Water Resources, Growth and Development

A Working Paper for Discussion

Prepared by The World Bank for the
Panel of Finance Ministers
The U.N. Commission on Sustainable Development

18 April 2005

OUTLINE

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1. Introduction

Water: a force for destruction and poverty – or for production and growth? Water has always played, and continues to play, a central role in human societies. It is an input, to a greater or lesser extent, to almost all production (in agriculture, industry, energy, transport, by healthy people in healthy ecosytems). It is also a force for destruction (catastrophically through drought, flood, landslips and epidemic, as well as progressively through erosion, inundation, desertification, pollution and disease). Water is quite literally a source of life and prosperity and a cause of death and devastation. Since the origins of human society, there has been a constant struggle to reduce the destructive impacts of water and increase its productive impacts. Many of the earliest civilizations, and particularly those on the floodplains of the world's great rivers, succeeded by harnessing and managing water, thereby increasing production and reducing the risk of destruction. As then so today, water resources development and management of water quantity and quality remain at the heart of the struggle for sustainable development, growth and poverty reduction. This has been the case in all industrial countries, most of which invested early and heavily in both water infrastructure and institutions[1], and it is the case in all developing countries, most of which have not invested sufficiently in water infrastructure and institutions. In some developing countries the unmet challenge of managing their water legacy is almost without precedent, yet, without doing so, we believe that sustainable growth and poverty eradication cannot be achieved.

Learning lessons from experience. As we explore the role of water in growth, lessons emerge that can guide us in designing better institutions and infrastructure to meet multiple economic, social and environmental objectives, and may provide insights for developing countries to "leap frog" their water resource investments and institutions. These lessons may lead to new development paths, which will reflect the changing values of societies as their economies grow.

This paper. Our goal is to provoke discussion and strengthen understanding and recognition of the importance of water institutions and investments in enabling and sustaining growth, specifically targeting an audience of political leaders, ministers of finance, macroeconomic planners and donors. This is just one of many critical discussions that must be held on the role of water and does not in anyway diminish the social, cultural and environmental significance of water management and development which should be incorporated wherever feasible — but the primary focus of this paper will be the dynamics of water, growth and poverty alleviation.

2. Water and Growth: What we believe we are seeing

Growth and water: three types of scenarios

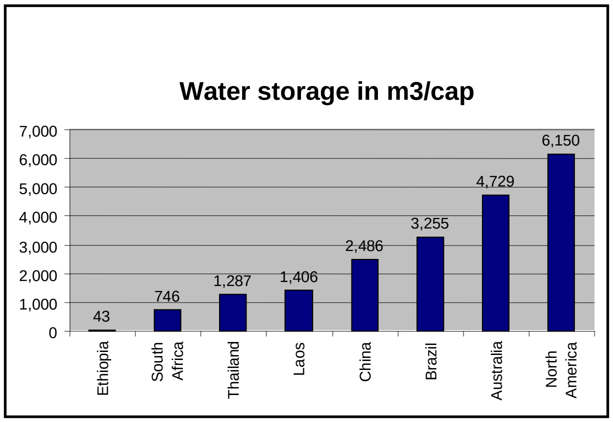
In all ***industrial countries***, the flows of almost all major rivers are regulated and managed, reducing peak flows, increasing low flows and protecting water quality, thus reducing the risk of water-related shocks and damage, increasing the reliability of water services for production, and reducing other negative impacts, such as disease. In many, but not all, industrial countries, climate seasonality, variability and extremes are limited in extent, possibly implying that countries that did not have an adverse climate regime had one less barrier to overcome, facilitating earlier, easier growth. Although varying widely, institutional aspects of water management are typically embedded in the political structure of governments and have often evolved over considerable time. Large and early investments have been made in bulk water infrastructure and in the human capacity required to operate and maintain these investments. In most cases, the infrastructure platform is mature and much greater emphasis is placed on water management, both to maximize the returns on investment as well as to respond to shifting

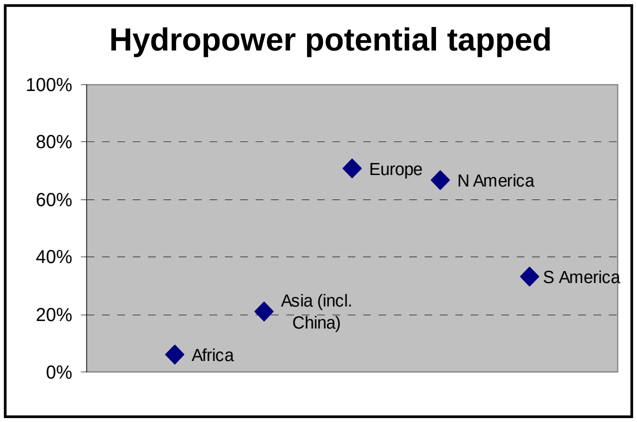
[1] In this paper, the term 'institutions' is used in a broad sense, incorporating capacity, organizations, policies, rules, and agreements; integrated water resources management includes the effective investment in water institutions and infrastructure.

societal perspectives, where high values are placed on environmental and aesthetic assets. These investments in institutions and hydraulic infrastructure were clearly a pre-condition for ***harnessing hydrology*** and we believe that they were also a pre-condition for sustained and broad-based growth and development.

In ***intermediate economies*** which are industrializing, much investment has typically taken place in water infrastructure – in some cases driven by windfall financing (e.g., from mineral wealth), in others from aid financing (at least initially), and in yet others through well-managed local or national growth. Many countries are successfully addressing catastrophic water risks, but have not yet achieved the infrastructure and institutional capacities that allow them to manage their water resources to optimize sustainable growth. In other words, downside risks are being managed, but upside potentials have not been developed. There are many cases, such as oil exporting states where financing has been available to build infrastructure, where institutional and human capacity may be inadequate to manage water resources and new infrastructure, emphasizing the imperative of balancing and sequencing investments in water institutions and infrastructure. Getting this balance right will be crucial for sustaining growth, which remains ***hampered by hydrology***.

In ***least-developed economies***, where climate seasonality, variability and/or extremes are often marked and capacity, institutions and infrastructure are inadequate, we often see very major impacts of specific catastrophic hydrologic events, and also, as a consequence of expectations of those events, risk-averse behavior and disincentives in all years, with serious and economy-wide consequences for growth. At the sectoral level, we see many consequences of unpredictable food production due to climate variability, the health impacts of poor water supply and sanitation, unreliable electricity supplies, and a poor investment climate due to water-affected transport and energy infrastructure. We often see an apparently very strong correlation between hydrology and GDP performance. The Finance Minister in India stated this quite clearly in the 1980s, saying "Every one of my budgets was largely a gamble on rain."[2] Where economic performance is closely linked to rainfall and runoff, growth becomes ***hostage to hydrology***.





Source: Palmieri, The World Bank.

These three broad types of 'Water and Growth Scenarios' are illustrated in the following three, very brief vignettes for each Type, which we have numbered in reverse order (for reasons that will become apparent later in the paper): Type 3 – industrial economies; Type 2 – middle-income economies; Type 1 – developing economies.

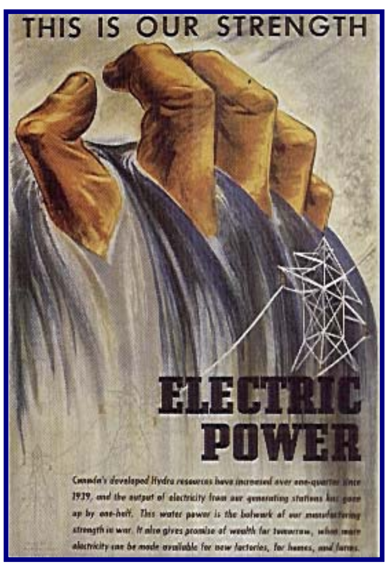
Growth achieved: harnessing hydrology

In Europe. In Europe, there is the special case of The Netherlands, where human settlement and survival has long been determined by sophisticated water infrastructure – the dykes and polders of the 'low country', and sophisticated institutions – water parliaments that were the foundation of modern Dutch democracy. A downstream nation on the Rhine, the Dutch struggled to shift from control of society by the

[2] Financial Times, June 18, 2001.

river to control of the river by society. The Rhine, shared by nine nations today, has long been an engine of Europe's economy, and has a complex institutional structure of demarcation and use evolved through over 500 treaties since the ninth century[3]; nevertheless, there remain some inter-state tension today (such as a recent case between France and The Netherlands at the Permanent Court of Arbitration.) Across most of the region, where a predominantly temperate climate means that the risks posed by water have always been relatively small, extensive investment in storage and river regulation to supply and protect industrializing cities and towns, the engines of rapidly growing economies, led to a relatively mature platform of hydraulic infrastructure by the early 20th Century. More recently, huge investments have occurred to develop hydropower resources, with over 70% of potential developed (in contrast to some 5% of Africa's hydropower potential that has been developed). France has about 26,000 MW of economically viable hydropower generation potential and has developed 25,200 MW of this. In Norway, almost all power needs are met from the 28,000 MW of installed hydropower capacity, with over 24,000 kWhr per capita per year of hydroelectric power generated (some going into regional power grids). This figure is over twice the electric power consumed per capita in the USA, over 10 times the world average, over 100 times the power generated per capita in Ghana, and 1,000 times that of Ethiopia.

In North America. The United States has invested trillions of dollars in hydraulic infrastructure, with huge structures built to open up the west and southwest to settlement, agriculture and industry. Hydraulic infrastructure on the Colorado River, including Hoover and Glen Canyon dams, has underpinned growth in the enormously successful economic development of California, Arizona and Nevada, in a region of aridity and variability originally settled by migratory people. These structures arguably provide the highest return to water anywhere in the world in Las Vegas, Nevada! To protect against the devastating effects of flood and drought, over 6,000 cubic meters of reservoir capacity per capita has been installed (this is a national average, with much higher per capita storage in the semi-arid western U.S.) – compared with 500 m^3/capita in middle-income, semi-arid Morocco, and less than 50 m^3/capita in Ethiopia, a nation wracked by flood and drought. The Colorado River has 900 days of storage (the Indus River has only 30 days.) The US Army Corps of Engineers has spent about $200 billion on flood management and mitigation since the 1920s. This investment has yielded an estimated $700 billion in benefits, and mitigated the impact of floods on the US economy to such an extent that flood damages have remained below 0.5% of GDP since that time[4]. In 2004, for example, despite the intensity and scale of the wave of hurricanes in Florida, and the area's naturally high flood risk, none of the extensive flood structures were breached and there was little or no flood damage. Agreements on transboundary rivers and lakes shared with Mexico and Canada have established strong intergovernmental institutions. Canada, a nation with the world's greatest endowment of fresh water, developed its hydropower resources early, resources which remain a backbone of the economy - and North America's least cost power.



Historical poster: Canada
Personal collection of Daryl Fields

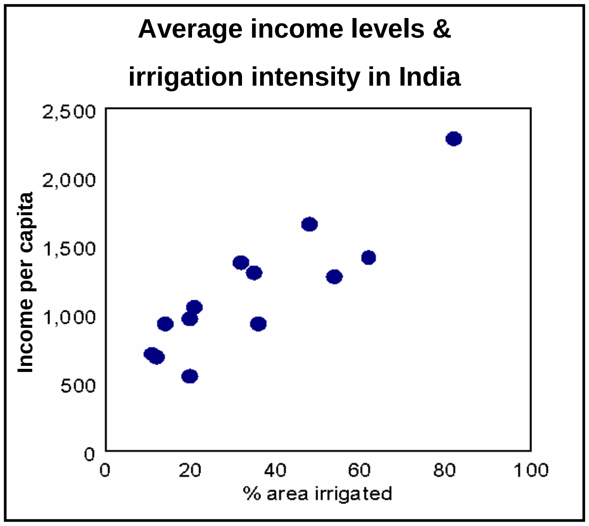
In Asia/Australasia. In Japan, water and culture are closely interwoven, with a long history of water management for transport and flood mitigation. The flood plains of Japan are just that – flood prone, yet some 40% of the population and 60% of the economy's productive assets are located in these areas. Preliminary data show that flooding, caused by heavy seasonal rains as well as typhoons, had serious impacts on the Japanese economy as recently as the 2nd World War, with single-year flood shocks occasionally exceeding 20% of GDP. From 1950 to 1975 , some ¥ 2 trillion was invested in river infrastructure (similar to the investment in railways). Since the 1970s, the impacts of flood on the

[3] Dombrowsky, 2001.
[4] Jerry Delli Priscoli, USACE, pers. comm..

Japanese economy have not exceeded 1% of GDP in any year,[5] a period of extraordinary growth for the Japanese economy. Even with this infrastructure stock, US$ 9 billion of public funds continue to be spent annually on flood management and mitigation. The story of Australia is very different. Here, aridity and variability supported a pastoral lifestyle of indigenous people that was changed dramatically by the import of skill and capital in the 19th Century. Heavy investments in water institutions (water is a state, not federal, responsibility, so inter-state negotiations are intense) and water infrastructure through the 20th Century underpinned the growth of the nation, providing power for industry (Tasmania described itself as the 'greatest hydroelectric state of the Commonwealth'), water for human settlement, and massive agricultural and livestock production. Growing activism and evolving social values are now placing high priority on managing environmental assets, with water quantity and quality markets emerging as key instruments for doing so.

Growth constrained: hampered by hydrology

In South Asia . Initial investments in Indian water resources management and multipurpose hydraulic infrastructure had massive regional impacts with very large multiplier effects on the economy, multipliers that appeared to be consistently larger for infrastructure than for other sectors.[6] There are also very direct correlations between irrigation and poverty. Investments in irrigation were associated with significant declines in poverty – irrigated districts averaged 25% poverty rates against 70% poverty rates in unirrigated districts. The benefits of improved water resources management and institutions are similarly significant. In Tamil Nadu, for example, robust management institutions that would allow a "flexible allocation" of water between uses could increase the state's production by 20% in the 20 years, relative to fixed allocations.[7]



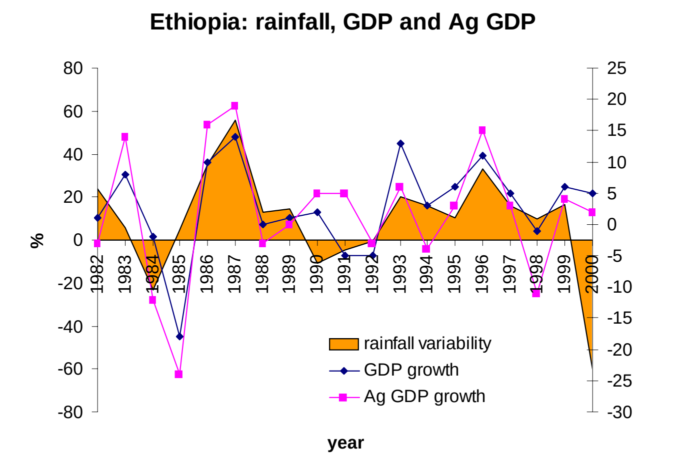
In South Africa. South Africa is an interesting middle-income case where apartheid-era water investments were made to ensure economic resilience for large-scale commercial farming, mining and financial services in the nation's heartland, while the rest (most) of the country had little water infrastructure. The Vaal River System, situated in a semi-arid region with highly variable rainfall and runoff, includes interbasin transfers with seven other rivers systems and 16 major dams; it also provides cooling water for power stations that generate about 50% of the electricity of Africa[8]. In seven of South Africa's nine provinces, more than 50% of its water is provided by inter-basin transfers. South Africa has about 750 m3/cap in artificial storage, about 12% of the 6500 m3/capita of the USA; but, on reflection, the figures are much closer, as South Africa's storage investments have only served a small proportion of the population. On the one hand, this strategy essentially provided full water security to minority-dominated growth poles within the economy, while the bulk of the population remained highly water vulnerable and without the essential services needed to grow and prosper. On the other hand, this massively reduced the vulnerability of these growth poles to water, creating a strong investment climate. With the dramatic change in government, this has arguably allowed South Africa today to spread its wealth across the nation. Today, high growth rates are being sustained and there are important shifts in values as pluralism and democracy take hold. For example, in recent legislation, specific flow allocations in each river basin

[5] Kenzo Hiroki, Japan Water Forum, pers. comm..
[6] See Bhatia and Malek (2003) on the case of Bhakra dam, and Peter Hazell (IFPRI) on irrigation in Tamil Nadu.
[7] John Briscoe, The World Bank, pers comm., who has provided broad advice on this paper.
[8] Basson et al, 1994.

are made for basic services to the poor and for in-stream environmental flows, before other allocations are considered.

Growth stalled: hostage to hydrology?

In Ethiopia. The persistent correlation between rainfall and GDP growth in Ethiopia is striking – and troubling. The effects of hydrological variability emanate from the direct impacts of rainfall on the landscape, agricultural output, water-intensive industry and power production. These impacts are transmitted through input, price and income effects onto the broader economy, and are exacerbated by an almost complete lack of hydraulic infrastructure to mitigate variability and market infrastructure that could mitigate economic impacts by facilitating trade between effected (deficit) and unaffected (surplus) regions of the country.



Source: de Jong, The World Bank (2005)

Preliminary results from current World Bank modeling efforts suggest that the economic cost of hydrological variability in Ethiopia is very high as a percentage of the nation's average annual growth potential. Economy-wide models that incorporate hydrological variability (which includes drought, flood and "normal" variability on the order of 20% around the mean) in Ethiopia show that projections of average annual GDP growth rates drop dramatically as a consequence of this variability. These diminished rates of growth will compound over time – seriously undermining growth and sustaining poverty.[9]

Management of Ethiopia's road network is also closely tied to hydrology. The cost of building and maintaining roads is high because of rugged topography and torrential tropical rains. This slows expansion of the system and results in the construction of unpaved roads. Today 90% of Ethiopia's roads are dry weather roads, and cannot be used effectively for 4 months of the year during the wet season. Over the period 2000-2002 almost 60% of the reported defects in unpaved roads (and 35% of defects in paved roads) were directly water related, a figure which does not include rain-induced landslides or infrastructure washouts. Moreover a clear correlation was seen between hydrological variability and the percentage of maintenance costs attributable to water. When it rains in remoter areas, farmers can produce crops but cannot get them to markets; when the rains fail, crops also fail, but roads are in good condition so food aid can be moved across the country – perpetuating dependence. The water resources challenge in Ethiopia is extremely serious, and the Government is increasingly aware of this. Much effort is now placed on building institutional foundations, with new legislation, decentralized water management, river basin plans, and considerable political capital expended on cooperation with riparian neighbors. Yet Ethiopia has very little hydraulic infrastructure, has great difficulty sourcing finance to construct it, and will probably anyway see low economic returns in the early stages of infrastructure development due to the scale of investment needed to make a significant difference. This points towards the imperative of ensuring that key growth poles are made resilient to water shocks, to reduce economic vulnerability, encourage investment and provide essential quantum shifts in growth, opening the door to broader poverty reduction.

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9 This estimate is based on the results of a stochastic, economywide multi-market model that captures the impacts of both deficit and excess rainfall on agricultural and non-agricultural sectors. See "Managing Water Resources to Maximize Sustainable Growth: A Country Water Resources Assistance Strategy for Ethiopia", The World Bank, 2005.

In Kenya. In Kenya the costs of flood and drought are stark. The La Niña drought of 1998–2000, and the El Niño floods of 1997–98 each had devastating economy-wide and society-wide impacts, as illustrated in our analysis of the financial costs, off government accounts, of these events. The 1997–98 El Niño flood caused damages estimated at 11% percent of GDP (over 3 months). Over 90% of the calculated flood losses were associated with *transport* infrastructure damage (88%) and water supply and sanitation infrastructure damage (5%). The La Niña drought caused damage amounting to some 16% of GDP in each of 1998–99 and 1999–2000 financial years. It is interesting to note that the majority of these losses were associated with foregone *hydropower* (26%) and *industrial production* (58%). Agricultural losses associated with the drought accounted for 15% of drought damages, of which 10% were crop and 5% livestock losses. The remaining 6% of losses derived from adverse health impacts. The full economic costs in both cases are probably much greater, because these estimates did not include costs such as those from famine, hunger and malnutrition; losses of lives and rural livelihoods; and risk-averse behaviors such as relocation of industries or farmers' reluctance to invest in farm inputs such as fertilizers and pesticides. [10] In a recent investment climate study[11], Kenya is shown to have very low competitiveness, with indirect costs for a firm about 3 times that of a strong performer. The largest share of the indirect costs is *transpor*t (31%) and *energy* (19%) – which are those sectors most affected by flood and drought. During 1998-2000, it is understood that major investors withdrew from Kenya due to unacceptable costs and risks.

Kenya: the impact of flood and drought

1997-8 El Nino Flood Impacts	**US$ millions**	%
Transport infrastructure	$777	88%
Water supply infrastructure	$45	5%
Health sector impacts	$56	6%
Total Flood Impacts	$878	
Flood Impacts as % of GDP 1997-8		11%

1998–2000 La Nina Drought Impacts	**US$ millions**	**%**
Hydropower losses	$640	26%
Industrial production losses	$1,400	58%
Agricultural production losses	$240	10%
Livestock losses	$137	6%
Total Drought Impacts	$2,417	
Drought Impacts as % of GDP 1998-2000		16%

Source: The World Bank (2004)

In Southern Africa and Mozambique. Watershed degradation is a serious and rapidly intensifying problem in many parts of Africa. Unintentionally, the settlement of vulnerable watersheds in one country, often by the very poor, can have major impacts on a downstream country – often on the very poor settled in the floodplains there. Mozambique is the most downstream riparian on eight international rivers, none of which has a fully functioning cooperative management institution. In the headwaters of these rivers, such as in Zimbabwe, it is the poorest, with the least capacity to invest, that scrape a living off the poorest land, settling the most vulnerable uplands, often with high slopes and thin soils. Forests are cut down, slopes are cultivated, and soils are eroded, resulting in minimal crop yields and unsustainable livelihoods. More insidiously, groundwater recharge is reduced and levels lowered, river flows become much more flashy and downstream flood and drought impacts are increasing. In the floodplains of Mozambique, it is the poorest who settle the most vulnerable and risky land closest to the river. In the Mozambique floods of 2000, 640 people lost their lives, half a million where displaced or trapped, and 2 million suffered severe economic difficulties. The floods contributed to an abrupt fall of GDP from an average annual growth rate of 7.5% over the period 1994-2003, to 1.5% in 2000, with agricultural output at negative 10.8%. The disaster's direct costs (i.e., physical damage to capital assets and inventories, valued at same-standard replacement costs) amounted to US$273 million, or about six percent of projected GDP for the year 2000. Indirect costs (i.e., flow effects such as foregone earnings) were estimated at US$212 million, and relief costs totaled about US$65 million. Total measurable flood costs therefore amounted to some $550 million or 12% of GDP.[12] There was no flow-control infrastructure (such as reservoirs) within the borders of Mozambique to mitigate the floods of 2000. The coordinated operation of existing flow-control infrastructure in upstream riparian countries, however, could possibly have done so.[13]

[10] "Toward a Water Secure Kenya", Water Resources Sector Memorandum, The World Bank, 2004.
[11] Business Environment & Comparative Advantage in Africa: Evidence from ICA data. The World Bank, 2005
[12] World Bank staff estimates in Dankova and Abrams, 2004.
[13] Sadoff, Whittington and Grey, 2002.

3. Water and Growth: What we think is happening

Water security and the minimum platform of water infrastructure and institutions

Water security. Water investments (in bulk water resources and water for food, energy, industry, navigation and in associated 'institutions') are initially made (by the state, the city, the firm, the farm, the family, etc.) to achieve some implicit level of 'water security'. We can define this as the reliable availability of an acceptable quantity and quality of water for production, livelihoods and health, coupled with an acceptable level of risk of high social and economic impacts of unpredictable water events (including the extremes of drought and flood). Water security is achieved when water underpins economic growth, rather than undermining it – or, in other words, when the net impact of water on growth is positive. Water security is demonstrated when investments in water focus on growth enhancement, rather than unfulfilled basic needs and risk mitigation. It is the point at which vulnerability to drought, flood and disease, or a lack of access to water-related services, no longer creates an overwhelming obstacle to growth. This 'water security' is a dynamic state: different in different parts of the world (reflecting geographic, social, epidemiological, economic and political factors) and changing over time as various of these factors shift with development.

The minimum platform of water infrastructure and institutions (MIP). We can also postulate that there is a basic level of 'water security' - which incorporates the idea of a 'minimum platform of water infrastructure and institutions'. Below this minimum platform, society and the economy is 'unacceptably' impacted by water (by any mix of water shocks and/or unreliable water for production or livelihoods). The tipping point in achieving water security will be the acquisition of a minimum platform of management capacity and infrastructure investment. Below the minimum platform, water obstructs growth overall, above the minimum platform water enhances growth overall. Until the 'minimum platform' is achieved, the scale of social impacts (e.g. morbidity, mortality, resource conflict) and related economic impacts (e.g. from institutional failure, production inefficiencies, disaster shocks) can be such that social fabric is significantly affected and economic growth cannot be reliably and predictably managed.

The challenge of achieving water security

The level of institutions and investment required for water security will differ across countries and across economic actors as a consequence of (i) the natural hydrology, (ii) the structure of the economy and economic resilience to water shocks, and (iii) risk aversion. A nation's hydrology will clearly affect the level of institutions and investment required to achieve water security. The absolute levels of water resource availability, its variability and its spatial distribution will largely determine the institutions and the types and scale of infrastructure needed to manage, store and move the resource.

An 'easy' hydrologic legacy. Relatively low rainfall variability, with rain distributed through the year and resulting perennial river flows sustained by baseflows, results in hydrology that is 'easy' to manage. In temperate parts of the world, much of which are now industrialized, achieving 'water security' by achieving the 'minimum platform' was straightforward and required comparatively low levels of skill and investment (primarily because water was sufficient, widespread and relatively reliable). Once this was achieved, growth was able to proceed without water being a significant constraint (although there may of course have been other unrelated constraints). Growth allowed further water investments, which increased water security (beyond the 'minimum platform'). As returns from new water investments gradually diminished, the infrastructure and institutional platform became mature, with water a reliable input to production and risks (i.e., 'insurance' costs) fully acceptable. At maturity, the need and incentive for *developing* new investments are low, while the returns from, and the incentives for, *managing* existing assets are high.

A 'difficult' hydrologic legacy. 'Difficult' hydrology to manage includes areas of absolute water scarcity and, at the other extreme, low-lying land where there is severe flood risk. Even more difficult hydrology is where rainfall is markedly seasonal (in the tropics one or two rainy seasons per year is typical) – a short season of torrential rain followed by a long dry season requires the storage of water. More difficult still is high inter-annual climate variability, where extremes of flood and drought create unpredictable risks to individuals through to nations and regions. Perhaps most difficult of all is a combination of extreme seasonality (intra-annual) and variability (inter-annual), which is characteristic of many of the world's poorest countries. With increasingly 'difficult' hydrology, the level of institutional refinement and infrastructure investment needed to achieve 'water security' becomes very significantly greater than in temperate (and less variable) climates; thus water is naturally a much higher constraint to growth. In addition, the quantum leap to achieve the 'minimum platform' is also much higher. As a direct consequence of the scale of this leap, it has not been achieved in many poor countries, so that 'basic water security' has not been reached and water remains a key constraint on growth - an unreliable input to production and the cause of major economic shocks. There are few incentives to manage what little infrastructure there is, while the returns to society from investing to achieve water security (essentially de-linking water from growth) could be very high, but there is insufficient wealth to invest. Taking this argument further, we postulate that societies in areas of water scarcity and/or high climate variability have remained poor and in a low-level equilibrium trap at least in part because it has been impossible for them to make the comparatively large investments needed to achieve 'water security' through reaching the 'minimum water infrastructure platform'

A 'transboundary' hydrologic legacy. The management and development of rivers whose basins fall within the borders of more than one state ('international rivers') is exceptionally complex, due, essentially to the 'anarchy' of international relations. The UN Convention on the Non-Navigational Use of International Watercourses, which was under preparation for some 20 years and adopted by the General Assembly of the UN in 1997,[14] will now not enter into force, as it has only been ratified by 13 states. Over generations, the border between France and Spain evolved so that today it mostly follows the watershed – a line of least dispute. Colonial rule resulted in geographic divisions in the 20th Century that seriously compounds the challenge of achieving water security. The carving up of Africa between Britain, France, Portugal, Italy and Germany has led to a complex legacy of international river basins per country (Guinea has 14, Mozambique 8) and countries per international river basin (the Nile basin has 10, the Niger basin 9). The partition of South Asia has also created great challenges. The need for robust international institutions is great, yet the international relations challenge for a poor nation to cooperate with one state on one river is high – with more than one state or on more than one river – or both – can be extremely high. The challenge of planning for optimal development is also complicated by the fact that relevant historical and current data – where it exists at all – is likely to be fragmented, non-uniform, and owned by different riparian states, and there may be few if any studies of the river system as a whole. There can be many lost opportunities and increased costs, in terms of environmental costs to the river from poor management, economic costs in sub-optimal development of the river, costs from political tensions over the river, and costs of all the other opportunities foregone through non-cooperation[15]. The legacy of international rivers can therefore very significantly affect the potential for managing and developing water for growth and poverty alleviation.

Sectoral perspectives. The primary thrust of this paper is on water resources, their economy-wide relationship with growth and poverty, and the way this impacts every segment of society, including at the farm and household level. At the same time, it is important to understand the impacts of the key water-related sectors on growth and the impacts of different water allocations between these sectors. Investments in water policies and infrastructure for different sectors have potentially very different consequences for growth and poverty. The role of water management and development in basin water supply and sanitation services or in agriculture, for example, has traditionally been seen as pro-poor. Investments in municipal water supply for industry, services and tourism has been seen as a strategy for economic diversification and growth. Investments in water for the environment have less often been examined in terms of their growth and poverty implications. But some of these assumptions are being called into question and the theories which underlay these assumptions are not consistently well articulated. The incentives for water use within sectors will also have welfare, growth and equity

[14] Salman and Boisson de Chazournes, 1998.
[15] Sadoff and Grey, 2002.

implications. In agriculture, for example, the balance between traditional subsistence agriculture (which generally targets the very poor and provides greater employment opportunities) and highly intensive production (which generates higher value-added to a smaller immediate beneficiary group) will significantly affect the value of agricultural production and the distribution of these gains. Similarly, inter-sectoral water resources allocations will affect the structure of economies, growth and patterns of development. The allocation of water among the agriculture, industry and services sectors, for example, will enable or constrain their relative growth, and give rise to very different economies over the medium term, with differing welfare impacts both in terms of overall growth and the distribution of this growing wealth.

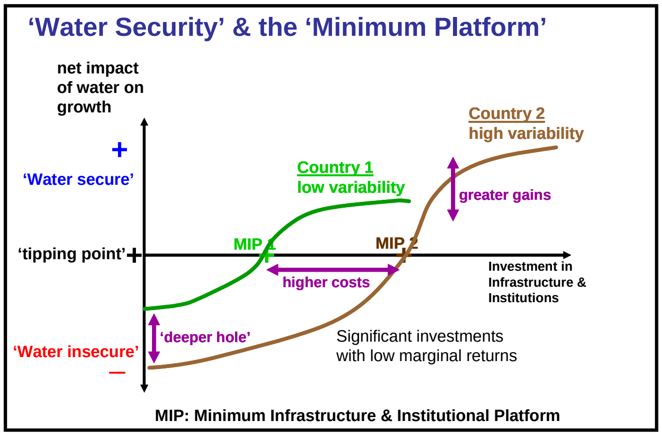
Economic structure and resilience. The structure of the economy will also affect the minimum level of institutions and infrastructure necessary for water security. The economy's reliance on water resources for income generation and employment, and its vulnerability to water shocks will all be relevant. Highly water-vulnerable economies, for example those whose rainfall is highly seasonal and/or variable, or are extremely water scarce, rely heavily on rainfed agriculture, or whose most productive assets or areas lie in flood plains, will require more extensive investments (higher 'minimum platforms') in order to reduce water insecurity and achieve the reliable growth that will lead to water security. This vulnerability will impact regions and sectors differently, creating incentives and disincentives for specific economic activities in particular geographic areas, which will influence both the structure of the economy and spatial patterns of growth, and hence impact overall growth and equity outcomes. Not only will these economies regularly suffer greater set backs from water shocks, but this vulnerability will likely prove a strong disincentive for domestic or foreign entrepreneurial investments that could shift the structure of the economy toward a more diversified, water-resilient structure. More diversified economies which are less water dependent, and wealthier economies that can more easily compensate those harmed by drought or flood, for example, might accept higher levels of hydrological uncertainty without slowing growth-focused investment. This suggests that efforts that guide structural change in the economy in order to achieve greater economic resilience to water shocks can reduce water insecurity and lower the minimum platform of institutions and investment in water management.

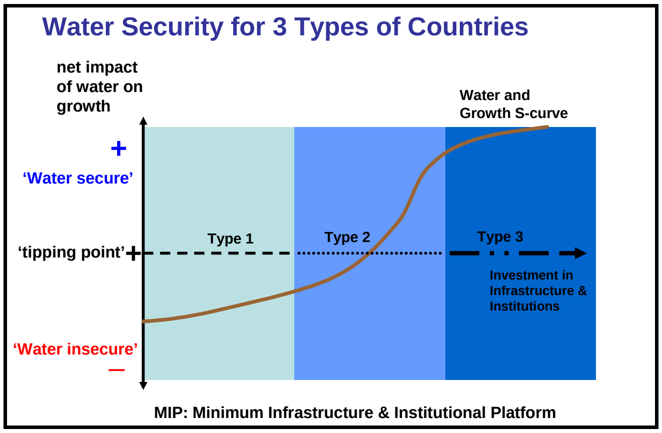
Risk aversion. In the poorest countries, where survival is a real concern for large parts of the population and there are few functional social safety nets, economic actors tend to be extremely risk averse, investing only after there is significant demonstration of returns. Levels of risk aversion will influence the threshold at which water security can be achieved. While the catastrophic effects of drought and flood extremes are apparent, it is less well recognized that even in years of average precipitation, expectations of high variability and endemic droughts and floods will affect economic performance and, potentially, the structure of the economy. In countries where hydrological variability is high and investments to achieve 'water security' are inadequate, variability is a constant economic risk to small investors (such as individual farm families) and large ones (such as industries), and to the nation. The perception of risk is amplified by occasional droughts and floods. The expectation of variability and the unpredictability of rainfall and runoff is likely to constrain growth and diversification by encouraging risk averse behavior at all levels of the economy in all years, as economic actors, particularly the poor, focus on minimizing their downside risks, rather than maximizing their potential gains. Individual farm families will quite rationally not invest in land improvements, advanced technologies or agricultural inputs, thus constraining agricultural output and productivity gains. Lack of such investments can lead to land degradation and desertification, which will result in a vicious cycle of reducing production and deteriorating assets. Similarly, there will be significant disincentives for investments in industry and services, which will slow the diversification of economic activities and maintain an economic structure that is based largely on low-input, low-technology agricultural production. The poorest countries may well face the highest risks, yet have the most risk-averse populations, the lowest infrastructure investment and the weakest institutions. This could well be a very serious low-level equilibrium trap, as these countries must reach higher levels of institutions and investment, beginning from the lowest levels.

Financing water security. Generally it has been the case that early investments in water security were public investment from fiscal resources. In Wealth of Nations, Adam Smith wrote that government should construct public works when these works are "of such a nature, that the profit could never repay the expense of any individual or small number of individuals, and which it therefore cannot be expected that any individual or small number of individuals should erect or maintain." When basic water security is achieved, and additional investments in water can be highly profitable (i.e., in agriculture or power), private investment responses are seen throughout the economy. All rich countries will have achieved 'water security', with a publicly funded 'minimum platform' in place. Most poor countries will not have achieved this.

Illustrating Water Insecurity and Security: a 'Water and Growth S-curve'

The S-Curve. The dynamics of water insecurity and security and the minimum platform of infrastructure and institutions can be illustrated in a 'Water and Growth S-Curve'. On the y-axis is a notional measure of the net impact of water on growth which runs from negative to positive, where water contributes to growth throughout the economy. Along the x-axis is cumulative investment in water institutions and infrastructure (the appropriate mix of investment in institutions and infrastructure is discussed below.) "MIP 1" marks the tipping point at which Country 1 achieves water security, and after which rapid growth is seen. Prior to this tipping point the returns to such investment are fairly modest. "MIP 2" marks the tipping point at which Country 2 reaches water security. This is farther out along the x-axis, suggesting that Country 2 required greater upfront investment than Country 1 to achieve water security. This higher tipping point could be a consequence of greater hydrological variability (or flood risk, or more international rivers, etc.) which puts Country 2 in a "deeper hole" than Country 1 because of the greater initial water insecurity due to high variability and the greater investment needed in institutions and infrastructure required to mitigate that variability. The 'S-Curve also illustrates the Type 1, 2 and 3 cases: Type 1 countries will be along the lower, water-insecure horizontal segment, Type 2 along the steep, tipping point segment, and Type 3 along the upper, water-secure horizontal segment.



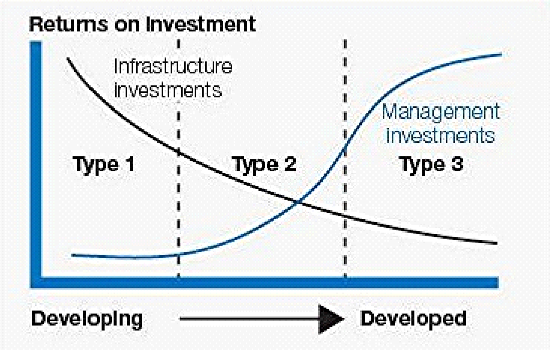


Implications for investment. It is important to note that the 'S-curve' reflects that early returns to investment in water resources, particularly in countries with high hydrological variability, are likely to be quite low. It is posited that a significant public investment will need to be made before there is adequate security for private investment to follow and growth to ensue – much like a road investment which will have little return until it joins two cities. If this is in fact the case, it has important implications for the way in which we assess the cost-effectiveness of early investments in water resources infrastructure. Marginal analysis of investment returns will likely show these early investments to be uneconomic, because marginal costs will likely outweigh marginal benefits until a significant stock of infrastructure has been built. But if the hypothesis holds true, growth will be slowed until such investments are made. This suggests that the standard tools of project economic analysis, such as marginal rates of return and ability-to-pay, which are commonly applied by governments and donors alike may be inappropriate to weigh crucial early investments, and their use may in fact forestall growth.[16] If the hypothesis holds true, a minimum platform of infrastructure should be identified by a straightforward needs analysis.

4. Water and Growth: the dynamics of institutions, infrastructure and values

The institutions/infrastructure inter-relationship. Throughout this paper, we have written of 'water institutions and infrastructure', as in all countries development of water resources will require investments in both. What is the balance and sequencing between them? All human society has always managed and developed water to the extent necessary to sustain lives and livelihoods at a particular level. Village wells and ponds, to canal systems, to earth bunds in the flood plains of great rivers have all been developed for millennia and each has been accompanied by institutional systems necessary to plan, develop, manage and maintain such infrastructure. In some cases, such institutions were an early form both of government – an emerging 'public sector' to manage public goods, as well as of business – an emerging 'private sector' providing services to meet public demand. Water institutions themselves will reflect the culture and political economy within which they fit: public to private; centralized and hierarchical to decentralized and participatory; rules-based to market-based. When we look across the world at the development of water resources, and particularly during the period of industrialization, what we believe that we are seeing in practice is represented schematically below. At all times, concomitant investments must be made in infrastructure and institutions, but when stocks of hydraulic infrastructure are low, investment in infrastructure will be a relative priority. Investment in management capacity and institutions becomes increasingly important as larger and more sophisticated infrastructure stocks are built. Most developed countries fall into "Type 3", where significant infrastructure investments have been made (in some cases arguably excessive investments) and where efforts are best directed toward strengthening water resources management. In "Type 1" countries, most of the world's poorest countries, infrastructure stocks are so low that investments in management do not have the same high returns. Middle-income economies fall into "Type 2". Without the infrastructure to store and deliver water and manage flows, there is neither the need nor the incentive for sophisticated management practices. This suggests that while developed countries are appropriately focused on the implementation of integrated water resources management, developing countries may do better to adopt a principled and pragmatic approach to management while putting greater emphasis on concurrent infrastructure investments.[17]

Balancing & sequencing investments in water infrastructure & management



Source: World Bank, China Country Water Resources Assistance Strategy 2002.

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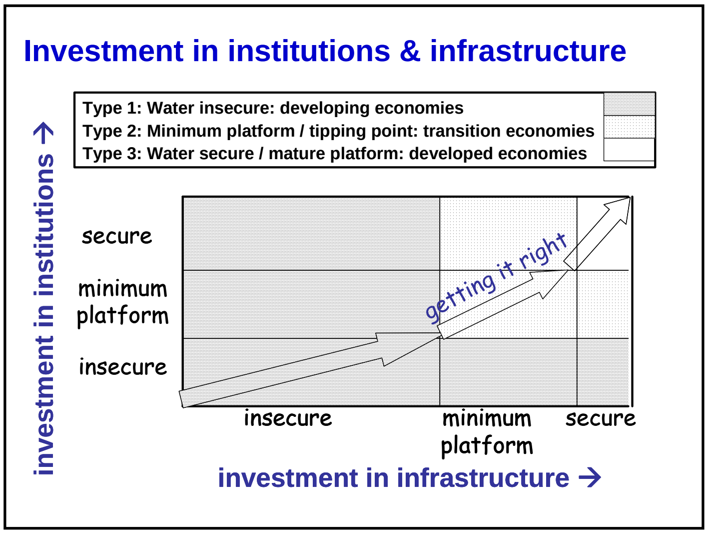
[16] A potentially quite important area for research in this regard would be an exploration of the way in which evaluation methodologies have generally followed rather than led development, and the dangers of adapting methodologies out of context. Reuss (2003), for example, characterizes current water resources planning in the U.S. as "planning by constraints" related to environmental and social imperatives, a formulation that may be appropriate for the U.S. with its highly developed infrastructure stock, but may be inappropriate for the poorest countries where basic needs water supply and flood and drought infrastructure is not in place.
[17] This is the message of the World Bank's 2003 Water Resources Sector Strategy.

The institutions/infrastructure balance. Failure to understand the issue of balance and sequencing within the context of specific country circumstances may lead to poor investment choices. One potential danger is that most donor nations are Type 3 and strongly focused on water resources management as a priority, when in fact the priority need of the Type 1 client countries may well be for investment in water resources infrastructure. It is important that Type 3 perspectives not misinform the development priorities of Type 1 countries. This must not be interpreted to mean that there should be no investment in management and capacity in developing countries, there must be management and capacity investments at all stages. Another way to look at this question is presented in the graph below. This graph shows an investment path that explicitly includes both investments in institutions and in infrastructure. In early years (Type 1), there is proportionately more investment in infrastructure than in institutions. Moving through a Type 2 to a Type 3 stage, the proportionality changes so that eventually infrastructure investments are quite small relative to investments in institutions and capacity.



The logic is the same: management and development must go hand-in-hand, but with greater infrastructure stocks to manage water, stronger institutions and better management practices become possible, necessary and will bring real benefits.

The transboundary institutions/infrastructure case. The case of international rivers is a particular one, of growing importance in a world of 260 international rivers, shared by about 90% of the world's population. While a basic premise of water resources management is that river basins are best managed and developed as an integrated whole, this is always legally and politically complex, due to the challenges of allocation between users and between uses. The management and development of international rivers is particularly challenging, due to the fact that there is no apex authority through which differences can be resolved and, although criteria for allocating water and the benefits of water can be drawn from a growing body of customary international water law, there is no consensus on the criteria for equitable allocation.[18] Developed (Type 3) economies have in most cases achieved a relative equilibrium in establishing fit-for-purpose institutional arrangements, including treaty regimes, dealing with issues of river infrastructure, and the quantity and quality of water flows. In many cases, the need for river infrastructure, such as locks for navigation or weirs and dykes for flood management (e.g., the Rhine) or hydropower facilities (e.g. the Columbia River), were primary drivers for adopting institutional solutions. In the second half of the 20th Century, with water quality a growing concern, there has been a growing emphasis on joint institutional solutions to restore riverine and lacustrine ecosystems (e.g., the Danube). The success of such arrangements will have been enabled by much broader international relations and agreements. With both middle-income (Type 2) and developing (Type 1) economies, there continue to be great challenges. Nations often seek to develop river segments within their own territories, settling for second or third best investments from an unconstrained basin-wide perspective, as the complexity of riparian relations is an obstacle to the development of the full potential that international rivers embody for growth and poverty alleviation. In extreme cases, tensions over international rivers can effectively halt their management and development. What we believe we are seeing is that the need for river infrastructure is often a major driver in reaching agreements where river flow – water quantity – is the issue; the 1960 Indus Basin Treaty between India and Pakistan was a pre-requisite for the Indus Basin development program that divided the rivers, as the 1959 Nile Agreement between Egypt and Sudan was for the Aswan High Dam, that stores water for Egypt. A focus on the benefits of cooperative management

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[18] Sadoff, Whittington and Grey., 2003.

– say for water quality – and of agreed (even cooperative) development – say for irrigation and power – can lead to viable transboundary institutions.

Changing values, changing objectives. As the wealth and education of the population of rich countries grow, so its values and objectives change; this is especially true for water resources management (institutions) and development (infrastructure). Ghandi believed that all India's rains should be stored so that famine could be overcome.[19] Writing in 2003, Martin Reuss of the U.S. Army Corp of Engineers describes the trend in water resources planning objectives in the USA as 'planning by constraints', setting limits to growth by placing high value on non-human needs.[20] Evolving societal values in Canada have led BC Hydro to re-engineer its hydropower structures, placing high value on improved in-stream flows and fisheries, at some (although not great) cost to hydropower production.[21] What we believe that we are seeing is that developing countries (Type 1) see an overarching imperative to increase the productive value and reduce the destructive cost of water in their economies, commonly at the expense of any other water-related objective. In middle-income economies, with growing wealth and education (rarely evenly spread), there is increasing awareness of the need to conserve aquatic ecosystems in their own right, although the pressure for growth and poverty eradication is generally stronger. In developed economies, with a fully mature hydraulic infrastructure platform, high value is placed, and much activism surrounds, the water environment, with even some investment in restoration of ecosystems to near-pristine conditions. This path of shifting values is both obvious as well as commonly unrecognized. In an increasingly globalizing world, there are pressures on Type 1 (developing) country institutions to adopt Type 3 (developed) country values: within this dynamic, however, Type 3 countries may not fully appreciate the immediate and often extreme growth and poverty challenges faced by Type 1 countries; and Type 1 countries may not fully appreciate how greatly their values are likely to shift with growth, and therefore do not seek to recognize this fact in their plans for growth and development. Herein lies a challenge. Hydraulic infrastructure is characterized by its longevity and by its broad impact on the environments and societies in which it is built. In virtually all developing countries, demand for water, food and power continues to grow and there is no question that hydraulic infrastructure is needed. Yet, to be robust, cannot options be selected and designed to allow their operation to adapt to changing values and priorities? Scale, site selection and operational characteristics can be assessed from a long-term planning perspective that incorporates these anticipated trends and emphasizes adaptability, ensuring that future generations inherit institutions and infrastructure that can readily adapt to their evolving values, demonstrating the wisdom of their forebears.

5. Water and Growth: infrastructure, aid and poverty

Water, poverty and wealth. What we believe we are seeing has major implications for development priorities and appropriate levels and mixes of investment in water resources, for program design, project economic analysis, and the potentials and constraints for developing countries to "leap frog" in water institutions and infrastructure. It suggests that we would expect to see a world where societies are poor where water is scarce or in excess, and/or water availability is highly seasonal and/or variable, because

[19] 'In this land of ours, fabulously rich in natural resources, there is the lofty Himalayas with its ever-lasting snows where, they say, dwells the Lord of the Universe. It has mighty rivers like the Ganges. But owing to our neglect and folly, the year's rains are allowed to run down into the Bay of Bengal and Arabian Sea. If all this water was trapped and harnessed for agriculture purposes by the construction of dams and tanks, there should be no famine or food shortages in India.' Mahatma Gandhi, 1946.

[20] "Replacing both the scientific efficiency model of the early twentieth century and the more recent economic efficiency model is an approach that I can characterize only as planning by constraints. The process emphasizes regulation and focuses on water quality, rather than quantity, issues. Rather than maximizing economic efficiency or optimizing the opportunity to meet public objectives, it sets limits to growth. To what extent it remains basically an anthropocentric process, in which sustainable development is justified economically as well as morally, or reverts to a biocentric ethic which grants to other living things a moral worth equal to that of the human population, is a great question. Certainly, any process that grants inherent moral worth to nonhumans establishes a system of competing claims that ultimately sets limits on human population, patterns of consumption, and technological development. Any equitable solution to these problems of competing claims with nonhumans would require the application of a system of ethics and a notion of justice that substantially modifies the value system of western civilization." In: "Federal Water Resources Planning" by Martin Reuss, Office of History, U.S. Army Corps of Engineers. (2003)

[21] Personal communications, Daryl Fields.

'water security' has not been achieved and the 'minimum platform' is not in place. There will be exceptions, in particular where major injections of external skill and capital have enabled water security to be achieved (e.g., Australia, the western United States). On the other hand, we can expect to see a world where societies are relatively rich where water is sufficient, widespread and reliable and 'water security' was easily achieved – mostly in temperate climates with low rainfall seasonality/variability. There will of course be other reasons why societies are poor or rich, but we postulate that the significance of water investment is considerable – and little recognized.

Water, growth and aid. This lack of recognition of the significance of water investment has serious consequences for poor countries. The focus of industrial countries is correctly on water *management*, not on water *development*, which has already achieved maturity, such that water only rarely has significant negative economic impact. However, this focus on management and away from development has permeated through to aid policy. There is little stomach among aid policy makers for supporting major water resources infrastructure development in poor countries and tackling the unavoidable tradeoffs that this entails. In some cases there is even an effective veto, such as for the financing of dams for storage, hydropower or other purposes. This position is strongly advocated by many (largely western) lobby groups. These groups often have access to substantial financial support and can therefore have significant political impact on the aid policies of donor governments and international organizations. There is little recognition of the implications of this for poor countries – in particular of the development costs of inaction – and of the moral hazard for rich countries. On the other hand, poor countries must not see infrastructure alone as a panacea; without the development of appropriate water institutions, badly-managed infrastructure will likely not support growth, it (and its associated debt) may even forestall growth. Unless these dynamics are recognized – by finance and planning decision makers in developing countries and by policy makers and aid administrators in developed countries – it will be extremely difficult for water security to be achieved in the world's poorest countries; growth cannot therefore be effectively managed, and these countries could as a consequence remain poor, irrespective of other aid interventions. If so, there is a major ethical dimension to this debate which needs to be articulated and addressed.

Water and growth: a focus for analysis. This working paper provides the background to an important theme of analysis currently being undertaken by the World Bank with several partners. This work seeks to identify the role of water in impacting growth – positively and negatively. This includes case studies of industrial, intermediate and developing countries: what are the key hydrologic characteristics (scarcity, excess, seasonality, variability…); is the country 'water secure' or 'water insecure' – i.e., is this a "Type 1, 2 or 3" case; how deep is/was the 'hole' that the country is/was in; what is the scale of investments in water infrastructure; what is the social and political investment in water institutions; what is the balance between institutions and infrastructure; what are key current and likely future water and growth issues? Answering these questions rigorously will support the operational work of the World Bank, as well as of governments and other donors. It will assist in providing the basis for: ensuring that macroeconomic and project economic analysis takes effective account of water; the assessment of the potential benefits and tradeoffs in investing in water institutions and infrastructure; and making informed investment choices.

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