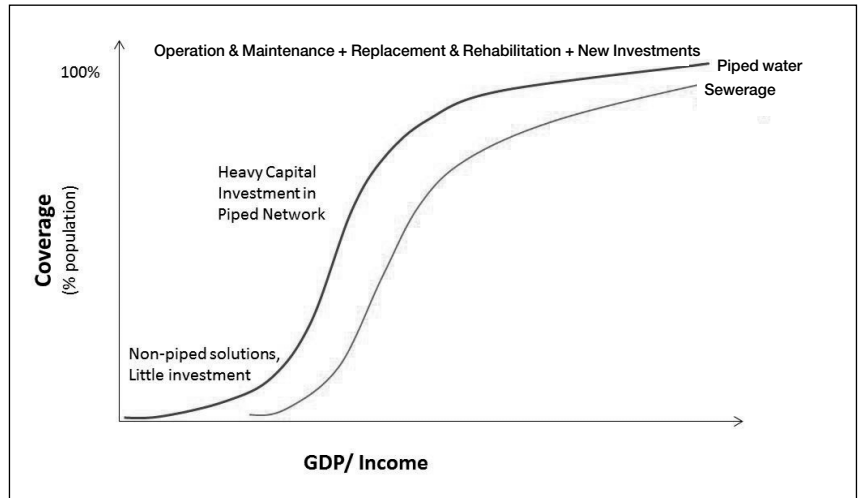


Figure 5 – Water and sanitation coverage vs. GDP

Figure 5 describes a typical municipal water and sanitation development path as GDP (income) increases. As shown in Figure 5, at low levels of GDP, both piped water and sewer coverage are very low; the capital costs of networked systems are too expensive for all but a small elite group of households. The State has other more pressing concerns, and the vast majority of households must rely on non-network water and sanitation services. As economic growth proceeds, piped water networks are built first, followed by sewer networks. As economic growth accelerates, network services become a priority for both the State and households, and there is a period of high capital expenditures as coverage expands. But capital expenditures do not typically drop because as the capital stock expands, the replacement and rehabilitation needs grow.

As shown in Figure 6, donors often play a significant role in financing and paying for capital investments at the start of this transition, but soon the financial burden becomes too large for donors, and the State plays the major role, financing and subsidizing the expansion of services. Gradually, as coverage approaches high percentages of the urban population, and most of the health and other productive gains are achieved, the State grows weary of the large annual capital subsidies and more concerned about the economic inefficiencies associated with low water tariffs. Customers are typically called upon to pay an ever greater proportion of the total costs. But even in many advanced industrialized countries, the State still often subsidizes a portion of the total annual costs of service.

However, along such a municipal water development path toward 100% piped water and sewer coverage, there are numerous major decisions. Sewerage flows may be combined (or not) with surface water runoff. Piped water can be delivered 24 hours a day, 7 days a week – or intermittently. Planners may decide that piped water services can only be provided if sewer lines are installed at the same time. Tariffs can be designed to encourage or discourage water use. The security of water supply deliveries can be enhanced through the use of a portfolio of raw water sources. Standards for water to be supplied to customers and for wastewater to be discharged to receiving waters can vary. Either private or public institutions may be selected as service providers at some stage along a development path.

In terms of river basin management and large scale water resources management, there has been more variation in the broad water development path chosen. For example, after the Second World War, Morocco chose an economic development path based on the development of a large irrigated agriculture sector. This in turn dictated the need for large scale water resources infrastructure. In contrast, Algeria chose a development path that concentrated on industrialization, with a consequent lower need for large dams and associated irrigation infrastructure.

But for the most part, when countries can afford to finance large infrastructure to store water for use during droughts, to supply irrigation schemes, to control floods, and to generate hydroelectric power, they

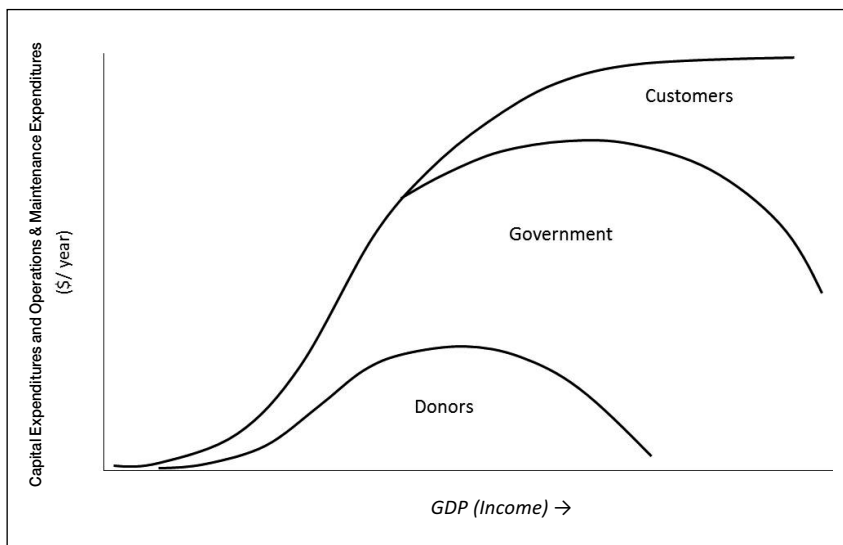


Figure 6 – Distribution of capital and O&M expenses for municipal piped network services (among donors, government, and customers) vs. GDP.

choose this water development path. Again donors and NGOs often advocate a “softer” environmentally friendly development path based on free-flowing rivers, nonstructural flood control measures, run-of-the-river hydropower facilities, and less dependency on mono-crop cultivation. But in countries with difficult hydrologies, the State has rarely given this “soft” water development path serious consideration. The imperatives of regional water development and food security trump “green” visions of river basin development (Whittington 2004).

However, there may be important strategic choices about how best to pursue a regional economic development strategy. For example, Ethiopia has seriously debated the pros and cons of a “hydropower first” water development path versus an “irrigation first” development path. In the Ganges basin there is a serious debate about the pros and cons of large dams in the Himalaya versus the use of groundwater for intrayear water storage for irrigated agriculture. There is also a serious debate in the Ganges about the pros and cons of continuing the current embankment policy for managing floods.

The fundamental choice for the State among alternative river basin development paths on an international river is typically between cooperative versus unilateral development. The economic benefits of cooperative development on an international river, especially in a world with the uncertainties introduced by climate change, are often large (Tilmant and Kinzelbach, 2012; Blackmore and Whittington, 2009). But States on a shared river may have complex, multi-faceted relationships, and development of the river cannot be divorced from each State’s focus on increasing power and security.

International donors may promote cooperative development on transboundary rivers by providing financing for large-scale infrastructure, facilitating an agreement for sharing the benefits (and costs) of cooperation, and increasing an understanding of hydrological realities. But despite such international efforts, genuine cooperative development remains the exception on transboundary rivers, and the State faces strong pressures to choose the unilateral river basin development path and forego the potential incremental economic gains from cooperation.

Summary

There are several points worth emphasizing from this discussion of basic concepts. First, economic analysis of investments in water security is

essential for undertaking well designed, appropriately scaled, cost effective projects and avoiding unnecessary costs of delay, inaction, and unwise investment. Intuition about the general importance of these investments – no matter how strong – cannot substitute for careful, thorough analysis of individual investment choices.

Second, defining the economic value of water security requires a comparison of two states of the world. For an economist, it is meaningless to refer to the economic value of “water security” in the abstract; it only makes sense to refer to the economic value of moving from one level of water security to another.⁶ This necessity of comparing the utility (or well-being) that a person receives from two different levels of water security is how Adam Smith’s diamond-water paradox was resolved. The change in utility or well-being that a person experiences as a result of a change in water security may be large or small depending on how close the attributes of water services in the two states of the world are to each other.

Third, because of the physical interdependencies in a large water resources system, investments in large water infrastructure affect many sectors and stakeholders, both positively and negatively. Any major investment will have a range of benefits and costs. Individual users will experience some of these effects and their user value of water may change. But individuals cannot easily see all the system-wide changes that result from such investments. It is the responsibility of the State to consider the system value of water.

Fourth, States often make a macro-level, strategic choice among competing regional economic development paths in which technical and engineering constraints, water resources availability, climate uncertainties, political and social dynamics, and environment quality, and economic growth are all considered. Once a regional development path is chosen, the “economic value” of specific steps along this path must be measured. Whether a specific investment, regulation, or other intervention makes economic sense at a particular time and place requires serious analysis of costs and benefits.

⁶ In a widely cited article in the journal *Nature*, Robert Constanza and his co-authors put an economic value on “nature” (including water resources) of US\$33 trillion per year, implicitly comparing two states of the world: one with nature and another without nature. A world without nature was essentially a meaningless concept, and provoked a strong, negative response from environmental economists (Bockstael et al., 2000).

THE STATE'S PERSPECTIVE ON THE VALUE OF WATER SECURITY

Over the last several centuries the modern State⁷ has made remarkable progress collecting information and developing an understanding of its people and natural resources. Censuses have evolved to describe populations, and surnames have been assigned to uniquely identify specific individuals. Cadastral systems have registered property and defined land boundaries. Some forests were removed from the control of local common property regimes in attempts to introduce scientific management. City plans and transportation arteries were regularized to facilitate trade, state control, and extraction of tax revenues (Scott, 1998).

Because water is a renewable resource that moves so quickly and easily through the hydrological cycle and across national boundaries, it has proved the most difficult natural resource for States to understand and control. As a result, it is difficult to estimate the changes in the system value of water associated with investments in new water resources infrastructure and other policy interventions. In part, due to the inherent variability of hydrological systems, hydrological data were more difficult to collect and analyze than information about most other natural resources. In some developing countries hydrological data are still treated as State secrets and so States often end up leaving themselves in the dark about basic hydrological facts and development opportunities. Hydrological data categorized as national security information might be compartmentalized, and thus States must make decisions without the full range of available information. In such situations it can be difficult to distinguish myths from realities about how a river basin actually behaves, and the risks and opportunities associated with alternative infrastructure investments (Sadoff et al 2013). For example, the Ganges is the world's most populous river basin with over half a billion inhabitants, yet even in the 21st century remarkably little is known about the way in which the river functions and how its waters are used.

States are often unclear about their water resources development options and the tradeoffs associated with different steps along a water development

⁷ The term 'State' is used broadly to refer to the civil government of a country and includes the authorities and agencies established by a government (for example river basin organizations.) While the "State" can be seen in contrast to households, it is clear that the State is not a monolithic entity but itself includes a range of stakeholders.

path. This lack of clarity makes water disputes between countries especially difficult to resolve because the objectivity of technical communities is suspect, and States cannot easily agree on the scientific facts. Because States struggle to understand the reality of water resources situations, it is hard to predict the decisions they will make when faced with complex strategic choices.

The Role of the State

From the perspective of the State, tackling the challenge of achieving water security is often not as simple as the economist's vision of balancing the costs and benefits of small incremental investments along a water development path. Indeed, poor water management can appear as a threat to the very existence of the State and a society. There are five principal reasons why reducing water-related risks and enhancing water productivity is so important to the State.

First, not all water-related threats result from variations in the hydrological cycle or natural events – some are man-made. Households and States can be confronted with water-related risks from the non-cooperative behavior of other States. It is the State's role to address the problems caused by the non-cooperative behavior of other States who share a transboundary river or aquifer. Citizens expect the State to take responsibility for reducing such risks. Failure to deal effectively with the non-cooperative behavior of foreign countries can call into question the legitimacy of the State.⁸

For example, after Singapore broke away from Malaysia in 1965, it remained highly dependent on Malaysia for its water supplies. At the time of its independence, Singapore obtained the majority of its water supplies from reservoirs in the Malaysian State of Johor, and transported these supplies via a pipeline to the island of Singapore. In his autobiography, the former Senior Minister of Singapore, Lee Kuan Yew (2000), describes the strategic importance that Singapore attached to the uninterrupted provision of water from Malaysia. At a meeting in 1965 between Dr. Mahathir Mohamad (the Prime Minister of Malaysia), and Lee Kuan Yew, Prime Minister Mahathir asked directly why Singapore was building up its Armed Forces (with the help of Israeli and Swiss advisers). Lee Kuan Yew recounts what he said in reply ...

⁸ For every State that worries about protecting its water supplies, there is an associated State that is feared to be planning offensive actions against water infrastructure. Such fears may be justified. For example, in the Korean War, the United States bombed North Korean dams in an attempt to both destroy North Korea's rice crop and its supply of hydroelectric power (Mearsheimer, 2001. p. 104).

“I replied equally directly that we feared that at some time or other there could be a random act of madness like cutting off our water supplies, which they [Malaysia] had publicly threatened whenever there were differences between us. ... The Separation Agreement with Malaysia was part of the terms on which we left [Malaysia], and had been deposited in the United Nations. If this was breached, we would go to the Security Council. If the water shortage became urgent, in an emergency, we would have to go in, forcibly if need be, to repair damaged pipes and machinery and restore the water flow. I was putting my cards on the table. He denied that any such precipitate action would happen. I said I believed he would not do this, but we had to be prepared for all contingencies.” (p. 276)

States also have great difficulty resolving competing claims over water rights. Uncertainty about water resources can introduce a strong status quo bias. States are typically extremely defensive about trading claims to water or relinquishing claims to water in exchange for something else when the implications of such trades are not well understood.⁹ It takes considerable time and effort for States to understand what they are trading and what deals are possible on transboundary rivers. Uncertainty over the terms of trade can create openings for offensive, unilateral actions, especially when neighboring States are unsure of the basic hydrological realities.¹⁰

Second, from the perspective of the State, when large water-related disasters strike (e.g., floods, droughts, cholera epidemics), many citizens experience losses at the same time. When citizens suffer routine, random losses, the State is typically not held accountable. Such losses can easily become accepted as part of normal baseline conditions. However, the legitimacy of the State is

⁹ For example, writing to Ayub Khan, the Prime Minister of Bangladesh, in 1961, Nehru described his worry that Bangladesh, a downstream riparian on the Ganges, could establish historic rights by prior use and preclude upstream development: “One more matter to which I must also refer, is the distinction you still seem to make between the rights of the upper and lower riparians in paragraph 7 of your letter, which implies that the lower riparian can proceed unilaterally with projects, while the upper riparian should not be free to do so. If this was to be so, it would enable the lower riparian to create, unilaterally, historic rights in its favor and go on inflating them at its discretion thereby completely blocking all development and uses of the upper riparian. We cannot, obviously, accept this point of view, especially when three fourths of the length of the Ganges lies in Indian territory, which gives India the priority in this river.” Nehru’s caution with respect to potential rival claims of water rights was especially illustrative given that India was the upstream riparian, that India used the majority of the irrigation diversions from the Ganges, and India was the regional hegemon.

¹⁰ For example, Prime Minister Meles Zenawi waited until February, 2011, a time of maximum turmoil in Egypt, to announce the construction of the Millennium Dam on the Blue Nile. Not only was Egypt distracted by internal political unrest, but the hydrological, financial, and social consequences of this large dam on the Blue Nile in Ethiopia were not well-understood by any of the parties.

called into question if it fails to mobilize adequately to large-scale, complex disasters such as floods, drought, and epidemics.

Third, water is an input (factor of production) into both irrigated and rain-fed agriculture, and thus the economic value of water in agriculture depends on the market prices of food. Food shortages may arise for a variety of reasons, including natural disasters, floods, droughts, crop disease, and disruptions in global trade. If, for whatever reason, food is in short supply and food prices spike, the economic value of water increases. Economists typically estimate the economic value of water in agriculture during routine or normal conditions – not during a food shortage. Taking a static perspective on the economic value of water in agriculture before a food shortage occurs risks ignoring the issue that the State is most concerned about – ensuring that its citizens are fed. This is another version of the diamond-water paradox: during an extended drought, water supplies to agriculture can become extremely valuable (like diamonds) when they are needed to feed a country's population.

Fourth, it is the State's responsibility to determine water allocations within a country's boundaries that balance the objectives of a high-growth, dynamic economy with societal notions of fairness and equity. When water supply is limited, its allocation among different users and uses falls to the State. Households cannot easily perceive how their actions with respect to water use affect users through a river basin or water-resource system. An individual water user would not typically consider how his actions would affect others on the system. However, it is the responsibility of the State to coordinate the actions of different water users and to resolve water allocation conflicts among its citizens. Failures of coordination and conflict resolution are perceived as failures of the State.

Fifth, the State is responsible for establishing the economic policies needed for poor countries to transition to a high-growth economy. Investments to improve water security cannot be viewed in isolation from the dynamic processes underway in the transition from a low-income to high-income economy. Improved water services and water resources management have important (but difficult to quantify) roles to play in the transition to a high-growth economy.

Water in a Dynamic, High-Growth Economy

As a poor country transitions to a high-growth development path, the percentage of the population that lives in cities typically grows steadily. When

China set out on its high-growth development path in the 1980s, over 80% of the population lived in rural areas. By 2006 this had fallen below 60%. People in rural areas, who are often stuck in low productivity agricultural employment, move to urban areas in search of higher wages and a better quality of life. Manufacturing and service firms with access to global markets are able to deploy this cheap labor and still pay higher wages than the agricultural sector.

This rural-to-urban migration creates enormous pressures on the State to improve education and infrastructure in urban areas. In a high-growth economy the public sector has an important role to play in enhancing the economic productivity and quality of life of these new urban residents (Haynes and Nijkamp, 2006). Investments in piped water and sewer infrastructure, and often flood control, are essential components of this package of education and infrastructure services that are needed to support economic growth. Piped water and sanitation services can reduce illness and save households' time, especially the time of children and women. They also complement investments in education in two important ways. First, children, who live in homes with high-quality water services, are better nourished and healthier, and so have greater capacity to study. Second, piped water services save children's time (especially girls) because they no longer have to carry water to the home and so have more time to study.

In some metropolitan areas (and some neighborhoods) infrastructure and forecast and warning systems to reduce flooding and improve drainage will be high priority. Investments in flood control infrastructure improve a city's investment climate in two main ways. First, they assure corporate investors that the risks of disruption to their global supply chains are minimized. Second, they protect an increasingly valuable labor force from lost time from work.

In a dynamic, high-growth economy these demographic and economic pressures translate into increased household demand not only for piped water services, but also for housing, electricity, schools, telecommunications, public transportation, and roads. Many cities need not only piped water and sewerage infrastructure, but new raw water sources as well. Both large scale water resources infrastructure (dams, canals, water transmission pipelines) and municipal water and wastewater network systems are hugely capital intensive and expensive, and in most places will require continual high-levels of investment for decades.

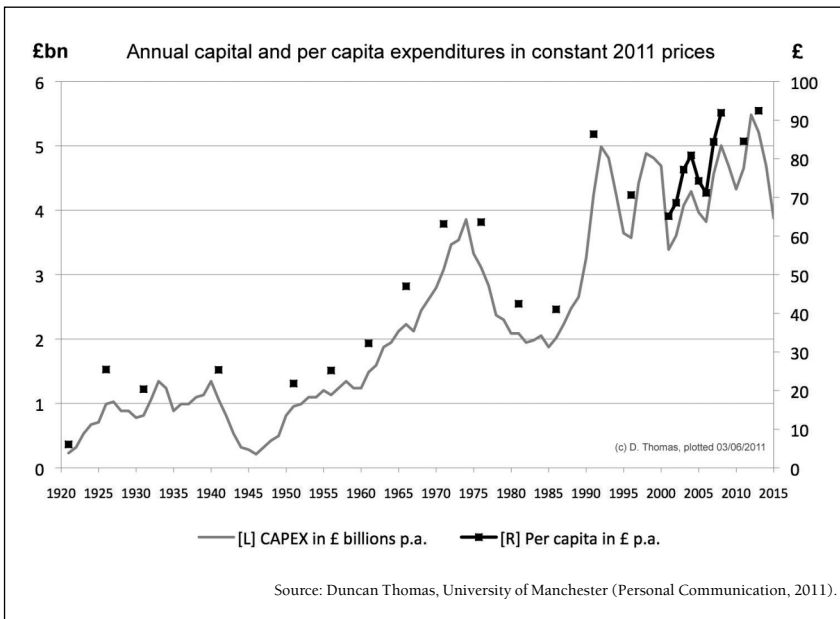


Figure 7 – Annual capital and per capita expenditures in the water industry in England and Wales, 1921-2015 (constant 2011 prices).

For example, Figure 7 shows the capital investments made in the water and sanitation sector in England and Wales from 1920 to the present. By the beginning of the 20th century, England and Wales had already made massive investments in urban water infrastructure, and one might imagine that the job was largely finished, and government could turn to other priorities. But Figure 7 shows that this was not what happened: investments increased—both in absolute magnitude and per capita—and by the end of the 20th century were at the highest levels ever.¹¹ Total annual costs (Capital Expenditures and Operations & Maintenance Expenditures) in England and Wales—a water-rich country—are currently about US\$40-50 per household per month – even after over a century of heavy capital investment.¹²

The State must provide finance for these water infrastructure investments. Historically, in most times and locations the private sector has played a

¹¹ Despite the long term upward trend, annual capital expenditures did fluctuate in England and Wales during the 20th century, reflecting in part the lumpy nature of large infrastructure investments. Surprisingly, capital expenditures remained relatively steady during the economic turmoil of the Great Depressions. As expected, capital expenditures fell off during World War II as public priorities focused on the war effort. From 1950-1975 there was a steady increase in capital expenditures, despite the fact that this was a period of fiscal austerity following World War II. From 1975-1990, capital expenditures fall off, and then from 1990-2011, they fluctuate at a high level.

¹² Of the total annual costs, approximately 40% was for operations and maintenance; 60% was for capital.

relatively minor role in financing large-scale water infrastructure. Because the responsibility of providing finance falls to the State, the Ministry of Finance and a country's top political leadership are typically involved in major water resources development decisions.

During rural-to-urban migration, higher household demand for education and infrastructure services is manifested in both the political process (as politicians gauge public frustration for example with poor public education and infrastructure), and in the market (as private providers often step into the gap between what workers in the new manufacturing and service sectors want and what the State is able to provide). These swelling urban populations have many pressing needs in addition to piped water and sanitation services. Household demand for electricity services in urban areas is especially high, even among the lowest income urban residents (Komives et al. 2003). The complementarities from investments in the power grid extend in many directions. Electricity provides power for lighting so that children can study at night, enhancing investments in education. It provides power for televisions, radios, mobile phones, and computers – all of which remove information asymmetries, promote entrepreneurial activities, provide recreational opportunities, and reduce the costs of financial transactions. Electricity also enables households to reduce the costs of some water-related services, including pumping and some point-of-use water treatment systems.

Volatile global capital flows and large, continual needs for capital investment in education and infrastructure means that it is risky for a country to try to finance too much of this urban investment from foreign sources. A cutoff of foreign capital flows can cause serious disruptions and inefficiencies in a high-growth development path. This means that much of the finance for education and infrastructure investment (including improved water and sanitation services, and urban drainage) should come from domestic sources. The principal source for domestic finance is usually the savings from the new urban population that is now employed in more productive jobs than those in the rural sector.¹³ The experience from high-growth economies is that these urban workers are often willing to save a remarkably high

¹³ Government may mobilize these domestic savings from urban workers in several ways, or allow the savings to be channeled through private sector intermediaries. Governments may also mobilize domestic savings from natural resources, especially the sale of oil & gas, and timber. But dependency on resource-extraction industries for foreign exchange has proven even more risky (problematic) than excessive reliance on foreign capital markets.

proportion of their new wages, especially if they believe that the high-growth development path will continue far into the future. As incomes continue to rise, these savings increase in absolute magnitude and are channeled into further improvements in infrastructure and education, either through private expenditures or increased public expenditures financed by tax revenues. This sets in motion a virtuous cycle between high incomes, higher savings, and higher investments in education and infrastructure, with positive spillovers in many directions. Richer urban populations can also pay directly for education and infrastructure services, which is one of the appeals of user charges for many such services when domestic savings are limited.

The unwillingness of successful States in high-growth economies to rely too heavily on foreign finance means that financial capital for infrastructure and education investments in those countries is scarce and must be allocated carefully. It is almost impossible to calculate all the interactions and complementarities from investments in the infrastructure and education sectors in a dynamic, high-growth economy. There is, however, little reason to think that piped water and sanitation services, or water resources investments more generally, are uniquely valuable or deserve the highest priority among other education and infrastructure needs. They are undoubtedly important, but it is impossible to generalize about the exact timing and sequencing of education and infrastructure investments. One common strategy for dealing with the uncertainty of investment returns in infrastructure and education is for a State to allocate its budget across multiple sectors rather than concentrating funds on, for example, improvements in water and sanitation.

The State (and its Ministry of Finance) is best placed to make decisions about the appropriate balance between local and foreign finance. Local officials will rarely refuse an offer of external finance for education or infrastructure improvements. They almost always want more external finance, and this may be too risky from a macroeconomic perspective.

The economic value of water security in a high-growth economy will be constantly changing. As an economy's economic base evolves, firms and households will place a higher value on the reliability and quality of water. The relative economic value of water in different uses will change. Service industries have much higher value-added per cubic meter of water than agricultural water users. Both firms and households will have more assets to protect, and the economic value of reducing the risks from floods will increase.

Economic growth leads to increases in the economic value of water security and also provides the capacity to finance the capital-intensive investments needed to improve water security. If the economy stagnates, or fails to get on a high-growth development path, the level of water security experienced by citizens of the industrialized countries is not achievable: the investments needed are simply too ambitious and expensive.

Nepal provides an example of what happens when the State fails to make investments in municipal water infrastructure. Figure 8 shows that in 2004 Kathmandu lagged behind other large cities in Asia in terms of the quantity and quality of water delivered to households. Since 2004 the situation has gotten much worse. The greater Kathmandu metropolitan area has swelled from a population of about one million in 1990 to a population of about 4 million today. Over this period of rapid population growth there has been essentially no investment in the municipal water and sanitation network due to a combination of factors – civil unrest and political insecurity, limited planning capacity, and weak governance.

The municipal water and wastewater infrastructure is now near collapse, providing water to most households with connections for only a few hours

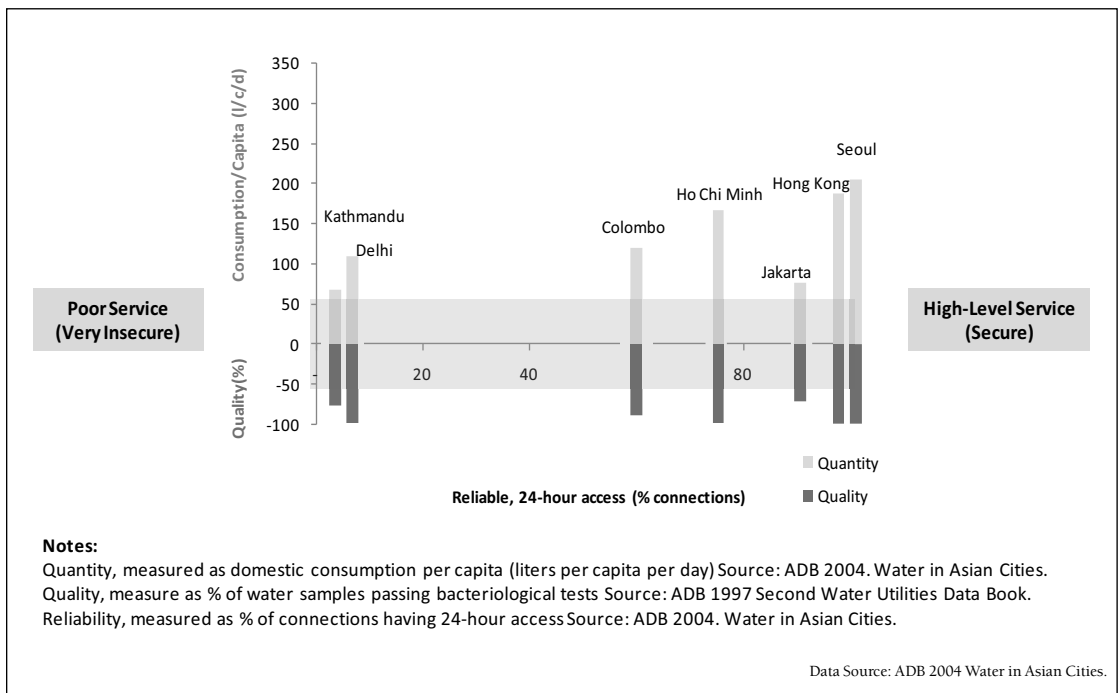


Figure 8 – Attributes of municipal water services in Kathmandu and other Asian cities.

a week. The social and economic costs of failing to provide modern water and sanitation infrastructure to four million people are difficult to quantify, but a few researchers have taken a stab at the calculations. Pattanayak et al (2002) estimated that average household costs of coping with the poor water system in Kathmandu in 2001 were about US\$3 per month, approximately 1% of average household income. But “avoided coping cost” estimates of the economic value of improved services are undoubtedly too low because they fail to account for the complementarities described above.

The Kathmandu example illustrates a potential obstacle that can arise on the development path toward the achievement of water security. When capital investments in water-related infrastructure are not made regularly, the backlog can become overwhelmingly expensive. The piped network infrastructure in greater Kathmandu is now almost completely depreciated. The remaining capital stock has little economic value. Citizens and the international donor community now face the daunting task of essentially rebuilding the entire water and sanitation infrastructure for four million people.

Summary

There are three key points about the State’s perspective on the economic value of water security. First, an essential role for the State is to make major water infrastructure and other policy decisions which will determine a country’s water development path. Economic development and growth will be a prime objective, but the State has other considerations to weigh in this decision. Increasing power and security are imperatives of the State that often trump economists’ notions of the economic value of increased water security.

Second, although there is a widespread consensus on the broad water development paths for municipal water and sanitation services and for river basin infrastructure development, States do confront important strategic choices, for example in balancing competing demands for municipal water supply, agriculture, energy and ecosystems uses. For the management of international rivers, the most important choice is usually between cooperation and unilateral development. There are strong pressures on the State to choose a unilateral river basin development path.

Third, the State has difficulty understanding complex hydrologic systems and development opportunities. Broad generic advice unrelated to timing and sequencing of decisions about a country’s specific development path is

rarely helpful. The State needs specific knowledge about its particular water resources situation, its options, and tradeoffs, not general global observations about the economic value of water security. Returning to our overarching questions for economists, this means that the State may have its own calculus for the macro questions regarding the costs of achieving or failing to achieve water security. But the role of economics remains essential in answering the set of microeconomic questions. Economic analysis provides discipline in the choice, design and sequencing of investments in the water sector.

THE PERSPECTIVE OF THE HOUSEHOLD ON THE ECONOMIC VALUE OF REDUCING WATER-RELATED RISKS

Economic Value of Reducing Risks from Floods and Droughts

Because most people in both low-income and high-income economies are risk averse, the true economic value of reducing the risks of floods and droughts will be more than the expected value of such losses. Nevertheless, examining the magnitude of these risks and associated expected losses is a good place to start in understanding the economic value of reducing such water-risks to households (i.e., how much households would be willing to pay to reduce such risks).

From a global perspective, life and property losses due to floods are not large. Table 1 presents the average number of flood deaths and average annual property losses by country over the period 1950-2010.¹⁴ As shown, large numbers of deaths from floods are associated with a few large rivers (the Yellow and Yangtze in China, and the Ganges-Brahmaputra in India and Bangladesh). About 93% of global deaths attributed to flooding from 1950-2010 occurred in India, Bangladesh, and China. Yet even in these countries the average annual risk of death due to flooding is extremely low – in the range of 3.5 in 100,000 (China) to 1.4 in a million (India). In many countries the risk of a person dying from a flood is comparable to the risk of dying from being hit by lightning – not something most people worry much about. Of course, these are national averages and the risks are higher for households living in the floodplain (lightning strikes are also concentrated geographically).

¹⁴ The global data presented in this paper on both floods and droughts are available for the period 1900-2010 from the World Health Organization's Emergency Events Database (EM-DAT). These data are annual averages at the country-level. In order to be included in the database, disaster events must result in one of the following: (1) ten or more reported deaths; (2) 100 or more affected people, (3) a declared state of emergency, or (4) a request for international assistance. The WHO compiled these data from numerous sources, including UN agencies, governments, and the International Red Cross. Because the data come from multiple sources, there are likely some inconsistencies. The mortality and damage estimates reflect losses that occur during a disaster event. The estimates do not include longer-term, indirect losses. The mortality loss is the number of confirmed deaths in addition to persons missing. Official mortality estimates are used, when available. Estimated damage reflects the short-term direct and indirect impacts on the local economy. Direct impacts include damage to infrastructure, crops, and housing; indirect impacts may include loss of revenue, unemployment, and destabilization of markets. The institutions reporting these losses did not use a standard method for quantifying damage estimates. Furthermore, losses in lower-income countries are likely under-reported due to inadequate data collection.

Average annual property and other financial losses from flooding are also quite small from a global perspective, averaging about US\$2.55 per person per year.¹⁵ As shown in Table 1, a few countries have annual per capita financial losses that are several times higher than the average.

There are several reasons countries may have high annual losses per capita. Some poor countries may have difficult hydrologies to manage and little money to undertake mitigation efforts (e.g., North Korea, Guyana). As such

Table 1 – Average number of flood deaths and average annual property losses by country over the period 1950-2010

Country	Average annual flood deaths	Average annual flood damages (thousands of 2010 US\$)	Flood Deaths per capita	Expected annual monetary loss per capita (2010 US\$)
WORLD TOTAL	38,577	11,618,630	8.45E-06	2.55
China	34,096	3,438,119	3.47E-05	3.50
India	988	837,729	1.37E-06	1.16
Bangladesh	854	336,339	9.02E-06	3.55
Venezuela	498	72,025	3.20E-05	4.63
Pakistan	244	281,648	2.52E-06	2.92
Iran	127	204,111	2.99E-06	4.80
Japan	127	258,778	1.16E-06	2.36
Brazil	106	215,832	8.36E-07	1.71
Indonesia	103	53,520	6.73E-07	0.35
Nepal	100	30,094	5.92E-06	1.79
Vietnam	87	65,952	1.64E-06	1.24
Mexico	69	96,933	9.82E-07	1.38
South Korea	65	76,850	1.75E-06	2.07
Haiti	63	102	1.12E-05	0.02
Afghanistan	62	12,717	3.71E-06	0.76
Philippines	52	44,533	9.39E-07	0.81
Colombia	49	29,681	1.76E-06	1.06
Thailand	48	124,025	1.05E-06	2.69
Somalia	46	0	8.52E-06	0.00
Netherlands	33	53,803	2.43E-06	3.98
Ethiopia	32	419	7.42E-07	0.01
Mozambique	32	38,652	2.67E-06	3.27
North Korea	30	407,746	1.79E-06	24.40
United States	30	1,311,559	1.33E-07	5.88
Algeria	29	18,161	1.43E-06	0.89

Cont.

¹⁵ The EM-DAT 2012 for estimated flood damages can include, “direct damages (e.g. damage to infrastructure, crops, housing) and indirect damages (e.g. loss of revenues, unemployment, market destabilization) consequences on the local economy.” There is not a standard methodology for estimating these damages, so each reporting country may include different categories of damage & loss.

Country	Average annual flood deaths	Average annual flood damages (thousands of 2010 US\$)	Flood Deaths per capita	Expected annual monetary loss per capita (2010 US\$)
Peru	29	3,787	1.59E-06	0.21
Morocco	27	9,289	1.29E-06	0.44
Tajikistan	26	14,171	6.17E-06	3.36
Yemen	24	73,425	2.13E-06	6.54
Spain	21	293,950	5.99E-07	8.36
South Africa	19	35,187	6.14E-07	1.12
Cambodia	19	8,773	2.13E-06	1.00
Sri Lanka	18	12,501	1.19E-06	0.83
Kenya	18	868	9.37E-07	0.05
Chile	17	18,053	1.48E-06	1.57
Italy	17	746,792	3.17E-07	13.94
Turkey	16	45,184	3.39E-07	0.94
Tunisia	16	20,463	2.30E-06	2.98
Ecuador	16	33,063	1.83E-06	3.91
Bolivia	15	41,820	2.57E-06	7.19
Honduras	15	9,609	3.61E-06	2.37
Guatemala	14	3,927	1.86E-06	0.52
Nigeria	14	2,614	1.68E-07	0.03
Dominican Republic	14	1,752	2.32E-06	0.30
Argentina	13	242,337	4.36E-07	8.29
Sudan	12	11,040	5.54E-07	0.51
Egypt	12	4,089	2.52E-07	0.09
Russia	12	145,976	8.58E-08	1.07
Romania	11	86,729	5.37E-07	4.09
Tanzania	11	415	5.03E-07	0.02
El Salvador	11	10,404	2.38E-06	2.35
Portugal	10	27,739	1.04E-06	2.95
Malawi	10	861	1.28E-06	0.12
Nicaragua	8	166	2.61E-06	0.05
Lebanon	7	315	2.53E-06	0.11
Laos	7	2,414	1.86E-06	0.63
Myanmar	7	3,500	2.01E-07	0.11
Ghana	6	8,417	4.81E-07	0.64
Angola	6	208	7.70E-07	0.03
Saudi Arabia	6	29,946	4.24E-07	2.30
Jordan	5	290	1.84E-06	0.11
Malaysia	5	23,926	3.40E-07	1.59
Hungary	5	24,280	4.90E-07	2.34
Australia	5	208,378	3.32E-07	14.59
Chad	5	20	8.57E-07	0.00

Flood deaths per capita are expressed in scientific notation. The world total value is 8.45 E-06. This can be interpreted as 8.45 flood deaths per million people occur, on average, each year globally. For China, the value is 3.47 E-05. This can be interpreted as 3.47 flood deaths per 100,000 people in China occur, on average, each year.

countries move toward dynamic, high-income growth paths, people almost certainly will place an increasing value on risk reduction. At some point along this development path investments in flood control will likely be economically justified from the perspective of both the household and the State.

Some high-income countries have undertaken considerable investments in flood mitigation, but still face difficult hydrologies and have increasingly valuable property at risk (Australia, Switzerland, Austria, and the Czech Republic). Many are in mountainous regions with property concentrated in narrow valleys where it is typically difficult and expensive to protect such property from high floods. In such situations further investments in structural flood control measures may not be economically justified. A more appropriate means of reducing the economic costs of flood risks would be to adopt various risk sharing and pooling mechanisms, such as insurance. In addition to risk sharing mechanisms, investments in enhanced hydrometeorological observation, flood forecasting, and warning systems can also be cost effective investments for many countries – particularly if they are designed to leverage regional information systems and advanced but contextually tailored technologies.

However, losses from the few, large catastrophic floods leave terrifying memories among survivors, and losses of both life and property are concentrated in time and space, making them harder and more costly to address, with the result that these losses loom large in the minds of both

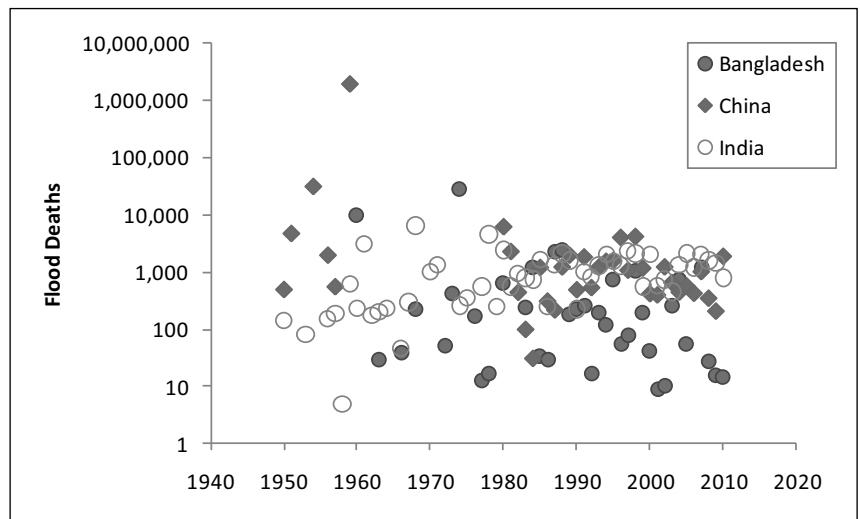


Figure 9 – Annual flood deaths in China, India, and Bangladesh year by year over the period 1950-2010. Data source: EM-DAT 2012

government officials and citizens. As incomes increase, it is common for States to spend public monies to attempt to mitigate these risks.

Figure 9 shows the annual flood deaths in China, India, and Bangladesh year by year over the period 1950-2010. As one would expect, annual flood deaths vary greatly from year to year and country to country, but in Bangladesh and China are trending down. This is probably due to a combination of both improved flood warning systems and investments in systems of embankments, in other words investments made to increase water security.

Globally, the average annual number of reported deaths due to drought is about 36,000 (comparable to the annual average deaths from floods), but these deaths from droughts are concentrated in fewer, smaller countries than deaths from flooding. The annual probability of dying from drought is in the range of 11 to 15 in 100,000 in Ethiopia, Sudan, and Mozambique—the countries with the highest drought mortality rates. In these countries the risk of dying from drought was higher than citizens of any country face from flooding. The majority of deaths from drought in the world occur in India (on average about 25,000 per year), where the average annual risk of dying from drought was about 3.4 in 100,000 over the period 1950-2010. China reported an annual average of only 58 deaths from drought over this period.

Globally, property and other financial losses from droughts appear to be almost an order of magnitude lower than the losses associated with floods (Table 3). The estimation of financial losses from droughts presents several issues not faced in flood damage assessments. In addition, the secondary, indirect damages from droughts may be large.¹⁶ Global estimates for the period 1950-2010 suggest per capita annual drought losses of about US\$0.55. The highest per capita property and other financial losses from droughts were in Australia (US\$27), Zimbabwe (US\$12), Canada (US\$10), and Spain (US\$9).

The fact that average mortality risks and property and other financial losses from floods and droughts are arguably low on a per capita basis does not

¹⁶ Drought damages may be under-reported because only losses within the year of the drought are considered. Therefore, loss of crop production in subsequent seasons is not considered by EM-DAT (UNDP 2007). In addition, estimating drought damages might be more challenging than flood damage assessment. Droughts often cause large indirect effects. Secondary impacts, such as changes in food prices can be larger than production impacts (Holden and Shiferaw, 2004). Lower-income individuals would likely be more affected by these price changes than people in industrialized countries. As household budgets become strained due to secondary effects of drought, overall spending may need to be reduced. In rural India, some households cope with the effects of drought by not sending children to school (Chatterjee et al 2005). On the other hand, unlike floods, droughts do not tend to have infrastructure damage.

Table 2 – Average number of drought deaths and annual damage estimates by country, 1950-2010

Country	Average annual drought deaths	Average annual drought damages (thousands of 2010 US\$)	Drought Deaths per capita	Expected annual monetary loss due to drought per capita (2010 US\$)
WORLD TOTAL	35,873	2,531,108	7.86E-06	0.55
India	24,595	72,408	3.41E-05	0.10
Ethiopia	6,596	6,558	1.51E-04	0.15
Sudan	2,459	0	1.13E-04	0.00
Mozambique	1,640	1,312	1.39E-04	0.11
Somalia	323	0	5.93E-05	0.00
Indonesia	153	8,031	9.99E-07	0.05
China	58	524,814	5.89E-08	0.53
Australia	10	390,542	6.89E-07	27.35
Swaziland	8	48	1.16E-05	0.07
Malawi	8	0	1.11E-06	0.00
Rwanda	4	0	6.91E-07	0.00
Madagascar	3	0	3.17E-07	0.00
Kenya	3	132	1.69E-07	0.01
Uganda	3	56	2.09E-07	0.00
Pakistan	2	5,300	2.43E-08	0.05
Burundi	2	0	4.28E-07	0.00
Papua New Guinea	1	0	3.16E-07	0.00
Angola	1	0	1.27E-07	0.00
Guatemala	1	524	8.98E-08	0.07
Afghanistan	1	21	3.63E-08	0.00
Brazil	0	181,637	2.60E-09	1.44
Bangladesh	0	0	3.12E-09	0.00
Paraguay	0	0	7.18E-08	0.00
Guinea	0	0	3.63E-08	0.00
Algeria	0	0	9.61E-09	0.00

Data source: EM-DAT 2012

Drought deaths per capita are expressed in scientific notation. The world total value is 7.86 E-06. This can be interpreted as 7.86 drought deaths per million people occur, on average, each year globally. For India, the value is 3.41 E-05. This can be interpreted as 3.41 drought deaths per 100,000 people in India occur, on average, each year.

Table 3 – Comparison of global flood and drought related deaths and damages

	Average annual deaths	Average annual damages (thousands of 2010 US\$)	Deaths per capita	Expected annual monetary losses per capita (2010 US\$)
Flood	38,577	11,618,630	8.45E-06	2.55
Drought	35,873	2,531,103	7.82 E-06	0.55

Data source: EM-DAT 2012

imply that they should not be reduced. Average annual reported global losses over the period 1950-2010 from floods amounted to US\$11.6 billion and from drought US\$2.5 billion. But it is important to recognize that floods and droughts can have long-lasting effects that are not captured by such damage

estimates. Following natural disasters, some families and communities experience long-term welfare declines as a consequence of asset loss, overwhelmed safety nets, or an inability to rebuild infrastructure. But these low values do argue for a careful weighing of the costs and benefits of policies and investments designed to reduce such risks and improve water security. Steps along a water development path that pass a cost-benefit test should be made, even if the net benefits seem small in absolute magnitude.

To the extent that households care about reducing the risks of floods and droughts, they should be willing to pay for interventions that reduce such losses. For economists, such estimates of household willingness to pay are (by definition) measures of the economic value of the interventions. Evidence suggests that low-income households' willingness to pay to reduce such risks is quite modest. Poor households face many sources of income shocks. Morduch (1995) estimated that households in rural South India were willing to pay about 16% of income to avoid all income variability. Since floods and droughts are only a small part of the multitude of risks faced by households, one would expect willingness to pay for flood and drought reductions to be only a small portion of the total for income smoothing.

Table 4 provides a summary of studies investigating household willingness

Table 4 – Summary of studies investigating household willingness to pay for drought and flood reductions

	Risk Management Tool	% of Households Willing to Purchase	Mean Willingness to Pay (per household per year)		Avg. Household Damages (% avg. household income in parenthesis)	Reference
			US\$ Equivalent	% Avg. Household Income		
Drought Risk Reduction						
Ethiopia	Weather Index Insurance	80%	\$0.60 to \$2.37 ^a	0.55	–	Hill et al, 2011
Indonesia	Ecosystem services – forest protection	–	\$2 to 3	3% of food expenditure; 10% of agricultural costs	–	Pattanayak and Kramer, 2001
Flood Risk Reduction						
Bangladesh	Insurance	51%	Crop insurance: ~\$31 Housing: ~\$23 Unemployment: ~\$22	2.4% 1.8% 1.7%	\$365 (30%) ^b	Akter et al, 2007
Bangladesh	Embankment Construction	40%	\$4.30	0.45%	\$190 (17%) ^c	Brouwer et al, 2008
U.S., Canada, Europe	Ecosystem services – wetland protection (for flood control)	–	\$139	–	–	Brouwer et al, 2008

a Represents range of WTP, at current USD exchange rate

b For severe, 5-year flood

c For annual flooding

to pay for drought and flood reductions. In Bangladesh, Brouwer et al. (2008) found that only 40% of households living in the floodplain were willing to pay any monetary amount for flood protection. Of the households that are unable to pay through monetary means, about 40% were willing to contribute in kind, through labor or donating a portion of their harvest.¹⁷

Why were vulnerable poor households who experience annual flooding not willing to pay for flood protection? Poor households obviously lack financial resources. In addition, about one in five households believed that floods are unavoidable, natural events. These households may forego flood protection since they view damages as inevitable. Households may also doubt whether insurance companies will actually pay for damages after a flood. An important reason is that a large majority believe that the central government (82%) or international aid agencies (12%) should pay for flood protection.¹⁸ Another study in Bangladesh examined households' willingness to pay for various components of flood insurance (Akter et al 2007). About half of respondents were willing to purchase flood insurance. A majority of households wanted crop insurance (about two-thirds) and housing insurance (over 40%). Only 35% wanted to insure against unemployment due to flood and just 20% were interested in health insurance. Of those unwilling to purchase insurance, many were unable to afford coverage, while others did not like the terms of the proposed policies. Stated willingness to pay was about 2% of household income for the most popular coverage policies.

Several studies have investigated household willingness to pay for crop and rainfall insurance in droughts. Weather index insurance offers payments to farmers when rainfall drops below a specified level. In Ethiopia, Hill et al. (2011) found that demand for weather index insurance is very responsive to price. A price increase of about US\$0.60 reduced demand by nearly 8 percentage points. While a slight majority of respondents were willing to purchase weather index insurance at a price of approximately US\$0.60 per year, only about 40% of respondents were willing to purchase if the price doubled to US\$1.20.

¹⁷ Of these, 75% preferred to make a contribution of their own labor, 20% preferred to make an in-kind payment of part of their crop harvest, and 5% stated that they were willing to trade part of their landholding for the construction of an embankment.

¹⁸ Strategic behavior may have been present in the first-round survey since about 20% of respondents who claimed to be unable to pay indicated in a follow-up survey that their answer was motivated by their belief that flood protection is the responsibility of the central government.

It is even possible that risk averse households would be less likely to purchase rainfall insurance since they may be uncertain about the benefits (Giné et al 2008). A rainfall insurance study in India found that the majority of households were not willing to purchase a policy that cost US\$4-6 per year. This low demand was due to a variety of factors. Many households did not understand the policy and others were unable to pay the premium. Other studies have sought to value ecological services that can reduce both drought and flood risks. Wetlands and forested areas can smooth hydrological cycles. One study in Indonesia found that farmers were willing to pay the equivalent of 3% of annual food expenditure (\$2 to \$3) for drought mitigation benefits (Pattanayak and Kramer, 2001).

Economic Value of Reducing Water-related Health Risks

The largest water-related mortality risks that households in developing countries face are from infectious diseases, not from floods or droughts. In 2004, worldwide deaths (not including malaria) from water-related infectious diseases were 52 per 100,000 people. This is in contrast to worldwide deaths from flood and drought combined of less than 1 per 100,000 people (Table 5).

Table 5 – Comparison of deaths per 100,000 for WASH-related diseases, floods and drought

	Deaths per 100,000
WASH-related Disease	52.00
Flood	0.86
Drought	0.80

Data source: EM-DAT 2012

In many parts of the developing world, water-related mortality risks have been falling rapidly over the past few decades and recent projections suggest that in East and Southeast Asia, the Middle East, and Latin America, economic growth and the associated increases in investments in piped water and sewerage infrastructure are likely to eliminate water-related mortality in the relatively near future (Jeuland et al, 2013). The two big exceptions to this global trend are in Sub-Saharan Africa and South Asia, where the forecast number of deaths from water-related diseases remains high for a few decades (Figure 10).

Although mortality rates from water-related diseases are currently so much higher than from floods and droughts, empirical evidence suggests that

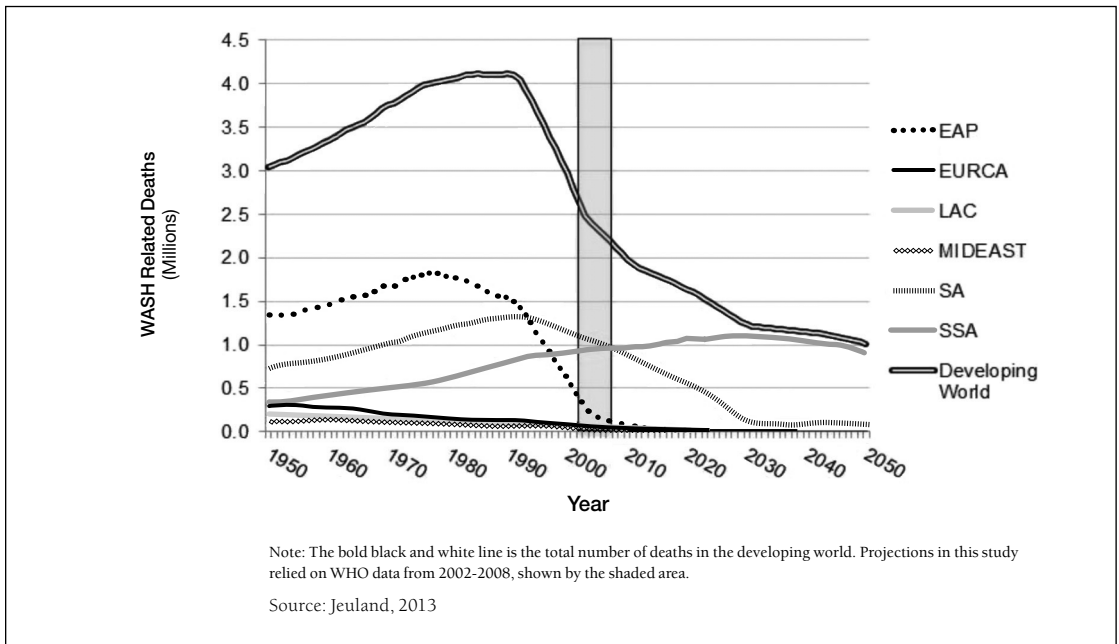


Figure 10 – WASH-related mortality 1950-2050, by world region.

households in developing countries are not willing to pay much for reducing water-related health risks (Kremer et al. 2008, 2010; Whittington, 2010). Public health professionals are often puzzled by the low household demand for preventative health services (including non-piped water and sanitation services) and the preference of States for expensive investments in piped water and sewer infrastructure in urban areas when low-cost non-network water and sanitation solutions are readily available and can achieve health benefits, especially for rural areas (Whittington et al. 2012).

There are several explanations in the literature for this low household WTP to reduce the risks from poor domestic water and sanitation services. First, households simply do not understand the health risks of poor quality water supplies and so they do not know their own interests.¹⁹ Second, households ignore the positive externalities associated with improved water and sanitation and so household willingness to pay for improved supplies is a poor measure of total benefits. Both explanations suggest that economic user value estimates of improving water quality based on either revealed or stated preference techniques are not a sound basis for policy decisions. A third

¹⁹ Spears (2011) has argued that such cognitive disability is actually endogenous, meaning that poverty and poor health may in part cause this cognitive dysfunction.

explanation is that in some countries households may be anticipating the kinds of decreases in water-related mortality rates shown in Figure 10 and are focusing their attention on other risks that do not seem to be improving.

There could be some truth in these explanations, but the evidence that poor households are not willing to pay much for the private benefits of preventative health interventions such as improved water quality is strong, and needs further explanation. We believe that the most important reason is also the simplest. Water-related risks are just one of many risks that poor households in developing countries must confront on a daily basis, and from their perspective, water-related risks do not merit special attention, or have a priority claim on the households' financial resources.

In order to survive, poor households must allocate much of their household budget to food purchases and other daily necessities. Nearly half of household spending in low-income countries is on food, compared to just 20% in high-income countries (Seale et al 2003). Water is certainly a necessity, but the quality of water needed is a matter of judgment and subject to tradeoff calculations. In very poor households, after purchases for food and other daily necessities are made, few funds remain to reduce water-related and other low-probably risks (Figure 11). Maintaining financial liquidity is an especially important means of juggling multiple risks, so committing

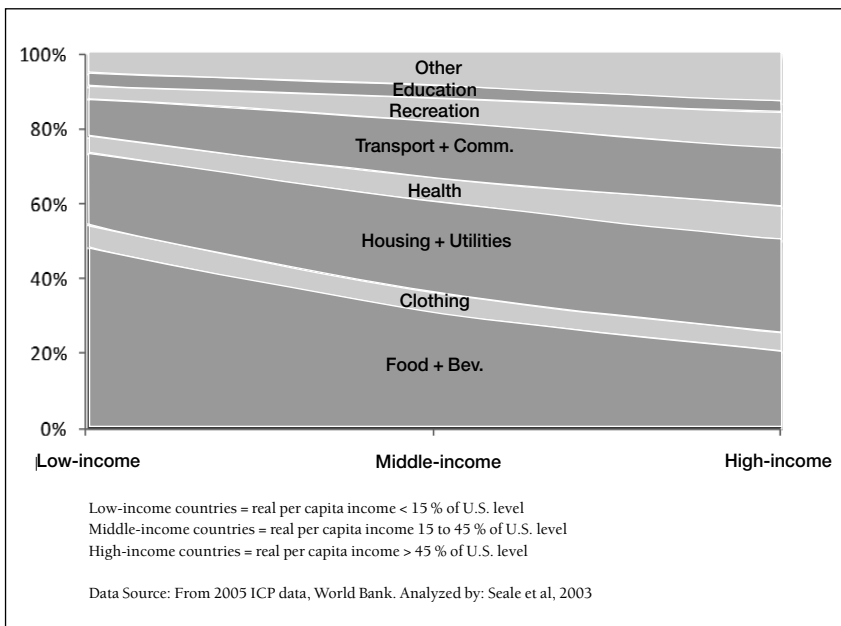


Figure 11 – Consumption Profiles 2005 (household + government spending), by country group.

funds in advance of a problem occurring for, say, improved drinking water quality, bednets, or vaccines has a high opportunity cost (i.e., cash is not available for emergencies that arrive unexpectedly).²⁰

Figure 12 and Figure 13 show the likelihood of death from different causes by age cohort in low income and high-income countries, respectively.

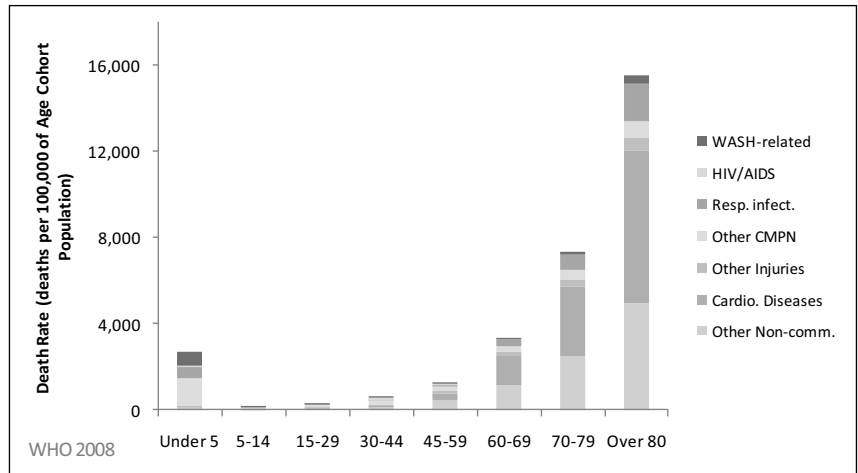


Figure 12 – Deaths in low-income countries by age cohort population, 2004.

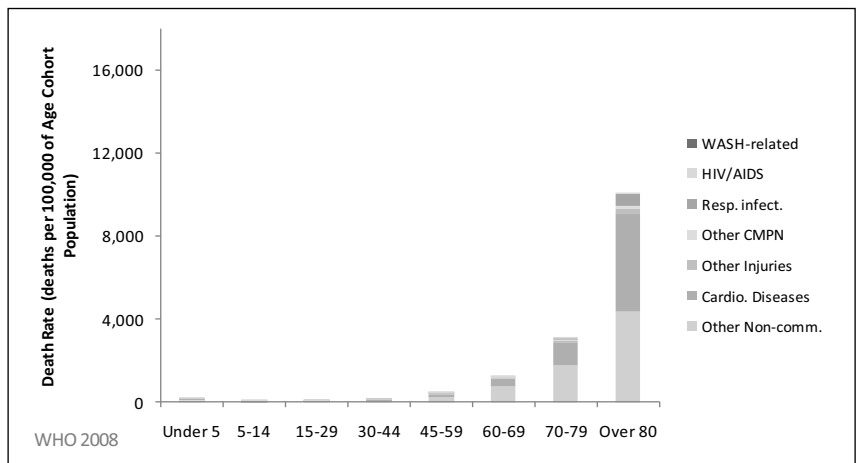


Figure 13 – Deaths in high-income countries by age cohort population, 2004.

²⁰ Poor households must cope with both uncertain income and uncertain losses. Uncertain expenditures pose a difficult challenge for poor households with variable incomes. Due to limited instruments to cope with risk, poor households often resort to informal borrowing, dipping into savings, reducing consumption of basic goods, or decreasing child school attendance (Jacoby 1997). A study of how poor households manage irregular cash flow found that the most frequent causes of income shocks in Bangladesh, India, and South Africa were injuries, disease, funerals, and loss of crops or livestock (Table 4, Collins et al 2009). Health risks can be particularly difficult to cope with because the poor often bear the full costs of illness, including treatment cost and foregone income due to work days missed. In Hyderabad, 24% of households needed to borrow to pay health expenses over a one-year period (Collins et al 2009).

These data illustrate several important points about the mortality risks that households face. First, in developing countries, for those over 5 years old, the risk of death from WASH-related causes is very small, both in absolute terms and relative to other causes. For individuals between the ages of 5 and 69, the average annual probability of death from all causes is 3,894 in 100,000; the annual probability of death from WASH-related causes is 116 in 100,000 – only 2-3% of the total mortality risk).

Second, water-related mortality risks for children under five are much higher (4.4 times higher) than for adults. Still, poor households do not have the luxury of concentrating expenditures on the water-related risks their children face. Only about 22% of the total mortality risk for the under 5-year olds is due to WASH-related diseases.

In contrast in high-income countries, death rates from all causes below 60 years of age are all very low; almost no one dies of water-related diseases. From the perspective of citizens of industrialized countries, death rates in developing countries, particularly those for children under 5, look appalling and morally unacceptable. But it should not be a puzzle that poor households in developing countries view these same mortality risks from a different perspective.

Summary

Three points are worth emphasizing from this discussion of the household's perspective. First, the available empirical evidence suggests that for many poor households the economic value (expressed by households' willingness-to-pay) of minimizing the risks from drought, floods, and water-related diseases is small because they face so many different risks and have so many demands on their limited financial resources. Evidence also suggests, however, that households' low willingness-to-pay for disease and disaster protection may result in part from a belief that these protections should be provided by the State, and should not be the financial responsibility of households.

Second, the largest water-related risk to households are health-related, and to households these risks probably appear largely random and uncorrelated with other risks. Therefore, with the exception of some epidemics (e.g. cholera), households are unlikely to hold the State responsible for a WASH-related illness.

Third, the economic value of reducing water-related risks is highly context dependent; the global averages presented here will not reflect household preferences where risks are especially high.

Real progress is being made toward water security. In the developed world citizens enjoy a reasonably water secure existence. In many parts of the developing world, water-related mortality risks have fallen dramatically

CONCLUDING REMARKS: WHAT IS TO BE DONE?

Rover the past few decades and the evidence suggests that if economic growth proceeds, water-related mortality will be virtually eliminated in the relatively near future in most parts of the world, (Sub-Saharan Africa and South Asia are exceptions, see Jeuland et al, 2013).

Yet today's progress toward improved water security could be undermined in the future by climate change, population growth, infrastructure deterioration, and economic and dietary transitions. While great gains are being made in ensuring access to water supply and sanitation services in many parts of the world, water-related disasters are increasing in frequency and the challenges of allocating water between competing uses are growing as economies and populations increase.

Economic interconnectedness means that risks to specific geographic locations can have global reach. The 2011 floods in Thailand disrupted global supply chains of commodities from rice to computer hard drives to cars, for a period of several months. While solutions for water security are highly context specific and therefore largely local in nature, the risks of failing to achieve water security can have global consequences.

In addition to the importance of managing the destructive 'downside' risks associated with water security, the 'upside' potential of improved water security is great and growing. Clean and abundant drinking water for growing populations of increasingly skilled and productive people; predictable water for irrigated agriculture; reliably predicted water for rain-fed agriculture; reliable and dependable municipal supplies for businesses and industrial supply chains will all be increasingly valuable as economies grow. The potential for water security to enhance economic productivity is great and increasingly important as water quality and quantity constraints increase.

To sustain and strengthen water security, the key economic questions raised at the beginning of this paper will remain relevant:

1. What is the right level of effort or investment in water security?
2. How does one identify economically attractive water projects?

To address the first question, one needs to understand the perspectives of both the household and the State in order to capture the full range of benefits and costs of increases in water security. The responsibility for making large-scale water security investments will rest with the State and should reflect the system value of water and careful consideration of alternative development paths.

Table 6 summarizes our discussion of the different perspectives of the household and the State on the economic value of increased water security. Households care about water user values while the State is responsible for developing an understanding of the system value of water in complex hydrological systems. Households cannot be expected to understand or care about the system value of water associated with alternative infrastructure investments if the State does not clearly present macro-level strategic choices. Most households focus on short-term steps along a given water development path whereas the State is responsible for taking a long term perspective and choosing among alternative water development paths. Citizens can be involved in collective decisions about strategic water investments, but it is the State's responsibility to ensure that citizens have the information they need to make informed choices. Households make *ex-ante* decisions about insuring against water-related risks, but *ex-post* they want help if disaster strikes. The State is the insurer of last resort.

Households may face water conflicts with their immediate neighbors, but the State is responsible for dealing with the noncooperative behavior of other States. The majority of households can only react to the current policy and infrastructure framework while the State is responsible for the timing and sequencing of the transformative infrastructure investments needed to

Table 6 – Summary Comparison of Household and State Perspectives

Perspective on ...	Households	State
Economic value of water	User value	System Value
Investment Planning	Steps along a water development path	Responsible for choice between alternative water development paths
Economic Value of Disasters	<i>Ex-ante</i> (Economic value determined before disaster)	<i>Ex-post</i> (Insurer of last resort)
Non-cooperative behavior	Conflicts with neighboring households	Conflicts with other States on shared water bodies
Dynamic, High-Growth Economy	Reactive (Little an individual household can do)	Proactive (Responsible for the policy framework, including water)
Knowledge base about water resources	Largely limited to very small geographic scale, site specific	Responsible for systems understanding, but difficult

achieve a dynamic, high growth economy. Households' knowledge about water resources systems is largely limited to a very local scale; the State is responsible for understanding the country's hydrological system and development options.

How can we reconcile these different perspectives of the State and households on the economic value of reducing water-related risks and enhancing the productive uses of water? What does this difference in perspectives mean for evaluating investments and policy interventions that move a country along a water development path toward a water-secure world?

The State's choice among alternative water development paths can be informed by information about households' preferences, but as we have described, the State has multiple objectives. The economists' concept of economic value may take a backseat to issues of national security or food security. Still, the State and citizens both have a strong interest in selecting a water development path that helps put the economy on a dynamic, high-growth trajectory.

The State may choose to inform citizens about the system values associated with selected interventions and engage civil society in a public discussion about alternative water development paths. However, in most countries it is rare for civil society to participate in a serious, reflective public discourse about the behavior of complex hydrological systems, the consequences of different policy interventions, and the choice between alternative water development paths. States themselves struggle to understand complex hydrological systems and how interventions will affect people across time and space, and facilitating such a public discourse is itself challenging (and risky from the State's perspective).

Households' assessment of the economic value of specific steps along a water development path (i.e., user values) will be highly relevant to the State in evaluating specific infrastructure investments. Users' perceptions about the economic value of water interventions must be carefully considered because they play a large part in determining how water-related services are used, and also because financing capital-intensive projects is always challenging for the State. Some cost recovery from users is typically needed, and if users' demand (economic value) is low, collecting revenues from users will be difficult.

The fact that household demand for interventions that reduce the risks of floods, droughts, and disease may in some cases be low reminds us of the

lesson from the diamond-water paradox – that the economic value of water is highly context dependent and often uncertain, and that it is incorrect to assume that the economic value of steps toward increased water security is always high. When household user values are low for the consequences of water infrastructure investments, this is strong evidence that there are better uses of scarce public funds. The State must be careful not to dismiss or ignore information on households' preferences because households hold local knowledge about the behavior of hydrological systems, the timing and sequencing of investments, and their own preferences that government bureaucracies typically lack.

Because many water problems are basically local in nature and require detailed local knowledge to solve, information on household user values is especially important. For example, the benefits and costs of most investments in small municipal water supply systems, rural water supply projects, and small irrigation schemes have few spillover effects outside the project area. The vast majority of the benefits and costs of interventions to solve such problems fall on groups within the local geographic area. Even investments in most large municipal water and sewerage systems are solutions to primarily local problems.

Solutions to some water problems do require a regional, national, or even international perspective because the benefits and costs of interventions to solve such problems have consequences outside of a local project area. The large costs of financing major water resources infrastructure (e.g., dams, transportation canals, and large irrigation schemes) are likely to fall on taxpayers outside the project area, not just on the direct beneficiaries. Also, the consequences of major water resources infrastructure investments – positive and negative – can be widespread in both space and time.

For both local and large-scale water problems the user values associated with steps along a water development path will be highly relevant to the State. However, the State must use considerable judgment in interpreting these user values and deploying them for planning purposes. This is because in a dynamic, high-growth economy these user values are themselves dynamic and dependent on the timing and sequencing of investments in both the water and other sectors (i.e., they are endogenous).

The different perspectives of the State and households discussed in this paper serve to emphasize that there is no simple, one-size-fits-all answer to the

question of the economic value of steps that lead to an improvement in water security. Decision-makers and water professionals, especially those working at the global level, must learn to live with the uncertainty and ambiguity associated with the dynamic nature of the economic value of increased water security along water development paths. Global advice on the economic value of increased water security that is devoid of local and regional realities, and knowledge about the specific water development path that a country is on is not only unhelpful, but it is pernicious in the sense that it appears to offer simple answers that are in fact unlikely to exist.

There is no alternative but for the State and its partners to roll up their sleeves and do the hard analytical work required to understand the behavior of complex hydrological systems and to determine the economic costs and benefits of various possible policy interventions to different stakeholders. A central challenge is to design a public sector decision-making process that will consistently and repeatedly pick the “winners” from alternative investments (steps) along a long water development path.

This returns us to the second set of questions which relate to making sound investments: given the complexity of water, how do we apply economic discipline to the choice, design and sequencing of investments in water security? The answer must be to undertake careful economic analysis, no matter how strong our intuition might be that a particular project is ‘clearly’ justified.

In an interview with Kishore Mahbubani, the Dean of the Lee Kuan Yew School of Public Policy at the National University of Singapore, the journalist Thomas Friedman asked for an explanation of Singapore’s long and consistently high rate of economic growth. Dean Mahbubani replied that Singapore had not done anything except what government officials learned at Harvard’s John F. Kennedy School of Government: to apply good micro-economic analysis, weigh the benefits and costs of alternative policy options, and do this over and over again in as many sectors as practicable.²¹

Finding the investments along a water development path that yield economic internal rates of return of 9% instead of those that yield 3% does not sound

²¹ Quoted in the New York Times (January 29, 2011): “... we learned all about what it takes to build a well-functioning society from you. Many of our top officials are graduates of the Kennedy School at Harvard. They just came back home and applied its lessons vigorously.”

very exciting, but over the long term, it makes all the difference.

At a minimum, all water investments should be subjected to cost-benefit analysis that compares two states of the world (with and without the project). The cost of delay and inaction associated with “doing nothing” must be included in the analysis as the “state of the world” that is avoided if the project is undertaken. The great expense and complexity of water security investments often delay both decision-making and implementation. Explicitly including the cost of delay and inaction as that state of the world that will result if no action is taken will enable decision-makers to make informed choices.

To capture the complex interrelationships of water projects, analysts should examine system values rather than user values of water. At a basin scale (either national or transboundary basins) this will often involve the development of hydrological-economic models. Simulation²² and optimization²³ models can be extremely useful in illustrating the costs and benefits to different groups of alternative investments and policy interventions. These models capture the range of tradeoffs across water uses in a basin, and illustrate the economic outcomes of alternative water resources development (infrastructure) and management (allocation) scenarios.

For truly transformative investments, computable general equilibrium (CGE) models are needed to capture economy-wide impacts (Yu et al 2010). CGE models estimate the effects of changes in one policy or sector on the rest of the economy. For example, if significant additional energy²⁴ were developed through a large scale hydropower investment, a CGE model could be used to see how this would impact energy pricing and availability, as well as energy-dependent industries, employment, and wages. An important challenge when using CGE models to evaluate large-scale water resource investments is to

²² Simulation models provide the simulated hydrological and economic outcomes of alternative development and management scenarios. The hydrological characteristics, infrastructure configurations, water allocations and constraints i.e., to meet ecosystems needs or treaty obligations, of the various scenarios are inputs into these models.

²³ Optimization models maximize economic benefits under specific constraints, in other words they describe the configuration of uses that will return the highest possible system values. The economic benefits to be maximized are specified in an objective function that includes the different activities that are the ‘objective’ of the investment, i.e., irrigation, hydropower. Constraints can also be included, i.e., to meet ecosystems needs or treaty obligations (see Harou et al, 2009, and Wu et al., 2013).

²⁴ There are many water projects that could have such transformative impacts, i.e., in Nepal where there are several hydropower projects under preparation each of which could more than double national energy production.

clearly articulate the counterfactual. What would capital have been used for if the water resources investment were not undertaken? And what would have been the economy-wide consequences of this alternative use of investment funds?

Alternatively, scenario analysis can be a useful approach for examining alternative 'states of the world' for water security. Scenario analysis does not rely on extrapolation of the past. Instead it allows for significant changes in course and turning points in policies and circumstances. It can illustrate a range of possible future states of the world, and, importantly, the development paths that lead to those outcomes. Such exercises could prove extremely useful at the basin, national and even global levels. In all such analyses, economists are challenged to address the issue of uncertainty.

Finally, there is the overarching question of development paths, and whether a particular investment might set in motion either desirable or undesirable path-dependent patterns of development. Moving a country onto a high-growth development path can fundamentally change the economics of water security. It takes sound analysis, well-designed institutions, and the ability to make good evidence-based decisions in the face of uncertainty and ambiguity, in order to stay on a high-growth water development path.

ANNEX

Arjen Hoekstra coined the term “water footprint” in 2002, but the underlying idea is based on J. Anthony Allan’s concept of “virtual water.” Prof. Allan described “virtual water” as the amount of water needed to produce a good or service, taking into account its entire production or supply chain. The water footprint of a country includes both internal and external water use (Hoekstra and Chapagain, 2007). The internal water footprint of a country is calculated as the sum of domestic water use across sectors (e.g. agricultural, industrial, and domestic) less the quantity of virtual water exports in exported goods. Factors that significantly influence the magnitude of a country’s water footprint include per capita wealth, consumption patterns (e.g. high meat diets), climatic conditions (e.g. evaporation rates), and water efficiency of agricultural practices. Lower-income countries can have large water footprints if they face high evaporation rates and low water agricultural productivity.

Some have extended the concept of virtual water to advocate that “water footprints”—direct and indirect water usage—have normative importance and should be minimized, similar to the desire to minimize “carbon footprints” to reduce the effects of climate change (Ridout and Pfister 2010a). Advocates of water footprints have argued that minimizing one’s water footprint is an important step toward environmental sustainability and a water-secure world (Hoekstra and Hung 2002; Ridout and Pfister 2010b). However, water use is not like carbon emissions. Carbon dioxide and other greenhouse gases are uniformly mixed, cumulative pollutants that contribute to climate change, so it makes sense to strive to reduce the carbon footprint of one’s consumption patterns. On the other hand, water is a renewable resource that circulates through the hydrological cycle.

Once used, water is returned to the environment through evaporation or runoff. However, water is temporarily unavailable for productive uses as it flows back through the hydrological cycle and may not be returned to the same geographical area. Therefore, the sustainability of water withdrawals for a given area is a more important goal than minimizing water footprints.

The basic problem with the proposal to minimize water footprints is that this strategy will result in economically inefficient production and inefficient water use. An elementary result in microeconomics is that efficient production requires that the marginal rate of substitution between factors of production be the same in all sectors (industries)—or that the ratio of the marginal products of two factor inputs must be the same in all sectors. This condition for efficient production cannot hold if one focuses only on increasing the marginal product of one factor (e.g. water). The catch phrase “more crop per drop” is bad economics, although it makes intuitive sense when irrigation water is obviously being wasted or used for low-value crops.

Some water conservation activities will make sense in many locations, but water footprints ignore local conditions and emphasize universal water conservation rather than a careful weighing of the costs and benefits of using less water in a specific activity. Water footprint calculations reveal nothing about the opportunity cost of allocating water to a specific use in a specific location. Even in a water-scarce area, if water is allocated to high-value uses and is well-managed, it may be economically inefficient to reduce water footprints further. Water footprints are simply estimates of water use during production and do not indicate the economic impacts of that use (Wichelns 2011).

Firms and nations rightly consider more than water inputs when determining efficient production and export strategies. Lopez-Gunn and Llamas (2008) find that international food trade is mostly driven by factors other than water availability. Secure markets and access to arable land are often more likely determinants of agricultural trade patterns than water resource availability (Kumar and Singh, 2005).

The National Water Commission in Australia has concluded that estimates of virtual water (and water footprints) are not a useful indicator for allocating scarce water to different uses (Wichelns, 2010). Many factors affect the value of water in alternative uses, including labor availability and the quality of arable land (Guan and Hubacek, 2007). Water security cannot be achieved simply by minimizing water footprints.

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